Food and Forage Legumes of Ethiopia: Progress and Prospects

ICARDA

International Center for Agricultural Research in the Dry Areas (ICARDA)

Food and Forage Legumes of Ethiopia: Progress and Prospects

Proceedings of the Workshop on food and forage legumes
22-26 September 2003, Addis Ababa, Ethiopia

Edited by

Kemal Ali
EIAR, Addis Ababa, Ethiopia

Gemechu Kenneni
EIAR, Addis Ababa, Ethiopia

Seid Ahmed
EIAR, Addis Ababa, Ethiopia

Rajendra S. Malhotra
ICARDA, Aleppo, Syria

Surendra Beniwal
New Delhi, India

Khaled Makkouk
ICARDA, Cairo, Egypt

M.H. Halila
ICARDA, Cairo, Egypt

Sponsors

ICARDA

Ethiopian Institute of Agricultural Research (EIAR)
Addis Ababa, Ethiopia

International Center for Agricultural Research in the Dry Areas
(ICARDA) Aleppo, Syria

Royal Netherlands Government

Published by

International Center for Agricultural Research in the Dry Areas

Recommended citation
Ali, Kemal; Kenneni, Gemechu; Ahmed, Seid; Malhotra, Rajendra; Beniwal, Surendra; Makkouk, Khaled; and Halila, M.H. (Eds). Food and Forage Legumes of Ethiopia: Progress and Prospects. Proceedings of the Workshop on Food and Forage Legume, 22-26 September 2003, Addis Ababa, Ethiopia. Sponsors: EIAR and ICARDA. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. 351 pp.

ISBN: 92-9127-185-4

Headquarters
International Center for Agricultural Research in the Dry Areas (ICARDA)
P.O. Box 5466, Aleppo, Syria
Tel: (+963) (21) 2213433, 2213477, 2225112, 2225012
Fax: (+963) (21) 2213490, 2225105, 5744622
E-mail: ICARDA@cgiar.org
Website: http://www.icarda.org

Nile Valley and Red Sea Regional Program (NVRSRP) of ICARDA
15 G. Radwan Ibn El Tabib Street, Giza
P.O. Box 2416, Cairo, Egypt
Phone: (20) (2) 5724358, 5725785, 5681254
Fax: (20) (2) 5728099
E-mail: icarda-cairo@cgiar.org

Ethiopian Institute of Agricultural Research (EIAR)
P.O. Box 2003, Addis Ababa, Ethiopia
Phone: (251) (11) 6462633-41
Fax: (251) (11) 6461294
Website: www.eiar.gov.et

Table of Contents

Section IV. Crop Protection

Section V. Forage Legumes and Food Science

Section VI. Research Extension and Socio-economics

Group photo for the participants of the "Food and Forage legumes of Ethiopia: Program and prospects" workshop held in Addis Ababa, Ethiopia, 22-26 September, 2003

Foreword

Food security is a critical and genuine concern in Ethiopia, where a significant segment of the population is food insecure and malnourished. Therefore, food production must be increased by more than 3-4% annually in order to cope up with the rate of population growth, in a way that the natural resources are best conserved. In such a situation, agricultural research has a vital role to play.

Although cereal crops are most important in Ethiopian agriculture in providing staple diet to the population, food and forage legumes are also significantly important in several ways. They not only foster food security as a major source of protein, but also serve as a good source of cash to the farmers and much desired foreign currency to the national economy. These crops are also flexibly grown in a wide range of agro-ecological zones and cropping systems and are adapted to low- and high-altitude areas and input situations, thereby diversifying the cereal-based cropping system and breaking the nutrient depletion and pest cycles.

Realizing their importance, the Ethiopian Government launched research efforts on these crops in the early 1950's. We are very happy to witness that good progress has been made in different aspects of these crops. Efforts made and results achieved on these crops in the country till the early 1990's were reviewed during the First National Food Legumes Workshop held separately for the lowland and the highland food legumes in 1990 and 2003, respectively. A Second National Workshop on these crops was organized in Addis Ababa during 22-26 September 2003 with the sponsorship of the Ethiopian Institute for Agricultural Research (EIAR), the Royal Netherlands Government and ICARDA. The workshop aimed to review research and extension efforts in food legumes in Ethiopia during the past decade, and thus provided a unique opportunity for different stakeholders of food legumes in the country including representatives of governmental and non-governmental development organizations, scientists from research and higher learning institutions and CGIAR centers and policy makers. We are happy to say that the Ethiopian legume researchers have made effective use of this golden opportunity to benefit from the rich experiences of renowned scientists from international organizations, feedback from the governmental and nongovernmental development organizations, and needs of policy makers for more effective and efficient future endeavors. We also believe that it contributed to the enhancement of knowledge with regard to different disciplines, motivation of researchers and development workers, which for sure will help in the sustained and better productivity and production of food legumes in the country.

ICARDA's collaboration with Ethiopia in food legumes goes back to 1985, when the latter joined the Nile Valley Project (NVP) on faba bean, which was coordinated by ICARDA from Cairo, Egypt. Subsequently, a Senior Food Legume Scientist was based in Ethiopia in 1986, in the then Institute of Agricultural Research (IAR). Ethiopia later became an active member of the then Nile Valley Regional Program (now the Nile Valley and Red Sea Regional Program) in 1990. The Ethiopia/ICARDA collaboration has been very successful and a good model of collaboration between a national program and an international center.

We are grateful to the Royal Netherlands Government, and the Director General of Centro Internacional de Agricultural Tropical (CIAT) for their recognition of this workshop as an important event and for rendering valuable technical, material and/or financial support. We also would like to thank the Organizing Committee of the workshop for a superb job in its organization and conduct. We hope that these proceedings would be a good reference document and serve a useful purpose. Finally, we wish success to the Ethiopian national food and feed legumes program in their future endeavors.

Tsedeke Abate
Director General
EIAR Addis Ababa, Ethiopia

Mahmoud B. Solh
Director General
ICARDA
Aleppo, Syria

Acknowledgments

This publication is the result of a collective effort and dedication of several perople. First come the authors of the papers in this volume, whose contributions are the essence of this publication. The guidance and support of EIAR and ICARDA management facilitated greatly holding the workshop and consequently publishing the proceedings. Dr. Tilahum Amede, Dr. Bayeh Mulatu, Dr. Ralph Roothaert, Ato Musa Jarso, Ato Getachew Agegnehu, Suhaila Arslan, and Aziz ur Rehman helped greatly in preparing the papers for publication. Special thanks are due to Ato Asnake Fikre, Ato Teshale Assefa and Ato Wondefrash Mulugeta for their sincere effort and assistance in organizing the workshop. There are many others behind the scene who provided inputs and encourgment, we thank them all.

The contributions of the following ICARDA/CIAT/ICIPE staff members are greatly appreciated: Dr. Ashutosh Sarker (ICARDA), Dr. Ismail A. Ahmed (ICARDA), Dr. Stephen Beebe (CIAT), Dr. Segenet Kelemu (CIAT), Dr. Robin Buruchara (CIAT), Dr. Tilahun Amede (CIAT), Dr. Srinivasan Sithanantham (ICIPE). In addition, the sincere efforts of Dr. R. Malhotra and S. R. S Beniwal in reviewing the manuscripts and making useful changes are greatfully achnowledged. Finally, Special thanks are due to Ms. Maha Abdel Mongi for her excellent work in formatting this proceedings.

The Editors

Acronyms

AACC	American Association of Cereal Chemists
AdARC	Adet Agricultural Research Center
ArARC	Areka Agricultural Research Center
AwARC	Awassa Agricultural research Center
AAU	Addis Ababa University
ACPSE	Agronomy and Crop Physiology Society of Ethiopia
AESE	Agricultural Economics Society of Ethiopia
AIRIC	Agricultural Implements Research and Improvements Center
AMRP	Agricultural Mechanization Research Program
ARARI	Amhara Regional Agricultural Research Institute
ARDU	Arsi Rural Development Unit
ASE	Agri-service Ethiopia
AU	Alemaya University
AURC	Alemaya University Research Center
BARC	Bako Agricultural Research Center
BARS	Bekoji Agricultural Research Station
BoA	Bureau of Agriculture
BILFA	Bean Improvement for Low Fertile Areas
CACC	Central Agricultural Census Commission
CADU	Chilalo Agricultural Development Unit
CCA	Crop Conservation Association
CBO	Community-based Organization
GB	Community Gene Bank
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro International de Agriculture Tropical
CIMMYT	Centro International de Mejoramiento Maiz y Trigo
COR	Client-oriented Research
CSA	Central Statistics Authority
CSFL	Cool-season Food Legumes
DA	Development Agent
DEFID	Department for International Development
DZARC	Debre Zeit Agricultural Research Center
EARO	Ethiopian Agricultural Research Organization
EASE	Ethiopian Agricultural Sample Enumeration
EEPA	Ethiopian Export Promotion Agency
EFLRP	Ethiopian Food Legume Research Program
EGTE	Ethiopian Grain Trade Enterprise
ENI	Ethiopian Nutrition Institute
ESAP	Ethiopian Society of Animal Production
ESE	Ethiopian Seed Enterprise
ETB	Ethiopian Birr
ETOPEC	Ethiopian Oilseeds and Pulses Export Corporation
EQSA	Ethiopian Quality and Standards Authority
EWSS	Ethiopian Weed Science Society
FAO	Food and Agricultural Organization
FEG	Farmers Extension Group
FNE	Forage Network in Ethiopia
FRG	Farmers Research Group
GMC	Genetically Modified Crop
GO	Government Organization
HARC	Holetta Agricultural Research Center
IAR	Institute of Agricultural Research
IARC	International Institute of Agricultural research
IBCR	Institute of Biodiversity and Conservation Research
IBPGR	International Board for Plant Genetic Resources
IBSRAM	International Board for Soil Research and Management
IPGRI	International Plant Genetic Resources Institute
ICARDA	International Center for Agricultural Research in the Dry Areas

ICIPE	International Center for Insect Physiology and Ecology
ICM	Integrated Crop Management
ICRA	International Center for Development Oriented Research in Agriculture
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IFA	International Fertilization Association
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Center for Africa
INTSOY	International Soybean Program
IPM	Integrated Pest Management
KARC	Kulumsa Agricultural Research Center
LER	Land Equivalent Ratio
LITP	Legume International Testing Program
LSB	Lare-seeded Bean
MAS	Marker-assisted Selection
MoA	Ministry of Agriculture
MWARC	Melka Werer Agricultural Research Center
MIARC	Melkassa Agricultural Research Center
MkARC	Mekele Agricultural Research Center
NAIA	National Agricultural Input Authority
NARC	Nazareth Agricultural Research Center
NARS	National Agricultural Research System
NARES	National Agricultural Research and Extension System
NBE	National Bank of Ethiopia
NCIC	National Crop improvement Conference
NCIP	National Chickpea Improvement Project
NEIP	National Extension Implementation Program
NRMRD	National Resources Management and Regulatory Department
NGO	Non-Governmental Organization
NSIA	National Seed Industry Agency
NSIPS	National Seed Industry Policy and Strategy
NSRC	National Soil Research Center
NVRSRP	Nile Valley and Red Sea Regional Program
NVRP	Nile Valley Research Project
NVRC	National Variety Release Committee
NVT	National Variety Trial
OECD	Organization for Economic Cooperation and Development
PA	Peasants Association
PADETES	Participatory Demonstration and Training Extension System
PARC	Pawel Agricultural Research Center
PED	Pre-extension Demonstration
PGRC/E	Plant Genetic Resource Center/Ethiopia
PNYT	Pre-national Variety Trial
PPB	Participatory Plant Breeding
PPRC	Plant Protection Research Center
PRVT	Pre-Regional Variety Trial
PVS	Participatory Varietal Selection
QSAE	Quality and Standard Authority of Ethiopia
RCB-REAC	Research Center-based Research Extension Advisory Council
RED	Research Extension Division
RFLP	Restriction Fragment Length Polymorphism
RPF	Resource-poor Farmer
RRF	Resource-rich Farmer
RVT	Regional Variety Trial
SRARI	Southern Regional Agricultural Research Institute
SG 2000	Sasakawa Global 2000
SGG	Seed Growers Group
ShARC	Sheno Agricultural Research Center
SnARC	Sinana Agricultural Research Center

SMS	Subject Matter Specialist
SNNP	South Nation, Nationalities and Peoples
SrARC	Sirinka Agricultural Research Center
SWP/PRGA	System-wide Program on Participatory Research & Gender Analysis
TGE	Transitional Government of Ethiopia
TIGR	The Institute for Genomic Research
TT	Transfer of Technology
VVT	Variety Verification Trial
WF	Women Farmers
WPB	White Pea Bean

Section I. General Papers

Production and Productivity of Pulse Crops in Ethiopia

Samia Zekaria

Central Statistical Authority, P.O. Box 1143, Addis Ababa, Ethiopia

ABSTRACT

Pulse crops are the most widely cultivated grain legumes in Ethiopian farming. They are essential part of the dietary requirement of most Ethiopians. Of the total area and production of these crops in Ethiopia, Amhara region accounts for about 48% of the area and production in the country followed by Oromiya region, which accounts for 36% of area and 37% of production. The major types of pulse crops in terms of area and production are faba bean, chickpea, field pea and haricot bean. In recent years, the grain yields of faba bean and chickpea in the longer rainy (*meher*) season have shown increasing trends, whereas the yields of haricot bean and field pea have shown fluctuating trends. On the contrary, the grain yields in the shorter rainy (*belg*) season are very low compared to that of the *meher* season. The area of fertilizer use under pulse crops has been constant (14%) over the past few years although it has fluctuated for individual crops. With regard to pulse production at the zonal level in the country, southern Wello in Amhara region and western Shoa in Oromiya region are the major pulse growing zones. Among districts (*woredas*), Dessie Zuria and Tenta in the Wello zone, and Dendi and Alem Gena in the western Shoa zone are the major pulse growing *woreda*s in the country. The data on how farmers use their agricultural produce show that more than three fifth of pulses produced is used for household consumption, whereas about one fifth is sold in the local markets. However, in some *woredas* of Amhara region over 60% of haricot bean and lentil were sold in 2001/02.

INTRODUCTION

Pulse crops, an essential part of the dietary requirement for most Ethiopians, are grown mostly by private peasant holdings under rainfed conditions. They contribute about 8% to total daily calorie intake of the Ethiopian diet against 63% of cereals and about 17% of potatoes and other tubers. On the other hand, the animal products contribute only 1.9% of the total daily calorie intake. In developed countries, the contribution of cereals to the daily calorie intake is 20% while that of the pulses and nuts is about 2.3% against 29.1% of animal products (FAO, 1996). Thus, the pulses (the edible seeds of food legume crops) serve as an important protein supplement in the cereal-based Ethiopian diet. They also form a significant export commodity group and help earn important hard currency for the country. According to Central Statistics Authority (CSA), between September 2001 and August 2002, 123,000 t of pulses valued at 352 million Ethiopian Birr were exported to different countries (CSA, 2002a).

PRODUCTION AND PRODUCTIVITY AT THE NATIONAL LEVEL

Pulse crops are not as widely grown as cereals in the country in terms of area and production. The contribution of these crops in 2001/2002 crop season in terms of area and production to the country's total crop area and production was about 13% and 9%, respectively (Table 1). Faba bean, chickpea, haricot bean and field pea are the major pulse crops that are produced in terms of area and production.

In the last few years, the total area and production under pulse crops in the country has shown an increasing trend (Table 2). The major pulse crops in terms of area and production are faba bean, chickpea, field pea and haricot bean. In the longer rainy (*meher*) season, the grain yield of faba bean has increased from 0.97 t/ha in 1996/97 to 1.21 t/ha in 2001/02 crop season (Table 3), which reflects a 24% increase in five years (CSA, 1996, 1997, 1998a, b, 1999a, b, 2000a, b, 2001a, b, 2002a, b). Similarly, the grain yield of chickpea in the *meher* season has increased from 0.85 t/ha in 1995/96 to 0.97 t/ha in 2001/2002 crop season, reflecting an increase of 14%. On the contrary, the grain yields of haricot bean and field pea have shown year to year fluctuations.

Table 1. Estimates of area, production and grain yield of *meher* (longer rainy season) season, 2001/2002 crop season.

Crop	Area (million ha)	Percent area	Production (million t)	Percent production
Cereals	6.370	79.64	8.7068	76.66
Pulses	1.016	12.71	1.0212	8.99
Oil seeds	0.426	2.90	0.2081	1.83
Total	7.812	100.00	9.9361	100

Source: CSA (2002a).

The grain yields of faba bean and haricot bean during the shorter rainy (*belg*) season are very low as compared to that of the *meher* season (Table 3). This is attributed to highly erratic rainfall during the *belg* season in recent years. There is no production of chickpea and field pea in the *belg* season.

Table 2. Estimates of area and production of pulse crops in Ethiopia.

Year	Area ('000 ha)		Production ('000 t)		
	Meher	*Belg*	*Meher*	*Belg*	Total
1995/96	904	104	811	52	864
1996/97	905	107	803	58	861
1997/98	837	108	680	38	719
1998/99	875	71	732	19	751
1999/00	1045	175	959	71	959
2000/01	1234	136	1074	28	1101
2001/02*	1017	-	1021	-	1021

Source: CSA (1996, 1997, 1998a, 1999a, 2000a, 2001, 2002a).

Table 3. Estimates of area, production and yield of selected pulse crops over years.

Crop Season	Area('000)		Production ('000 t)		Grain yield (t/ha)	
	Meher	*Belg*	*Meher*	*Belg*	*Meher*	*Belg*
Faba bean						
1995/96	336.72	*	359.367	*	1.07	*
1996/97	329.31	4.02	320.676	1.828	0.97	0.46
1997/98	266.17	4.10	259.667	1.583	0.98	0.39
1998/99	296.41	3.28	285.160	0.657	0.97	0.20
1999/00	359.1	*	388.682	*	1.08	*
2000/01	426.24	*	452.841	*	1.06	*
2001/02	369.15	-	447.063	-	1.21	-
Haricot bean						
1995/96	101.17	54.36	78.361	30.743	0.78	0.57
1996/97	112.81	76.65	94.764	44.872	0.84	0.59
1997/98	92.19	57.54	54.846	22.748	0.60	0.40
1998/99	129.45	52.90	102.489	14.322	0.79	0.27
1999/00	166.02	150.14	132.888	61.997	0.80	0.41
2000/01	186.74	89.72	148.964	16.997	0.80	0.19
2001/02	119.88	-	98.674	-	0.82	-
Chickpea						
1995/96	144.97	-	123.241	-	0.85	-
1996/97	147.90	-	126.461	-	0.86	-
1997/98	169.97	-	137.131	-	0.81	-
1998/99	167.65	-	138.837	-	0.83	-
1999/00	184.79	-	164.627	-	0.89	-
2000/01	211.71	-	175.734	-	0.83	-
2001/02	184.80	-	179.821	-	0.97	-
Field pea						
1995/96	180.46	-	139.575	-	0.77	-
1996/97	158.11	-	106.303	-	0.67	-
1997/98	119.75	-	92.725	-	0.77	-
1998/99	141.95	-	98.486	-	0.69	-
1999/00	152.20	-	115.998	-	0.76	-
2000/01	204.76	-	141.365	-	0.69	-
2001/02	175.23	-	147.270	-	0.84	-

(-) indicates no data available; * indicates estimates not reliable. Source: CSA (1996, 1997, 1998a, 1999a, 2000a, 2001a, 2002a).

Both the organic manure and chemical fertilizers are applied to the pulse crops in Ethiopia. The precise data on the organic manure application are not available. However, data on fertilizer application to pulse crops from CSA indicate that fertilizer in the form of diammonium phosphate (DAP) or urea is applied to 14% of the total area of pulse crops in the country (Table 4). Fertilizer application on different pulse crops varied from 22% in haricot bean to 5% in chickpea in 1997/98 crop season. Fertilizer-applied area under faba bean varied from 19% in 1997/98 to 21% in 2000/01 crop season. In general, pulse crops area under fertilizer application is by far less than that for cereals (44 %), and wheat and *tef* (66% and 53%, respectively) in particular.

PRODUCTION AND PRODUCTIVITY AT THE REGIONAL LEVEL

As mentioned earlier, Amhara and Oromiya are the two major pulse producing regions in the country. The Amhara region occupies the largest area (48%) and contributes to the largest production (48%) in the country (Table 5), which is followed by Oromiya region that has 36% of the area and contributes to 37% of the national production.

Production and Productivity in Amhara Region

In Amhara region, faba bean, chickpea, field pea and grass pea are the major pulse crops in terms of area and production. The grain yields of these pulse crops vary from 1.24 t/ha for faba bean to 0.65 t/ha for lentil (Table 6). In this region, the average grain yields of grass pea and faba bean are higher than their national averages.

According to the Ethiopian Agricultural Sample Enumeration (EASE) results, 1.8 million land holders grew pulse crops in both rural and urban areas of Amhara region on an area of 531,665 ha, producing 508,000 t (CSA, 20002a). Of these, the numbers of urban holders growing pulses were only 8,505 producing 1,500 t with lower average grain yields than that of the rural areas. In Amhara region, southern Wello is the major pulse growing zone followed by southern Gonder, northern Gonder, and northern Shoa (Table 7). In southern Wello zone, 375,681 holders grew pulse crops in both rural and urban areas on an area of 97,241 ha, producing 97,428 t of various types of pulses. In urban areas, 2,541 holders cultivate pulse crops on only 536 ha, where grain yields are lower than that of the rural areas. In this zone, Dessie Zuria district (*woreda*) is the largest producer of pulse crops followed by Tenta and Mekdela districts (Table 8), where highest yields were obtained of faba bean followed by grass pea and field pea (Table 9).

Table 4. Area ('000 ha) under fertilizer use of selected pulse crops in Ethiopia over years.

Year	Total Pulse	Faba bean	Field pea	Haricot bean	Chickpea
1997/98	837.34	51.66	23.74	20.62	7.62
	(13.9%)	(19.4%)	(19.8%)	(22.4%	(4.5%)
1998/99	875.36	57.98	35.60	20.35	4.65
	(14.1%)	(19.8%)	(25.1%)	(15.7%)	(2.8%)
1999/00	1,004.91	69.63	27.15	28.55	3.66
	(13.2%)	(19.4%)	(17.8%)	(17.2%)	(2.0%)
2000/01	1,233.93	87.31	5.19	39.73	30.66
	(14.0%)	(20.8%)	(2.5%)	(21.3%)	(14.5%)
Mean	997.89	66.65	22.92	27.31	11.64
	(13.8%)	(19.9%)	(16.3%)	(19.2%)	(6.0%)

Source: CSA (1998a, 1999a, 2000a, 2001a).

Table 5. Area and production of pulse crops by region, 2001/02 crop season.

	Area ('000 ha)		Production ('000 t)	
Region	Number	Percent	Number	Percent
Tigrai	42,71	4.20	43.296	4.25
Afar	0.10	0.01	0.029	0.00
Amhara	488.18	48.07	492.023	48.23
Oromia	363.96	35.84	378.068	37.07
Somali	1.35	0.13	0.628	0.06
Benishngul-Gumuz	6.68	0.55	6.044	0.47
S.N.N.P.R	108,56	10.69	96.461	9.46
Gambella	0.12	0.01	0.071	0.01
Harari	0.03	0.00	0.013	0.00
Addis Ababa Administration	4.89	0.48	4.368	0.43
Dire Dawa Administration	0.20	0.02	0.214	0.02
Total	1,015.11	100.00	1019.630	100.00

Source: CSA (2002a).

Table 6. Estimated area, production and grain yield of pulse crops in the rural areas of Amhara region (2001/2002), *meher* season.

Crop	Area (ha)	Production (t)	Grain yield (t/ha)
Pulses	488,184	492,023	
Faba bean	168,945	210,139	1.24
Chick pea	109,432	103,875	0.95
Field pea	78,145	64,092	0.82
Faba bean	22,518	16,918	0.75
Lentil	40,121	25,986	0.65
Grass pea	53,966	59,193	1.10
Lupine	7,217	5,932	0.82

Source: CSA (2002a).

Table 7. Area and production of pulse crops by zone in the rural areas of Amhara region (2001/2002), *meher* season.

Zone	Area (ha)	Production (t)
N. Gonder	75,801.00	75,090.1
S. Gonder	78,714.13	69,651.4
N. Wello	39,952.93	43,927.0
S. Wello	80,306.83	89,854.2
N. Shoa	72,659.95	73,129.5
E. Gojam	70,374.08	73,903.0
W. Gojam	46,662.89	48,601.1
Waghmra	13,089.33	10,232.3
Awi	9,095.90	6,534.3
Oromiya	1,526.57	1,100.5

Source: CSA (2002a).

Production and Productivity in Oromiya Region

In Oromiya region, faba bean, chick pea, field pea and haricot bean are the major pulse crops. The average grain yields of these pulse crops vary from 1.22 t/ha for faba bean to 0.88 t/ha for field pea and lentil (Table 10). The average grain yields of chickpea and field pea from this region are higher than that of the country's average.

Table 8. Area and production of pulse crops in the rural areas of different districts (*woreda)* in southern Wello Zone (2001/2002).

Woreda	Area (ha)	Production (t)
Habru	889	986
Mekdela	6507	6151
Tenta	5599	8795
Kutaber	2758	3830
Ambasel	3440	5108
Tehuledere	1017	1567
Werebabu	600	804
Kolu	1288	1336
Dessie Zuria	10724	15389
Legambo	5038	4629
Sayint	8326	6755
Debresina	5073	5216
Kelala	7753	6056

Source: CSA (2002b).

Table 9. Area, production, and yield of selected pulse crops in the rural areas of Dessie Zuria woreda (2001/2002).

Crop	Area (ha)	Production (t)	Yield (t/ha)
Faba bean	5,101.61	8,758.5	1.717
Field pea	1,224.02	1,676.9	1.370
Grass pea	1,327.28	2,053.1	1.547

Source: CSA (2002b)

According to EASE (CSA, 2002a) data, western Shoa is the major pulse growing zone of Oromiya region followed by eastern Shoa, northern Shoa and Arsi (Table 10). However, it is Arsi zone that is the largest producer followed by western Hararge. Among the districts (*woredas*), Dendi district is the largest producer (8201.9 t/ha) followed by Ambo (7894.7 t/ha) and Cheliga (7125.8 t/ha) districts (Table 11).

Table 10. Area and production of pulse crops by zone in the rural areas of Oromiya region, (2001/2002).

Zone	Area (ha)	Production (t)
Western Wellega	19,879	1,619
Eastern Wellega	18,392	1,946
Illubabor	14,683	1,061
Jimma	24,393	2,691
WesternShoa	75,592	9,143
Northern Shoa	52,172	4,723
Eastern Shoa	53,952	5,409
Arsi	49,404	63,264
Western Hararge	12,440	14,643
Eastern Hararge	7,243	8,805
Bale	18,882	15,272
Borena	16,929	10,163

Source: CSA (2002a).

The grain yields of faba bean, chickpea and grass pea in Dendi *woreda* of western Shoa were reported as 1.36, 1.13 and 1.44 t/ha, respectively (Table 12), which are less than that of Dessi Zuria *woreda* of Amhara region.

UTILIZATION OF PULSE CROPS

It is often said that Ethiopian farmers' produce is only enough for their own household consumption and survival. However, this is not statistically substantiated. In an effort to fill this knowledge gap, CSA collected data on crop utilization through the 2001/02 EASE (CSA, 2003). In the census, crop utilization was defined as the amount of agricultural produce used for own consumption, sale, seed, wages in kind, animal feed, and other purposes. The holders were asked to quantify their yearly crop utilization experiences in percent, based on their common practices. The results obtained from Amhara region are highlighted here.

In Amhara region, more than 61% of pulses produced were used for household consumption, about 16% for seed, and 19% for sale (Table 13). The remaining 4% of pulses were used for wages, animal feed and others. Crop wise utilization for household consumption varied from 21% for soybean to 26% for fenugreek and 68% for faba bean. About 11% of field pea and 59% of fenugreek were sold in the local markets during 2001/2002. In southern Wello zone of the Amhara Region, more than 72% of field pea was utilized for household consumption, whereas 42% of lentil produce was sold in the local markets during 2001/02.

CONCLUSIONS

In Ethiopia, mostly subsistence farmers grow pulse crops under rainfed conditions. The pattern of rainfall distribution in the country predicates the suitability of a particular region for pulses production. Thus, the most suitable areas are Amhara, Oromiya, and Southern regions. The highland pulses have the largest share in total production of pulses. Compared with the last few years, there has been a significant increase in both area as well as total pulses production during 2001/2002 crop season with the share of these crops being 13% in area and 13% in production.

Policy makers, planners, analysts in the government, researchers and others are the users of the statistical information. This information can also help to evaluate the performance of programs and projects; make informed decisions; set appropriate targets, priorities and monitor the performance; and feed this information back into the policy process. The same is true with researchers; they could also get useful statistical information on how far the farmers have adopted the results of their research outputs, and how successful are their technology transfer activities.

Table 11. Area and production of pulse crops by district (*woreda*) in rural areas of western Shoa zone, 2001/2002.

Woreda	Area (ha)	Production (t)
Ginde Beret	1,958	2,745
Jeldu	2,372	3,661
Ambo	6,062	7,895
Cheliga	4,113	7,126
Bako Tibe	1,081	1,423
Dano	837	914
Nono	3,314	3,639
Tikur	214	320
Ameya	3,910	3,634
Wonchi	1,178	1,334
Dendi	6,634	8,202
Ejerie	4,368	5,438
Ada Berga	3,036	4,732
Welmara	1,976	2,419
Alem Gena	6,828	6,970
Kersana Kondaliti	5,831	5,864
Tole	3,628	4,135
Elu	3,430	4,338
Dawo	3,032	3,629
Welisona Goro	2,601	2,785
Becho	4,251	4,158
Kokir	3,122	3,964
Meta Robi	1,818	2,100

Source: CSA (2002a)

Table 12. Area, production and yield of selected pulse crops in rural areas of Dendy *woreda* of western Shoa (2001/2002), *meher* season.

Crop	Area (ha)	Production (t)	Yield (t/ha)
Faba bean	1,560	2,118 (25.82%)	1.36
Chickpea	1,416	1,593 (19.42%)	1.13
Grass pea	2,176	3,136 (38.23%)	1.44

Source: CSA (2002b).

Table 13. Selected pulse crop production and utilization in rural and urban holdings in Amhara Region, 2001/2002.

Crop Name	Total Production (t)	Percent Utilized for: Household consumption	Seed	Sale	Wage in kind	Others
Pulse	507,358	61.18	15.78	18.66	1.90	2.47
Faba bean	211,165	68.37	16.14	11.38	1.89	2.21
Fenugreek	5,976	25.72	13.88	59.17	0.55	0.67

Source: CSA (2003).

REFERENCES

CSA 1996. Agricultural sample survey report on area and production for major crops, 1995/1996. Volume I. Statistical Bulletin 152. Central Statistical Authority (CSA), Addis Ababa.

CSA.1997. Agricultural sample survey report on area, and production for major crops, 1996/1997. Volume I. Statistical Bulletin 171. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 1998a. Agricultural sample survey report on area and production for major crops, 1997/1998. Volume I. Statistical Bulletin 180. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 1998b. Agricultural sample survey report on farm management practices, 1997/1998. Volume III, Statistical Bulletin 193. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 1999a. Agricultural sample survey report on area and production for major crops, 1998/1999. Volume I. Statistical Bulletin 200. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 1999b. Agricultural sample survey report on farm management practices, 1998/1999, Volume III. Statistical Bulletin 207. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 2000a. Agricultural sample survey report on area and production for major crops, 1999/2000. Volume I, Statistical Bulletin 227. Central Statistical Authority (CSA), Addis Ababa, Ethiopia. CSA. 2000b. Agricultural sample survey report on farm management practices, 1999/2000. Volume III. Statistical Bulletin 227. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 2001a. Agricultural sample survey report on area and production for major crops, 2000/2001. Volume I, Statistical Bulletin 245. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA.2001b. Agricultural sample survey report on farm management practices, 2000/2001. Volume III. Statistical Bulletin 245. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 2002a. The 2001/2002 Ethiopian agricultural sample enumeration, Preliminary results, Part I. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 2002b. The 2001/2002 Ethiopian Agricultural sample enumeration, Preliminary results, Part II. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 2003. The 2001/2002 Ethiopian agricultural sample enumeration, Results for Amhara region, Part II B. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

National Seed Industry Policy and the Status of Legumes Seed System in Ethiopia

Belay Simane

Quality Control and Certification Department, National Agricultural Input Authority
PO Box 9197, Addis Ababa, Ethiopia

ABSTRACT

Improved seed is the most cost effective way of increasing agricultural production and productivity. In Ethiopia, the seed system is a very complex chain of events that aims to supply high quality seeds in adequate amounts and at reasonable prices. The history of the seed industry in the country has undergone different phases. A National Seed Industry Policy and Strategy (NSIPS) was formulated in 1992 and came into effect in 1993 with the establishment of the National Seed Industry Agency (NSIA). The policy and strategy were followed by the seed legislation with proclamation No. 206/2000 to regulate the seed industry on a sound basis and protect seed producers, distributors and farmers. The policy and the strategy are in accordance with the country's economic policy and encourage the role of both the public and private sectors in the seed industry. In NSIPS, ample emphasis has been given to agricultural research institutions, public and private farms and farmers as major stakeholders of the seed industry. Variety evaluation, release, registration, seed quality control and distributions are given due considerations in the seed policy and strategy documents. Variety release guidelines are available for field and horticultural crops. Conditions for release, supporting documents for application, evaluation procedure, amendments and forms are available. The variety release guidelines are under revision to harmonize with the regional and international regulations. The number of varieties released so far for pulse crops are below the desired numbers. The genetic identity and purity of each seed lot is done by following the guidelines of the Organization for the Economic Cooperation and Development (OECD) system. Seed standards set for most pulses are respected in the formal seed multiplication. Seed inspection and certification are important sub-components of seed quality control following the seed standards. Presently, improved seed production and distribution to farmers is very minimal. There is no *private* seed company engaged in the country in seed production of pulse crops. Although the current status of seed situation is shaky in terms of seed multiplication, but the situation could be reversed with a strong commitment and concerted efforts of both research and development institutions by employing both the formal and farmer-based seed multiplication schemes.

INTRODUCTION

Ethiopia's primary development objective is to attain relatively fast, broad-based and more equitable economic growth with macroeconomic stability. An additional and equally important objective is relative price stability to protect the poor from the ills of inflation and thereby encourage saving and long-term investments. Several policy reforms have been made in order to establish healthy and competitive environment by involving the private and public sectors, even though there are several problems in their implementation.

Despite an abundant potential of arable land, the level of production and productivity in Ethiopia is low to meet the minimum 2100 K calories per head per day of the highly increasing population, the export, and the local agro-industry requirements. The area under crops as well as overall production has remained stagnant for several years. The crop productivity has also remained low at an average of 1.2 t for food grains, 0.87 t for pulses and 0.45 t for oil crops as compared to relatively much higher yields obtained at research stations and demonstration plots at the farmers' fields. This low performance, among many other factors, is partly attributed to the very low use of the improved agricultural inputs.

The use of improved seed is the most cost effective means of increasing agricultural production and productivity. This is even more important in Ethiopia in view of increasingly limited available arable lands, declining soil fertility, and an ever-growing population. These facts increase the importance of promotion and use of good quality seeds as a means to intensify food production.

The seed sector is a very complex chain of events that aims to supply seed of high quality in adequate amount, at the right time and place, and at reasonable prices. Seed quality refers to both the genetic quality and to the optimum physical, physiological and sanitary conditions. The country has got a well formulated seed industry policy and development strategy as of 1992 to enhance a successful national seed industry system. Seed marketing study of November 2000 commissioned by the Ethiopian Seed Enterprise (ESE) indicates that the size of the available seed market of certified seed in the country can aim at 75,000 to 100,0000 t. On the other hand, the penetrated market size is about 20000 t per annum. Despite considerable efforts by the Government and non-government institutions to promote improved seeds and fertilizers, the use of these inputs by farmers remains one of the lowest in the world. The average national fertilizer consumption is only 25 kg/ha of nutrients, whereas the area covered by improved seeds are about 28% (NAIA, 2002). However, fertilizer and improved seed uses have shown a significant increase during the last six years. There are several pests in Ethiopia (NAIA, 2002) that cause significant pre- and post-harvest losses (up to 50% yield losses). Despite such high yield losses in the country, pesticide use by the small farm holders is extremely low.

In recent years, the agriculture sector has responded positively to reforms aimed at enhancing market incentives and private sector initiatives. There has been progress in production and productivity of the traditional agriculture through provision of modern inputs such as fertilizers, seeds and pesticides through the extension package program. The program also expanded to cover wide areas as opposed to the past efforts, which were contained to limited areas. Evaluations of this program have demonstrated productivity increases of major staple food crops by at least twice or 2-4 times on participant farmers' fields. However, pulses were not included in the promotion and popularization of extension activities.

Improved seeds, fertilizers and pesticides together constitute a package to increase production and productivity of different crops, and they are made available under the current extension intervention program. Establishing a composite input distribution system so that a farmer can get all the needed inputs for crop production under one roof has been evident in many developing countries. The new Five-year Agricultural Development Plan requires convergence in the availability of quality seeds, fertilizers and pesticides, as one without the other cannot give optimal returns. Ensuring their timely and adequate availability, their quality, sound marketing practices, availability of credit, problems of remote locations, and semi-arid areas are common to all the inputs. This called for the establishment of the National Agricultural Input Authority (NAIA) by a proclamation (No 206/2002), responsible for the establishment and implementation of an agricultural inputs supply system that ensures adequate, timely and quality inputs supply right up to the grass roots level (FDRE, 2002a).

The objectives of this discussion paper are to: (i) explain the seed industry policy and strategy in Ethiopia, (ii) present an overview of the seed system framework, and (iii) highlight the status of improved pulses seed production.

POLICY ISSUES

The policy and strategy address issues to create enabling environment for both formal and informal seed systems. The purpose of the seed policy is to facilitate and regulate the production and marketing of quality seed. Proclamations, guidelines and seed standards issued in line with the National Seed Industry Policy and Strategy (NSIPS) (1992) are conducive for the development of a sustainable seed system. The seed proclamation No. 288/2002 defines the institutional framework with the basic tasks, responsibilities and responsible authorities for the development of the seed industry (FDRE, 2002b). A manual on Plant Breeders Right (PBR) has been drafted and is expected to be approved by the council this year. The main objectives of the National Seed Industry Policy and Strategy are to:

1. Streamline, evaluate, release, register and maintain the varieties developed by national programs;
2. Develop an effective seed production and supply system through participation of public and private sectors;
3. Encourage the participation of farmers in germplasm conservation and seed production;
4. Create functional and institutional linkages among the players of the seed industry; and
5. Regulate seed quality, seed import-export trade, quarantine and other seed-related issues.

Appropriate quarantine rules and regulations are also in place to control the importation, production and distribution system of healthy and good quality seed (Plant Protection Decree No. 56 of 1971). The basis of quarantine service in Ethiopia is in line with the International Plant Protection Convention of 1951 and the Inter-African Phytosanitary Convention of 1967. Ethiopia is a signatory to both of these conventions as well. The Plant Quarantine Regulation No. 4/1992 that focuses on the control of imports and exports, and disposal of refused plants/seeds that have entered in the country has filled the gaps of the previous quarantine rules and regulations.

The national seed industry has registered some achievements in the promotion and development of improved varieties. Private entrepreneurs are getting attracted to the seed business in many parts of the country, which is vital for reliable, sustainable, competitive, and cost-effective seed system. However, developing a healthy and competitive seed industry by mobilizing both the public and the private sector is still far away from the reality. Some of them need conceptualization of issues in order to build a sustainable seed system, whereas others need capacity building. Because many stakeholders are involved and it follows generation system, seed production planning is also complicated, and at times very difficult to plan and coordinate. The most important task of NAIA, therefore, will be to effectively organize all the institutions involved in the seed chain and clearly define their role in the seed chain.

THE SEED SYSTEM

The seed system in Ethiopia basically consists of two components: the formal seed sector and the farmers' seed system (informal). However, an equally important third component of emergency seed programs also exists, which is often implemented by NGOs and other relief organizations. The formal seed system covers from variety development to marketing of seeds. The present development policies of this system are generally adequate to address problems related to sustainable seed supply. However, lack of coordination of all the sector activities is a common feature.

Every certified seed lot is derived from a particular lot of breeder seed via a known number of generations according to the nomenclature system of Organization for the Economic Cooperation and Development (OECD) (Table 1). In order to maintain the genetic identity and purity of each seed lot, a strict generation system is used. Therefore, quality control and certification process is undertaken as the major component of this seed system. Seed laboratory testing will be decentralized using the central National Seed Testing Laboratory (NSTL) and the newly constructed eight Regional Seed Testing Laboratories located at different strategic locations of the country.

A great deal of efforts and resources have been spent in food crops for potential areas. As far as its endeavors in seed sector, high value crops, export crops and crops for marginal areas require more focus.

Variety Release and Registration

Variety release guidelines are available for field and horticultural crops. Conditions for release, supporting documents for application, evaluation procedure, amendments and forms are included in the guidelines. For locally produced varieties, applicant will enter varieties intended for release for at least one season variety verification trial (VVT). In total two seasons' data from previous stages, national/regional yield trials, are needed.

Existing variety release and evaluation is done by a standing National Variety Release Committee (NVRC) and various ad-hoc technical committees drawn from different institutions. The system has enormous limitations to plan and coordinate the activities due to various assignments of different committee members. Experiences in other countries show that it is possible to carry out the variety release by contracting independent institutions or building capacity of the regulatory body, like NAIA. The variety release and registration procedures will have the following amendments:

1. The variety release guideline will be revised in 2003 to harmonize with the regional and international regulations, the coordination of variety verification trials (VVT) by an independent institution, DUS (Distinctness, Uniformity and Stability), VCU (Value for Cultivation and Use) test).
2. One season variety verification trial combined with two seasons data from previous testing in similar agro-ecological zones.
3. Data from on-farm trials along with their socio-economic data will be recommended but these trials should be done concurrently with VVT so that the trials do not claim extra-time for release of varieties.
4. Appropriate data to support recommendations: yield, agronomic data, disease reaction and G x E interactions, and
5. Relevant quality data.

The breeder or institution responsible for developing varieties, which have been approved for release, would be expected to maintain an appropriate quantity of breeder and pre-basic seed for use in replenishing and restoring commercial seed of the variety to the desired genetic purity (Table 2).

Table 1. Summary of seed classes and responsible institutions.

Generation	Seed class	Responsibility
1	Breeder	Research institutions/Breeders are responsible for producing this category from nucleus seed.
2	Pre-basic	A second-generation of breeder seed. The research institutions/seed units should be responsible to make enough quantity available. Quality control.
3	Basic	Production of enough quantity of basic seed of all crops including hybrid maize should be the responsibility of ESE. EARO should make an agreement with ESE regarding the patent right of Inbred Lines of hybrid maize. Quality control is compulsory and it is NAIA's responsibility.
4	Certified-1	*Private sector*: production of marketable and profitable crops. *Public Sector:* Crops that are not produced by the private sector (Developmental aspect), Profitable crops like hybrid maize to supplement the private sector. Quality control is compulsory and it is NAIA's responsibility.
5	Certified-2-4	Basically produced by Cooperatives through farmer-based seed multiplication scheme. It is applicable only for open-pollinated crops. Quality control is compulsory and it is NAIA's responsibility.

* Certified 1, 2-4 indicates numbers of cycles of certified seeds.

Improved Seed Production

The total national area devoted to pulses is little less than a million ha with 0.91 million t of total grain production. The productivity, however, is very low with an average productivity of only 0.9 t/ha ranging from 0.64 t/ha for lentil to 1.2 t/ha for faba bean (CSA, 2000). The total number of released varieties so far for all pulse crops is 65 (Table 3). In addition, there are 19 candidate varieties for release in 2003. On the other hand, ESE is multiplying seed for commercial purposes only of 16 varieties on a total of 815 ha expecting 91.9 t of improved seed, which is insignificant considering the total production area. This situation calls for attention of all stakeholders to discuss the methods to promote, multiply and distribute the available technologies in pulse improvement program.

Seed Quality Control and Certification

A complete formal seed quality control system comprising of the following will be enforced:

Inspections: Involving inspection of field, processing plants, stores and markets;

Seed testing: Involving sampling, variety and germination analysis, purity analysis, moisture analysis, seed health and vigor testing, and

Certification: Labeling in order to confirm the origin and variety purity of the seed lot is compulsory for all crops.

Seed standards for 74 crops including pulses have been set for field inspections, isolation from potentially contaminating crops and permitted disease and weed levels (ESA, 2000). The standards are formulated by striking a balance between the maximum obtainable quality and the required seed quantity, which is in line with the international approach. Seed production fields that fail to meet these standards are rejected for seed purposes. However, for some crops the seed standards require revision following the OECD system.

The country follows compulsory and voluntary seed certification. Compulsory certification has been enforced for major food crops including pulses. All horticultural crops except pepper, garlic, Irish potato and sweet potato are under voluntary certification.

Seed Promotion and Extension

More focus on popularization of new varieties should be carried out as soon as they are registered. Variety Gazette and public media will be exploited as much as possible. Educational campaigns would be carried out through demonstrations, field days, radio and television broadcasts, and newspapers. Both public and private seed farmers should aggressively exercise study visits, workshops, and seminars.

Table 2. Minimum quantity of breeder's seed of pulse crops required in seed stock.

Crop	Seed stock class	Breeder's seed required (kg)	Pre-basic seed required (kg)	Breeder's nucleus seed in cold storage (kg)
Faba bean	New release	100	1500	25
	Renewal stock	100		
Field pea	New release	125	1000	2.5
	Renewal stock	25		2.5
Chickpea	New release	125	1000	3.0
	Renewal stock	25		3.0
Lentil	New release	10	1000	2.0
	Renewal stock	15		2.0
Haricot bean	New release	10	1000	2.5
	Renewal stock	20		2.5
Soybean	New release	10	1000	1.5
	Renewal stock	10		1.5
Vetch	New release		1000	0.25
	Renewal stock	3.5		0.25

Source: NSIA (2001).

Table 3. Number of released varieties, varieties multiplied for seed by Ethiopian Seed Enterprise (ESE) and the national production and productivity of pulse crops.

No.	Crop	No. of released varieties	Varieties multiplied (2003) No.	Area (ha)	Yield (t)	Candidate varieties for 2003	National grain production Area (ha)	Production (t)	Productivity (t/ha)
1	Faba bean	14	3	251	326	0	369,000	447,000	1.21
2	Field pea	8	3	142	175	2	175,000	150,000	.86
3	Chickpea	7	3	51	47	4	185,000	180,000	.97
4	Lentil	8	2	26	25	2	60,000	38,400	.64
5	Haricot bean	18	4	295	294	8	119,900	99,000	.82
6	Soybean	8	1	50	50	3	1,769	1,620	.91
7	Cowpea	2	0	0	0	0	0	0	0
	Total	65	16	815	919	19	910,669	9,160,205	.9026

Source: NAIA (2003); CSA (2000).

Seed Production Planning and Coordination

Planning a seed production program requires a business approach. It should start with an assessment of market demand and be followed by an analysis of expected returns and risk factors before final allocation of resources. As seed production involves various steps its planning becomes rather complicated. Changes in demand cannot be met immediately by appropriate changes in production because certified seed production depends on the availability of registered or basic seed.

Excessive production of basic seed in a declining market for certified seed of the particular variety can amount to substantial wastage of expenses. Also, holding stocks of lower generation seed to meet any sudden increased demand is often costly. However, 20% of the expected demand should be kept as a security stock at all levels. All regions and private seed farms should submit their demand one year in advance in order to properly plan and coordinate.

CONCLUSIONS

The seed system in Ethiopia, which consists of formal, informal (the farmers' seed system), and emergency seed programs, is a very complex chain of events that aims to supply high quality seed in adequate amounts, at the right time and place, and at reasonable prices. The country has got a well formulated seed industry policy and development strategy as of 1992 to enhance a successful national seed industry system. It recognizes both the formal and informal seed systems. However, there is a long way to go for developing a healthy and competitive seed industry by mobilizing both the private and public sectors. Existing variety release, and evaluation is done by NVRC and various ad-hoc technical committees drawn from different institutions. The system has enormous limitations for planning and coordinating the planned activities, and thus actions have been initiated to standardize the variety release guidelines as stated above in Variety Release and Registration.

Every certified seed lot is derived from a particular lot of breeder seed via a known number of generations according to the nomenclature of OECD system. In order to maintain the genetic identity and purity of each seed lot, a strict generation system will be used. Therefore, quality control and certification process will be undertaken as the major component of the seed system.

Although ESE is multiplying seed of 16 varieties of pulse crops on a total area of 815 ha, it is insignificant considering the total production area under these crops in the country. This situation calls for attention of all the stakeholders to discuss ways to multiply and promote the use of improved seeds, and distribute the available technologies in pulses improvement programs. Aggressive seed promotion works and timely seed research *per se* are very important in order to utilize the yield potentials of the improved varieties.

REFERENCES

CSA. 2000. Agricultural Survey 1995-2000. Central Statistics Authority (CSA), Addis Ababa, Ethiopia.

ESA. 2000. Seed specification for various pulses. Ethiopian Standard Authority (ESA), Addis Ababa, Ethiopia.

FDRE. 2002a. Proclamation No. 206/2000. National Agricultural Input Authority Establishment Proclamation. Federal Negarit Gazeta 8th year No. 36. Federal Democratic Republic of Ethiopia (FDRE), Addis Ababa, Ethiopia.

FDRE. 2002b. Proclamation No. 288/2002. Seed proclamation. Federal Negarit Gazeta 8th year No. 36. Federal Democratic Republic of Ethiopia (FDRE), Addis Ababa, Ethiopia.

NAIA. 2002. Agricultural input project. Submitted to the World Bank. National Agricultural Input Authority (NAIA), Addis Ababa, Ethiopia

NAIA. 2003. Crop variety register. Issue No. 5. National Agricultural Input Authority (NAIA), Addis Ababa, Ethiopia. 121 pp.

NSIA. 2001. National variety release procedures and mechanisms. National Seed Industry Agency (NSIA), Addis Ababa, Ethiopia. 73 pp.

NSIPS. 1992. National seed industry development policy and strategy. National Seed Industry Policy and Strategy (NSIPS), Addis Ababa, Ethiopia. 75 pp.

ICARDA Strategies in Food Legume Improvement Research: Present Status and Future Implications for Ethiopia.

A. Sarker, R.S. Malhotra, S. Khalil, M.H. Halila and W. Erskine

International Center for Agricultural Research in the Dry Areas (ICARDA)
P. O. Box 5466, Aleppo, Syria

ABSTRACT

Lentil, faba bean and chickpea are the most important and popular food legume crops in Ethiopia. Their seeds are prime source of dietary protein and other essential micronutrients (Zn, Fe, B-Carotene) of majority of its population, especially in the rural areas. From human, animal and ecosystem health points of view and for income generation amongst the marginal farmers, improvement of food legumes has become important to Ethiopian crop research and development programs. ICARDA has established a close collaboration with the Ethiopian national program to improve food legume crops. Through continued cooperation, the country has developed improved varieties and production packages, enriched with substantial amount of exotic germplasm and scientific information, and have received support in human resources development. Through joint efforts, new genotypes have been constructed with appropriate phenological adaptation to a highly variable environments; biotic and abiotic stress resistance and for other traits of interest. To date, six lentils, four faba bean and one Kabuli chickpea improved varieties have been released from ICARDA-supplied germplasm by the Ethiopian National Food Legume Program for commercial cultivation in the country. Future thrust should be placed on research for developing varieties with combined resistance to key stresses and rich in nutritional quality keeping participatory and market-driven approaches in view.

INTRODUCTION

The International Center for Agricultural Research in the Dry Areas (ICARDA) is working in partnership with national programs to meet the challenge posed by a harsh, stressful and variable environment in which the productivity of rainfed cropping systems must be increased. The challenge is addressed through research, training and dissemination of information. Among food legumes, the Center has a world responsibility for the improvement of lentil and faba bean, and a regional responsibility in Central and West Asia and North Africa for the improvement of Kabuli chickpea. Ethiopia is one of the major lentil, chickpea and faba bean producing countries in Africa, evidenced by their production records and food habit of its people. Faba bean is grown in many regions of Ethiopia including Tigrai, Gondar, Gojam, Wellega, Wollo, Gamu Gofa and Shoa up to 3000 m asl. It is grown in 371,000 ha with a productivity of 1.2 t/ha (FAO, 2004). Lentil is predominantly grown in the highland and semi-highland regions, which occupies an area of 75,000 ha, and produces 510 kg/ha. Although *desi* type chickpea is mostly grown in Ethiopia, demand for Kabuli type has increased in recent years. Chickpea is also widely cultivated (196,000 ha) in the highland and mid-highland regions mainly on clay soil. There are several indigenous popular food preparations from food legumes. From nutritional point of view, the amino acid profiles of food legumes (faba bean, lentil, and chickpea) satisfy the requirements of human nutrition when mixed with cereals. Most of these food legumes are also used as snacks, either roasted or fried. The fresh green pods/or seeds of faba bean, pea and lentil in the highlands are consumed as a curry with cereal *injera* (a pancake bread from *tef*) at least twice a day. In faba bean, all above ground parts, other than grains, contain 6-17.6 % protein (Li- Juan et al., 1993), and if faba bean is fed to lactating cow, milk increase is considerable. Lentil is mainly eaten as *wot*, a soup, which supplements lysine, an essential amino acid in a barley- and *tef*-based diet. Additionally, food legumes contribute to nutritional security by providing considerable amount of P, K, Fe, Zn and vitamin A (Bhatty, 1988; Savage, 1988).

Among various food legumes, lentil is a cash crop of the farmers of Ethiopia since it receives high prices compared with all other food legumes and main cereal crops such as *tef*, barley and wheat (Bejiga and Anbessa, 1994). Recently, Ethiopia exported lentil to India (Bejiga, personal communication). Large variation and frequent fluctuation has been observed in yields of these pulse crops due to erratic environmental factors, and prevalence of various biotic agents, most particularly diseases.

Since its inception, ICARDA has been collaborating with the Ethiopian National Food Legume Program (ENFLP) in developing and exchanging improved genetic materials, segregating populations, sources of quality traits and resistance to various stresses, through Legume International Testing Program (LITP). A decentralized breeding approach is being followed, where targeted segregating populations are sent to Ethiopia and selections are made in local edapho-climatic conditions. Crosses are planned in consultation with national scientists, and local landraces are involved in cross combinations.

AGRO-ECOLOGY, MAJOR STRESSES, AND BREEDING OBJECTIVES

The food legume breeding programs at ICARDA are built upon the foundation of the germplasm collection, physically as the source of variation for breeding, philosophically on the study of the patterns of variability of landraces, which have yielded the basic information on adaptation. Also, based on the understanding of the local constraints to production and consumer requirements of different areas, the breeding program at ICARDA aims to address the specific needs of different agro-ecological regions.

Lentil in Ethiopia is traditionally grown in various cropping systems depending on elevations. At the lower elevations, it is cultivated in rotation with *tef*, whereas durum wheat is the dominant cereal in the rotation with lentil at higher elevations. The growing period is characterized by mild and relatively short winter compared to West Asian condition. Among various biotic stresses, rust disease caused by *Uromyces fabae*, wilt/root rots (*Fusarium, Rhizoctonia, Sclerotium,* etc.) and pea aphid, are the key factors limiting lentil production in Ethiopia. Among diseases, rust is the most devastating, and may cause complete crop failure in epidemic years (Bejiga et al., 1998). Drought is the most common abiotic stress causing substantial yield loss, but in some years water-logging poses serious threat. In Ethiopia, faba bean is grown as rainfed, and therefore drought is the main factor for yield reduction. In faba bean, chocolate spot (*Botrytis fabae*) , Ascochyta blight (*Ascochyta fabae*) and rust (*U. fabae*) are the key diseases of the crop, and of late a parasitic weed, broomrape (*Orobanche crenata*) has become a threat to its cultivation. Yield of Kabuli chickpea is constrained by Ascochyta blight (*A. rabei*) and Fusarium wilt (*F. oxysporum f sp. ciceri*) diseases, and drought. Larger seed size of Kabuli chickpea is one of the attractive traits for the farmers and consumers.

A world collection of wild and cultivated germplasm of lentil, faba bean and Kabuli chickpea is maintained at ICARDA and has been used in breeding programs to address these stresses (Table 1). The food legume improvement program at ICARDA generally uses parents of diverse origin with known traits with the aim to combine gene(s) to contribute to yield and resistance to major biotic and abiotic stresses. Crosses are commissioned in consultation with the local scientists to address the breeding objectives of Ethiopia. For example, in lentil, crosses with early maturing parents having resistance to rust and wilt-root rot are important.

Table 1. Genetic resources of lentil, chickpea and faba bean conserved at ICARDA.

Crop	Cultivated	Wild	Total
Lentil	10,556	568	11,124
Chickpea	12,021	266	12,287
Faba bean	10,723	5,891	16,614
Total	33,300	6725	40,025

AREAS OF COLLABORATION

Supply of Genetic Materials

Historically, lentil landraces from Ethiopia have a very narrow genetic base (Erskine et al., 1989). To widen the genetic base, improved landraces and elite breeding lines and populations developed at ICARDA are supplied to ENFLP according to their demand through LITP and also through special dispatches. Nurseries comprising of pure lines, sources for stress resistance and segregating populations are delivered to select desirable lines/single plants. A substantial number of faba bean nurseries were supplied from Egypt through the Nile Valley and Red Sea Regional Program (NVRSRP) based in Cairo, Egypt. With a decentralized breeding approach, and according to changing national requirements, demand for segregating populations developed by ICARDA has increased considerably in the recent years. Targeted crosses are made at ICARDA in consultation with the national colleagues involving improved cultivars and elite landraces from Ethiopia.

Human Resources Development

Both research and training are important to provide a sustainable development to agriculture at the national levels. Ethiopian scientists and technical staff are trained on hybridization technique, experimental designs, data capturing, management, analysis, and reporting. This was accomplished through long-term and short-term courses, individual training, and group courses. Senior scientists and research administrators visit ICARDA to exchange ideas, develop joint research plan and project proposals. In-country training courses were also organized in Ethiopia for the benefit of larger number of participants. ICARDA scientists also take part in workshops, annual and regional planning meeting in Ethiopia, and exchange experiences and views. A summary of human resources development activities for Ethiopia is shown in Table 2.

Collaboration through Regional Network

A regional network on wilt/root rots in food legumes is operational in Ethiopia, Sudan, Egypt and Yemen under the aegis of ICARDA's NVRSRP, administered from Cairo, Egypt. Scientists from the region share their experiences, research material and findings, and develop common strategies to address the research needs. Collaborating scientists jointly publish research results.

PROGRESS MADE

Cultivar Development

Development of high yielding cultivars with resistance to major stresses and appropriate phenological adaptation is the key breeding objective of ENFLP activities. Use of low input improved production package is of prime importance for easy adoption by resource-poor farmers in Ethiopia.

The national program has so far released six lentil, four faba bean and one Kabuli chickpea varieties, emanated from ICARDA-supplied genetic materials. The first lentil variety Chalew was released in 1985. Then, Chekol was released in 1994, which was followed by Gudo, Adaa and Alemaya. Grain yield of these varieties ranges from 1.5 to 2.6 t/ha, and they have high level of rust resistance. Besides, Adaa and Alemaya are resistant to wilt/root rots, and Alemaya is moderately resistant to pea aphid. Among them, Adaa and Alemaya are the most popular lentil varieties adopted by the farmers. Recently, another variety Assano has been released for large seed size, moderate resistance to Ascochyta blight and root rots, and high resistance to rust with a yield potential of 3.1 t/ha. In 2004, Teshale and Alem Tena were released for rust and wilt resistance and higher yield. Virtually, all lentil varieties released in Ethiopia have been developed in collaboration with ICARDA.

In faba bean, varieties Shallo and BPL 18021-2 (Holetta-2) are high yielding with improved level of resistance to chocolate spot and rust diseases. However, Bulga 70, Kassa, Tesfa and Mesay have been released for high yield and wide adaptation. In Kabuli chickpea, variety Arerti has been released for high yield and tolerance to fusarium wilt.

Selection for Specific Traits

Lentil landraces from Ethiopia are susceptible to rust, the most devastating disease of lentil in Ethiopia. ICARDA is perusing a decentralized approach in rust research and is done in "hot spots". Debre Zeit Agricultural Research Center (DZARC) of Ethiopia is one of the most epidemic hot spots for lentil rust disease in the world. Over the years, a number of genotypes from ICARDA have been supplied to Ethiopia, which have shown high level of resistance against the disease. Some of the rust-resistant promising lines are: ILL 6792, -6811, -7212, -7617, -2501, - 4605, - 5675, -5724, -5745, - 5782, -5871, -6002, -6008, -6924, 6028, -6049, -6242, -6471, -6788, -7978, and –7981

In recent years, Ascochyta blight has become a serious threat to lentil cultivation. It has been observed that mostly the early-maturing genotypes are highly vulnerable to this disease. The disease affects the plant and seed as well. Quality of infected seeds deteriorates, and thus the affected seeds lose their market value. The following lines showed resistance to the disease in natural epiphytotic conditions: ILL 156, ILL 319, ILL 358, ILL 5588, ILL 7537, FLIP 86-38L, FLIP 98-27L, FLIP 2003-34L, FLIP 2002-20L, FLIP 93-3L, FLIP 95-34L, FLIP 96-49L, and FLIP 97-29L.

A range of soil-borne pathogens causing wilt and root rot diseases substantially affect lentil production in Ethiopia. Under the Wilt/Root Rot Network, DZARC has established a homogeneous wilt-sick-plot to screen the lentil breeding materials against wilt/root rots, which has been instrumental in identifying resistant materials. Some of the released varieties are resistant to wilt/root rots. In addition, a number of resistant lines have been selected from International nurseries, viz., FLIP 86-18L, FLIP 86-38L, FLIP 88-34L, FLIP 94-3L, FLIP 95-57L, FLIP 95-50L,ILL 2580, and ILL 669.

The Ethiopian faba bean program has also been strengthened through the supply of ICARDA international nurseries and segregating populations. Lines having combined resistance to chocolate spot (*B. fabae*) and rust (*U. fabae*) are BPL 710, ILB 938, ILB 1415, ILB 4725 and ILB 4726. Two high yielding varieties with improved resistance to chocolate spot and rust diseases, Shallow, developed through hybridization (KUSE 2-27-33 x ILB 1179-2), and BPL 18021 (Holetta-2) have been released by Sinana Agricultural Research Center (SnARC) and Holetta Agricultural Research Center (HARC), respectively.

Table 2. Capacity building of Ethiopian researchers at ICARDA, 1979-2002.

	Headquarters training courses			Non-headquarters courses			
Year	Long-term courses	Short-term courses	Individual Non-degree	Individual degree	In-country courses	Regional/ Sub- regional	Total
1979	1	-	-	-	-	-	1
1981	1	-	-	-	-	-	1
1982	-	-	-	-	-	-	-
1983	1	-	-	-	-	-	1
1984	1	-	-	-	-	-	1
1985	1	-	2	-	-	-	3
1986	1	-	3	-	-	-	4
1987	4	-	3	-	-	-	7
1988	-	1	5	2	22	-	30
1989	3	5	8	1	-	4	21
1990	2	6	3	5	-	-	16
1991	1	5	7	7	-	-	20
1992	-	1	5	5	-	-	11
1993	-	1	4	1	-	-	6
1994	-	3	-	1	-	-	4
1995	-	-	-	2	-	-	2
1996	-	-	-	1	-	-	1
1997	-	-	1	-	-	-	1
1998	-	-	-	-	10	-	10
1999	-	-	1	-	-	-	1
2000	-	-	-	-	-	-	-
2001	-	-	4	1	-	-	5
2002	-	-	-	1	-	-	1
Total	16	22	46	27	32	4	147

FUTURE THRUSTS

ICARDA's future research thrust for food legume improvement in Ethiopia will have emphasis on the following:

1. Stability in production of legumes. To stabilize productivity, future research thrust should focus on: a) combined resistance against chocolate spot, rust, Ascochyta blight and *Orobanche*, and response to supplemental irrigation in faba bean; b) rust and wilt/root rots diseases combined with drought tolerance in lentil; and c) development of Kabuli chickpea cultivars with resistance to wilt and drought.
2. Weed control through appropriate rotation with cereal crops.
3. Acceleration of seed production and distribution of the improved varieties to enhance adoption of the improved varieties.
4. Farmers' participatory approaches in the form of Participatory Varietal Selection should be followed to enhance adoption. This will also facilitate exploitation of specific adaptation (Ceccarelli et al., 2000), which is vital for highly variable environment of Ethiopia. Moreover, the approach also facilitates seed diffusion through farmer-to-farmer dissemination, which is important, as formal seed sector is weak in case of food legume crops. Among other advantages, biodiversity is maintained, and farmers are empowered in technology development and transfer.
5. The adaptive research should be intensified through farmer's active participation. Large-scale farmers' field demonstrations, on-farm evaluation of newly developed technologies should be carried out to demonstrate to the farmers, and to eventually enhance adoption.
6. Quality and nutrient traits should be taken into consideration in cultivar development. Nutrient-dense pulses varieties, particularly with higher protein, P, K, Fe, Zn and B-Carotene need to be developed to enrich the nutritional status of the consumers.
7. Varietal development program should be market-oriented, as the food legumes play an important role in international trade in Ethiopia. Ethiopia earns foreign currency through exporting some of these pulses in foreign markets. Therefore, research direction should focus both on domestic and international demands.

CONCLUSIONS

The ENFLP is engaged in research to increase productivity and production of food legumes through genetic enhancement and development of improved production technologies. Progress has been made to develop improved varieties and production technologies, which are under dissemination process. However, to enhance the technology transfer process, strong linkages are essential among researchers, extensionists, seed production agencies, NGOs and other players in this endeavor. A farmer-participatory approach needs to be adopted and institutionalized to achieve rapid adoption and impact. With concerted efforts of all it is expected that Ethiopia will be self-sufficient in food legume production in near future.

REFERENCES

Bejiga, G., N. Tadesse and W. Erskine. 1998. We fixed rust, next wilt and root rots. *ICARDA Caravan* 9: 12-14.

Bejiga, G. and Y. Anbessa. 1994. Genetics and breeding research in lentil. p. 162-182. *In* Asfaw Telaye et al. (Eds.). *Cool-season Food Legumes in Ethiopia*. Proc. First National Conference on Cool-season Food Legumes, 16-18 Dec.,1993. Addis Ababa, Ethiopia. IAR (Institute of Agricultural Research), Addis Ababa, Ethiopia.

Bhatty, R. S. 1988. Composition and quality of lentil (*Lens culinaris* Medik.): A review. *Canadian Institute of Food Science and Technology* 21: 144-160.

Ceccarelli, S., S. Grando, R. Tutwiler, J. Baha, A. M. Martini, H. Salahieh, A. Goodchild, and M. Michael. 2000. A methodological study on participatory barley breeding. I. Selection phase. *Euphytica* 111: 91-104.

Erskine, W., Y. Adham and L. Holly. 1989. Geographic distribution of variation in quantitative characters in a world lentil collection. *Euphytica* 43:97-103.

FAO. 2004. Production Year Book 2003. FAO, Rome, Italy.

Li- juan, Lang, Yu Zhao-hai, Zheng Zhao-jie, Xu Ming-shi, and Ying Han-qing. 1993. The importance of Faba Bean as a Fodder Crop. p. 14. In Faba bean in China, State-of-the Art Review. ICARDA.

Savage G.P. 1988. The composition and nutritive value of lentils (*Lens culinaris*). *Nutrition Abstracts and Reviews (Series A)* 58:320-343.

Section II. Breeding and Genetics

Collection, Conservation, Characterization and Sustainable Utilization of Grain Legumes in Ethiopia

Tesema Tanto and Eshetayehu Tefera

Institute of Biodiversity Conservation and Research (IBCR)
P.O. Box 30726, Addis Ababa, Ethiopia

ABSTRACT

Ethiopia is one of the major Vavilovian centers of diversity for several grain legume crops. Lupine, field pea, and wild ancestor of cowpea are supposed to be of Ethiopian origin. Like any other crops in Ethiopia, both man-made and natural factors of genetic erosion threaten the resource-base of grain legume crops. These factors include displacement of heterogeneous crop populations by few uniform varieties, change in farming systems and land use, destruction of natural habitats, recurrent drought, etc. Since the establishment of the then PGRC/E (Plant Genetic Resources Institute of Ethiopia) in 1976 and the present IBCR (Institute of Biodiversity Conservation and Research) in 1998, the scientists have conducted a series of systematic crop explorations, collection, characterization and evaluation programs to sustainably conserve and utilize these dwindling resources. To date, a total of 7250 accessions of grain legume crops have been conserved *ex situ* under short- and long-term storage conditions. Of these, 5320 accessions have been characterized for basic qualitative and quantitative traits. Significant numbers of the grain legume germplasm accessions have been utilized in the national pulse improvement program, and as a result promising types of improved varieties have been developed and released for farmers' use. Furthermore, the characterized accessions have provided some basic indicators and values for further research. However, efforts were not aimed at specific merits, for instance, tolerance to biotic and abiotic stresses, nutrition content, and other useful characters. Thus, an integrated approach should be adopted to fill the missing gap and to tap every desirable trait to address various sustainable conservation, research and utilization programs. For this, pulse crops adapted to the marginal areas and relatively neglected but potentially useful ones should be given special consideration in collection, characterization, evaluation and sustainable utilization of these valuable genes in crop improvement programs.

INTRODUCTION

Grain legumes or pulses were among the earliest food crops that were cultivated by man and are important source of protein in the diets of the Ethiopian population. The protein content in pulses varies from 17 to 25% (except 40% in lupine and 38% in soybean), which is twice that of cereals and slightly more than protein percentage of meat, fish or eggs (Gabrial, 1984). Moreover, they contain large amount of essential amino acids lysine and tryptophan that are relatively low in cereals.

In Ethiopia, pulses are major important crops next to cereals, are cheap sources of protein, and play modest role in export market. They also significantly contribute to enhancing soil fertility. However, their production and productivity are by far below their expected potential. In the Ethiopian Gene Bank, more than 12 species of grain legumes are so far collected and conserved *ex situ* (Table 1). Moreover, seven of these grain legumes are simultaneously conserved in 12 *in situ* (on-farm) crop conservation sites that have been established in four regional states of the country since 1995 by the Institute of Biodiversity Conservation and Research (IBCR). Of the grain legumes grown and conserved in Ethiopia, nine of them, namely, faba bean, field pea, haricot bean, lentil, chickpea, cowpea, pigeon pea, lupine and grass pea in their order are presently considered in this paper. Of these, characterization data of five grain legumes were analyzed and are presented here (Tables 2-7).

Table 1. Grain legumes accessions conserved in the Ethiopian Gene Bank.

Types of grain legume	Total holding	Altitude range (m asl)	Accessions characterized
Vicia faba	2034	1290-3810	1030
Pisum sativum	1616	1800-3350	1404
Phaseolus species	409	1100-2300	315
Lathyrus sativus	573	1600-2900	433
Lens culinaris	600	1290-3450	600
Cicer arietinum	1155	1290-3450	1155
Vigna species[1]	64	1350-1900	23
Cajanus cajan	46	1100-2320	-
Lupinus species	212	1600-2800	-
Trigonella foenum-graecum	541	1450-3150	360
Canivalia species	few	about 1990	-
Total	7250		5320

[1] Figures are for two *Vigna* spp., viz., *V. unguiculata* and *V. radiata*.

Table 2. Variation in agro-morphologic traits [mean ± SD] for chickpea across former provinces.

Former province	Plant height (cm)	Days to flowering	Number of pods per plant	Number of seeds per pod	Primary branch	Secondary branch
Arsi	(25)* 31 ± 5.8	(25) 51 ± 5.4	(25) 55 ± 28	(14) 1.5 ± 0.5	(25) 1.8 ± 0.4	(25) 3.5 ± 1.5
Bale	(13) 31 ± 5.8	(13) 51 ± 5.3	(13) 50 ± 32	(8) 1.6 ± 0.5	(13) 1.8 ± 0.4	(13) 4.0± 2.2
Gomogofa	(11) 34 ± 4.3	(11) 56 ± 5.0	(11) 58 ± 28	(8) 1.6 ± 0.4	(11) 1.6 ± 0.5	(11) 3.9 ± 1.6
Gojam	(159) 37 ± 3.9	(158) 53 ± 3.7	(159) 90 ± 51	(59) 1.5 ± 0.3	(159) 1.8 ± 0.4	(159) 3.5 ± 1.0
Gonder	(101) 36 ± 4.4	(101) 51 ± 4.4	(101) 79 ± 49	(60) 1.5 ± 0.4	(101) 1.7 ± 0.6	(101) 3.6 ± 1.6
Hararghie	(37) 33± 6.3	(36) 51 ± 6.2	(37) 46 ± 29	(23) 1.7 ± 0.4	(37) 1.8 ± 0.5	(37) 4.3 ± 2.8
Illubabor	(2) 36 ± 4.2	(2) 59 ± 0	(2) 64 ± 6	(2) 1.3 ± 0.01	(2) 2.0 ± 0	(2) 3.5 ± 0.7
Shewa	(341) 33 ± 5.7	(342) 50 ± 4.3	(342) 67 ± 43	(143) 1.5 ± 0.3	(342) 1.9 ± 0.4	(342) 3.3 ± 1.2
Sidamo	(30) 30 ± 5.2	(30) 52 ± 5.7	(30) 38 ± 12	(18) 1.6 ± 0.5	(30) 1.8 ± 0.6	(30) 3.9 ± 2.1
Tigray	(18) 31 ± 2.7	(18) 49 ± 5.7	(18) 44 ± 18	(18) 1.6 ± 0.5	(18) 1.3 ± 0.5	(18) 3.9 ± 1.3
Wellega	(4) 31 ± 2.1	(4) 49 ± 3.8	(4) 65 ± 23	(2) 1.4 ± 0.2	(4) 1.5 ± 0.6	(4) 3.5 ± 0.6
Wello	(30) 33 ± 3.9	(30) 48 ± 6.6	(30) 63 ± 40	(23) 1.7 ± 0.4	(30) 1.4 ± 0.5	(30) 3.8 ± 1.7
Unknown	(16) 37 ± 4.4	(15) 52 ± 5.5	(16) 75 ± 36	(5) 1.7 ± 0.4	(16) 1.7 ± 0.5	(16) 2.9 ± 0.8

* The numbers in the brackets indicate the number of accessions that are characterized for each agronomic trait.

Table 3. Variation in agro-morphologic traits [mean ± SD] for field pea across the former provinces.

Former province	Days to flowering	Flowers per plant	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Days to maturity	Thousand-seed weight (g)	Seed size (cm)
Arsi	(57)* 74 ± 11	(28) 3.8 ± 2.3	(57) 113 ± 38	(57) 9.9 ± 4.4	(57) 4.9 ± 0.9	(57) 138 ± 23	(37) 665 ± 523	(26) 3.5± 0.7
Bale	(43) 71 ± 13	(21) 4.3 ± 3.1	(41) 105 ± 40	(41) 9.9 ± 5.6	(38) 5 ± 0.9	(41) 140 ± 22	(26) 715 ± 515	(19) 3.5 ± 0.7
Gomogofa	(15) 73 ± 10	(8) 4.4 ± 3.7	(15) 113 ± 31	(15) 10.0 ± 4	(13) 4.6 ± 1.3	(15) 142 ± 20	(9) 618 ± 336	(7) 3.7 ± 0.5
Gojam	(52) 79 ± 9	(23) 3.3 ± 1.1	(52) 106 ± 26	(52) 10.9 ± 5.1	(51) 5.1 ± 1	(52) 141 ± 15	(36) 578 ± 452	(23) 2.9 ± 0.5
Gonder	(64) 79 ± 9	(31) 5.9 ± 5.9	(64) 114 ± 32	(64) 9.7 ± 4.9	(62) 5 ± 0.9	(64) 142 ± 17	(34) 744 ± 444	(26) 3.3 ± 0.7
Hararge	(45) 74 ± 5	(32) 3.1 ± 1.2	(43) 122 ± 31	(43) 12.2 ± 5.5	(38) 4.5 ± 0.9	(43) 153 ± 13	(37) 745 ± 367	(32) 3.8 ± 0.5
Illubabor	(5) 77 ± 3	(5) 3.4 ± 1.1	(5) 143 ± 14	(5) 11.6 ± 3.9	(5) 4 ± 0.7	(5) 168 ± 2	(5) 920 ± 325	(5) 3.8 ± 0.5
Keffa	(7) 82 ± 14	(5) 3.2 ± 0.8	(7) 107 ± 48	(7) 13 ± 10	(5) 3.8 ± 0.8	(7) 138 ± 21	(5) 197 ± 120	(3) 3.1 ± 0.1
Shoa	(210) 80 ± 9	(77) 7.1 ± 6.2	(210) 105 ± 32	(210) 9 ± 4.2	(119) 5 ± 1.2	(210) 150 ± 18	(68) 723 ± 436	(190) 3.2 ± 0.7
Sidamo	(9) 80 ± 14	(5) 5.2 ± 2.8	(8) 108 ± 36	(8) 9.9 ± 3.7	(5) 5 ± 1.6	(8) 151 ± 11	(5) 403 ± 322	(4) 2.6 ± 0.6
Tigrai	(26) 77 ± 9	(23) 4.3 ± 2.7	(26) 124 ± 94	(26) 9 ± 3.9	(25) 4.5 ± 1.1	(25) 147 ± 19	(24) 584 ± 405	(23) 3.1 ± 0.7
Wellega	(39) 84 ± 11	(29) 5 ± 3.3	(38) 112 ± 32	(39) 9.9 ± 4.9	(37) 4.7 ± 1	(37) 150 ± 16	(33) 667 ± 410	---
Wello	(152) 67 ± 10	(80) 21 ± 14	(152) 130 ± 41	(152) 12.5 ± 7.6	(142) 5.3 ± 1.1	(142) 139 ± 17	(122) 234 ± 332	---
Unknown	(58) 73 ± 11	(3) 6 ± 1.2	(57) 107 ± 31	(57) 9 ± 3.1	(47) 5.7 ± 0.9	(57) 135 ± 15	(37) 155 ± 183	—

* The numbers in the brackets indicate the number of accessions that are characterized for each agronomic trait.

Table 4. Variation in agro-morphologic traits [mean ± SD] for haricot bean across the former provinces.

Former province	Days to flowering	Plant height (cm)	Days to maturity	Number of pods per plant	Seed length (cm)	Seed thickness (cm)	Thousand-seed weight (g)	Number of seeds per pod
Arsi	(1) 46	—	(1) 86	(1) 30	(1) 0.64	(1) 0.5	(1) 2149	(1) 6.5
Bale	(5) 46 ± 10	(2) 30 ± 4.8	(5) 86 ± 5	(4) 25.8 ± 8.1	---	(5) 1.9 ± 1.3	(2) 1666 ± 200	(5) 5.4 ± 1.7
Gomogofa	(26) 54 ± 7	(15) 31 ± 4	(26) 87 ± 12	(24) 21 ± 12	(25) 7.6 ± 5	(25) 1.9 ± 1.1	(8) 1767 ± 698	(25) 5.5 ± 1.2
Gojam	(34) 50 ± 14	(14) 29 ± 4.8	(34) 84 ± 21	(15) 14.4 ± 6.8	(31) 6.0 ± 4.8	(31) 1.5 ± 1	(15) 853 ± 314	(28) 5.5 ± 0.7
Gonder	(1) 61	--	(1) 102	(1) 23	---	---	---	---
Hararge	(26) 49 ± 6	(14) 32 ± 6	(26) 83 ± 6	(22) 16.1 ± 4.1	(26) 5.8± 4.2	(26) 1.6 ± 1	(13) 1304 ± 272	(26) 5.3± 0.9
Illubabor	(5) 44 ± 14	—	(5) 85 ± 11	—	(4) 1.1 ± 0.04	(4) 0.5 ± 0.1	(8) 797 ± 555	(4) 5.4 ± 0.9
Keffa	(1) 41	—	(1) 79	—	(1) 1.1	(1) 0.5	(1) 1023	—
Shoa	(11) 44 ± 3	(4) 29 ± 4.7	(11) 82 ± 4	(6) 20 ± 7.9	(11) 4.3 ± 4.6	(11) 1.2 ± 1.1	(6) 1569 ± 283	(11) 5.7 ± 0.9
Sidamo	(24) 45 ± 6	(4) 34 ± 2.8	(25) 78 ± 16	(12) 17.6 ± 5.6	(24) 3 ± 3.9	(24) 0.8 ± 0.7	(20) 1502 ± 569	(24) 5.8 ± 0.7
Tigrai	(6) 55 ± 18	(1) 26	(4) 105 ± 31	(1) 24	(4) 5.7 ± 5.7	(3) 1.5 ± 0.9	(6) 947 ± 451	(4) 5.6 ± 0.4
Wellega	(42) 50 ± 13	(20) 30 ± 6	(42) 90 ± 24	(29) 22 ± 16	(37) 7 ± 4.8	(37) 1.7 ± 1	(11) 1130 ± 420	(37) 6 ± 1.9
Wello	(3) 54 ± 16	—	(3) 89 ± 13	(2) 20 ± 14	(3) 2.5 ± 3	(3) 1 ± 0.9	(2) 1692 ± 69	(3) 8.5 ± 4.4
Unknown	(6) 48 ± 5	(2) 29 ± 3.5	(6) 88 ± 6	(6) 28 ± 11	(6) 3.5 ± 3.9	(6) 1 ± 0.8	(5) 1885 ± 357	(6) 6.5 ± 0.8

* The numbers in the brackets indicate the number of accessions that are characterized for each agronomic trait.

Table 5. Variation in Agro-morphologic traits [mean ± SD] for cowpea across the former provinces.

Former province	Days to flowering	Days to maturity	Pod length (cm)	Pod width (cm)	Beak length (cm)	Seed length (cm)	Seed width (cm)	Number of seeds per pod
Gomogofa	(10) 68 ± 9	(10) 107 ± 4	(6) 14 ± 1.8	(6) 6.9 ± 0.8	(6) 8.8 ± 4.7	(6) 7.3 ± 1.1	(6) 5.3 ± 0.6	(6) 12.3 ± 2.8
Gojam	(2) 74 ± 3	(1) 103	(2) 11 ± 0	(2) 5 ± 0	(2) 4.5 ± 0.7	(2) 6 ± 0	(2) 4 ± 0	(2) 13.4 ± 0.9
Hararge	(1) 74	(1) 120	(1) 15	(1) 8	(1) 6	(1) 7.5	(1) 6.5	(1) 11.2
Shoa	(3) 79 ± 4	(3) 111 ± 13	(3) 10.7 ± 1.2	(3) 5.2 ± 0.8	(3) 5.7 ± 1.2	(3) 6.3 ± 0.6	(3) 4.2 ± 0.3	(3) 11.5 ± 1
Wellega	(1) 60	(1) 109	(1) 12	(1) 6	(1) 7	(1) 6	(1) 4	(1) 13.4

* The numbers in the brackets indicate the number of accessions that are characterized for each agronomic trait.

Table 6. Variation in agro-morphologic [mean ± SD] for grass pea across the former provinces.

Former province	Days to flowering (50%)	Plant height (cm)	Days to maturity (90%)	Number of pods per plant	Thousand- seed weight (g)	Number of seeds per pod	Number of primary branches	Number of secondary branches
Arsi	(1)* 49	(1) 52	(1) 109	(1) 25	(1) 89	(1) 3	(1) 1.8	(1) 9
Bale	(5) 52 ± 7	(5) 84 ± 27	(5) 124 ± 25	(3) 92 ± 63	(3) 998 ± 713	(3) 3 ± 0.6	(3) 2.5 ± 0.4	(3) 7 ± 0
Gamo Gofa	(1) 55	(1) 71	(1) 155	(1) 63	(1) 189	(1) 1	-	-
Gojam	(88) 53± 8	(88) 58 ± 12	(88) 116 ± 24	(52) 48 ± 29	(40) 279 ± 345	(40) 2.4 ± 0.6	(49) 2.5 ± 0.6	(48) 7.6 ± 1.5
Gonder	(35) 52 ± 10	(35) 61 ± 19	(35) 115 ± 18	(35) 46 ± 37	(18) 670 ± 607	(18) 2.8± 0.6	(17) 3.3 ± 0.4	(17) 6.7 ± 0.9
Illubabor	(3) 40± 11	(3) 44 ± 6	(3) 103 ± 11	(1) 26	(1) 70	(1) 3	(2) 2.6 ± 0	(2) 6.6 ± 0
Shoa	(133) 56± 7	(133) 78± 20	(133) 131± 9	(133) 75 ± 48	(129) 1083 ± 668	(129) 3.2 ± 0.5	-	-
Tigrai	(36) 58 ± 3	(36) 78 ± 15	(36) 132 ± 3	(36) 121 ± 72	(35) 1256 ± 246	(36) 3.2 ± 0.6	-	-
Wellega	(3) 54 ± 1.2	(3) 67 ± 11	(3) 128 ± 0	(3) 86 ± 19	(3) 1240 ± 0.6	(3) 3.3 ± 0.6	-	-
Wello	(27) 54 ± 6	(27) 72 ± 15	(27) 129 ± 1.6	(27) 87 ± 42	(29) 1245 ± 289	(28) 3.1 ± 0.7	-	-
Unknown	(77) 67 ± 9	(77) 86 ± 16	(77) 132 ± 3	(77) 117 ± 58	(77) 1237 ± 286	(77) 2 ± 0.6	-	-

* The numbers in the brackets indicate the number of accessions that are characterized for each agronomic trait.

Table 7. The magnitude of variability of some qualitative and/or phenotypic traits in five grain legumes as expressed by Simpson (S') diversity index.

The trait or character	No. of observed variables	Computed diversity index (S') for different grain legumes				
		Grass pea	Cowpea	Haricot bean	Field pea	Chickpea
Seed color	3	(359)* 0.01	(15) 0.50	-	-	-
Seed uniformity	4/3	(358) 0.42	(15) 0.53	-	-	(201) 0.63
Seed shape	7	-	(15) 0.80	-	-	-
Anthocyanin	6	-	-	(200) 0.66	-	-
Pod color	4	-	-	(86) 0.57	-	-
Growth habit	9/3	-	-	(195) 0.69	-	(577) 0.57
Flower color	3	-	-	-	(589) 0.13	-
Lodging	4	-	-	-	(763) 0.49	-

* The numbers in the brackets indicate the number of accessions that are studied for each trait, * The diversity index (S') was calculated using the formula $1-\sum x_i^2$, where x_i is a dividend value of the number of observed variables to the total number of observations or number of accessions/samples.

Origin, History and Geographical Distribution of Grain Legumes in Ethiopia

Taxonomically, grain legumes are classified under the family *Leguminosae,* which belongs to one of the three largest families of flowering plants with some 690 genera and about 18, 000 species (Purseglove, 1987). The global archaeological evidence of grain legumes' cultivation, that is as old as cereals, is dated back to about 5,000 B.C. However, the exact date of introduction and/or cultivation to Ethiopia is unknown, but is considered at an early date (Dawit et al., 1994). Vavilov (1951) anticipated that they had long been in Ethiopia and developed their own series of endemic cultivars. He also considered Ethiopia as an important center of diversity for food legumes.

Faba bean

The global domestication of faba bean or broad bean (*Vicia faba* L.) was believed to be around 5,000 B.C. (Zohary, 1977). There is insufficient evidence to be precise about the exact origin of the crop, but it is widely believed that the center of primary diversity and origin is somewhere in the Near- and Middle East (Lawes et al., 1983). Of the five routes of cultural radiation of *Vicia faba*, the direction to Ethiopia via Egypt was noted by Cubero (1974). Thus, Ethiopia is a secondary center of diversity for faba bean. In Ethiopia, the crop is grown in most of the regional states, but the major producing regions include the highlands of Oromiya, Amhara and SNNP (South Nation, Nationalities and Peoples). Considering the former provinces, Yohannis (2000) indicated that the highlands of Arsi, Bale, Gojam, Gonder, south and west Wello, the Chercher highlands of Hararge, the Arjo and Shambu highlands of Wellega, some parts of Keffa, Atsibi, Hagereselam areas of Tigrai, and Hagere Mariam and Gamogofa areas of Sidamo (listed in descending order) are important producers of faba bean. Faba bean has the largest number of 2034 accessions in the Gene Bank compared with other pulse crops.

Field pea

The cultivation of field pea (*Pisum sativum* L.) can be traced to the Swiss lake-dwellers (Onwueme and Sinha, 1991). According to them, there are two views on the center of origin and diversity. The first indicates that field pea evolved in the Mediterranean areas and in Central Asia, whereas the second indicated that it originated in Ethiopia, from where it had spread to the Mediterranean region in the prehistoric times. In Ethiopian agriculture, field pea is one of the most staple food legumes that is regularly used in the dietary food system of the people. As far as its typology is concerned, field pea is categorized into four types: the white/cream colored small-seeded pea, shriveled seed of various color, indented gray seed, and indented pink seed. A total of 1616 accessions of field pea are stored in the Ethiopian Gene Bank (Table 1), which is the second largest collection after faba bean. As indicated in the table, the collection covers the altitudes from 1800 to 3350m asl.

Haricot bean

Among seven species of *Phaseolus* commonly listed in literature, *P. vulgaris* L. is the most important food grain legumes grown in the tropics and subtropics including Ethiopia. *P. vulgaris* is probably native to tropical South America (Onwueme and Sinha, 1991), from where it was perhaps introduced to Africa and other continents. In addition to the American origin (Meso-American center), Baudoin et al. (2001) indicated other two centers of origin and diversities, the North and South Andean centers of origins. The crop, which is variously named as haricot bean or field bean or common bean, is broadly interpreted to include all beans of diversified color, size or shape, as well as some times the lima beans and tepary beans (Onwueme and Sinha, 1991). Such diversity in traits (seed color, seed size or seed shape, and mode of plant growth) was also proven under Ethiopian condition in the year 2002 in a report made by Eshetayehu et al. (2002), which stated that haricot bean was the most variable grain legume as compared to 11 other pulse crops collected from four regional states of the country. The crop has a wider variability for seed length (0.6-7.6 cm) and seed thickness (0.5-1.9 cm) (Table 5).

In Ethiopian agriculture, *P. vulgaris* is broadly cultivated in the lower and intermediate altitude areas. It is mostly grown in the Ethiopian Rift Valley and other areas mainly encompassing east and central Oromiya, Gomogofa, Sodo, Areka and Omosheleko areas of SNNPR, and many dry land parts of the Amhara and Tigrai regional states. During the last few years, 409 accessions of farmers' varieties/primitive cultivars of haricot bean were collected and conserved from 13 former provinces of Ethiopia (Table 2).

Lentil

Dawit et al. (1994) reviewed earlier literature and reported that the age of lentil crop (*Lens culinaris* Medik.) dates back to 6000-8000 B.C. The Lidia-Kurdistana region (in southern Turkey-northern Iraq) is perhaps the place of domestication and center of origin of the crop (Cubero, 1981). Lentil is an important highland, cool season food legume in Ethiopia. It is one of the grain legumes listed by Harlan (1968) that moved to Ethiopia from Asia, although the exact date of introduction is unknown. The Ethiopian lentil, which belongs to the *macrosperma* race known as *G. aethiopicae* (Barulina, 1930; and Muehlbauer et al., 1985), is cultivated in the highlands of Ethiopia and widely used in the dietary food system of the country.

Chickpea

Chickpea (*Cicer arietinum* L.) or gram appears to have originated in West Asia, from where it was introduced to India, tropical Africa, Central and South America, and Australia in the recent times (Onwueme and Sinha, 1991). Similarly, chickpea introduction to Ethiopia had perhaps taken place from this area. In line with this idea, Dawit et al. (1994) stated that agriculture in the high plateaus of Ethiopia was primarily based on plants originated from West Asia. Moreover, Harlan (1968) stated that chickpea and other food legumes (lentil, field pea and faba bean) were of West Asian origin and possessed wide genetic diversity in Ethiopia.

Now a day, because of the frequent occurrence of short rainfall pattern in the country, fast maturing grain crops like chickpea are getting important and becoming popular with the farmers. Furthermore, its peculiar nature of growing at the end of the main rainy season in less and/or residual moisture level has its own advantage. As far as conservation of its genetic diversity is concerned, 1155 accessions of chickpea germplasm are conserved *ex situ* in the Ethiopian Gene Bank (Table 1). These accessions have been characterized for some quantitative and qualitative traits (Table 2). Moreover, for the last few years chickpea has also been conserved under on-farm/*in situ* conservation sites of the IBCR.

Cowpea

Cowpea (*Vigna unguiculata* L. Walp) is one of the three important subspecies of the species *V. unguiculata,* which is a widely cultivated grain legume of the world (Onwueme and Sinha, 1991). According to them, one wild species, *V. dekindtiana,* occurs in Africa. It is the wild ancestor of the cultivars that was domesticated in the Ethiopian region or West Africa or perhaps widely throughout the African Savanna zone more than 4,000 years ago. They also anticipated that cowpea reached the new world from these areas and Europe in the 17^{th} century. Vanderborght and Baudoin (2001) also confirmed that South and East Africa areas were the primary center of diversity for cowpea.

Although cowpea is the second most important food grain legume of tropical Africa, next to *P. vulgaris*, it is the least cultivated and scarcely distributed pulse crop through different geographical and/or growing regions of Ethiopia. However, it is significantly important in the Gomogofa zone and especially in Woredas (districts) of Konso, Derashe and Hamerbako of SNNPR. It is also fairly distributed in the northern part of Ethiopia bordering Eritrea, pockets of Shoa, Gojam, Wellega and Hararge. On the other hand, cowpea is a drought-tolerant annual crop in conditions where moisture deficiency has less effect on seed formation but mainly on vegetative growth stage. It grows with less rainfall and under more adverse conditions than haricot bean. It can be produced in a great variety of soils, although it flourishes if planted on well-drained, light sandy loam soils. Cowpea, like any other leguminous crop, is also grown for improving soil fertility.

Despite the remarkable potential of the crop in drought-prone areas, less attention was given to it during the past collection missions, and as a result only 57 accessions were collected from different cowpea growing areas of Ethiopia (altitudes of 1360-1900 m asl) (Table 1). These materials are conserved *ex situ* in the Ethiopian Gene Bank. Recognizing the importance of cowpea in the future research directives, 19 of the collected accessions were characterized for some quantitative and qualitative traits (Table 5). These data and the seed materials are ready for further research and/or improvement program.

Pigeon pea

Pigeon pea *(Cajanus cajan* L. Millsp.*)* also known as red gram, *arhar, tur*, Congo-bean/pea, alberga and no-eye pea, is the main pulse crop in tropical and sub-tropical regions, and known to be an ancient African grain legume. It has been reported to occur in the Nile Valley in the wild state (Yadav, 1992) and cultivated therefore more than 4000 years, from where it was taken to India (Onwueme and Sinha, 1991). The diversity of the species is also found in east Africa (Singh et al., 2001). However, the center of origin of the crop between Africa and India is a controversial issue. Singh et al. (2001) reported that it was originated in India, whereas Yadav (1992) anticipated it as an African origin. The scarce but often cited archeological evidence of one seed in ancient Egyptian tomb and the wild occurrence in Africa favors an African origin. On the contrary, the range of diversity of the crop in India in much larger extent made Vavilov to list it as of Indian Origin. Furthermore, Singh et al. (2001) finally mediated that it was only one close relative of pigeon pea, *Cajanus kerstingii,* which was endemic to Africa, while *C. cajan* originated in India.

India is the leading producer of pigeon pea, where 90% of the world's pigeon pea is produced, and is followed by three African countries (Uganda, Malawi and Tanzania), which are considered as the major producers in Africa. However, there are pockets of potential areas of pigeon pea production in Ethiopia. These areas include the western belt of SNNPR particularly the Gamo Gofa and Walayita administrative zones, which encompass about nine *woredas*, and very few pocket localities of former Wello, Shoa, Hararge and Bale provinces. This toddler cultivation and distribution trend to new localities showed its potential for further expansion and improvement. Moreover, the drought-tolerance and wide-adaptability nature of the crop could scale-up its importance. To date, 39 germplasm accessions have been collected from different geographical areas of the country, and a total of 46 accessions are presently stored in the Gene Bank. However, none of these accessions is yet characterized in the field.

Lupine

The genus *Lupinus* comprises a large group of herbaceous, prostrate and shrubby plants with exactly unknown number of species till date (Planchuelo and Hill, 1999). According to their rough estimates it accounts for 500 taxa, but more than 1700 published botanical names. In Ethiopia, apart from one native and one cultivated *(L. albus)* species, at least four species have been introduced for trial as forage crops, green manure, soil and water conservation, or ornamentals (Hedberg and Edwards, 1989). Most Lupine species are native to the new world while only 12 species occur in the old world, that is, the Mediterranean region and North Africa (Bermudez et al., 2000). According to Swiecicki et al. (2000) a total of 13065 numbers of accessions of lupine collections are available in the world. These accessions globally reside in 16 centers in 14 countries, among which 84% belong to the domesticated lupine species. The Ethiopian national Gene Bank has a collection of 212 accessions.

The geographical distribution of lupine in Ethiopia covers mainly eastern and western Gojam and southern and northern Gonder zones of the Amhara regional states, and the former provinces of Gamo Gofa, Shoa and Tigrai to a lesser extents. Apart from its food value, lupine is also very much popular for its medicinal uses throughout the country. The need for exploiting its diversity, therefore, demands further promotion in its conservation and improvement.

Grass pea

Grass pea (*Lathyrus sativus* L.) is native to southern Europe and West Asia, and it is the cheapest pulse of India where it is grown widely (Purseglove, 1987). Ethiopia is considered as a secondary center of diversity, and it is distributed throughout the country in black clay soils between altitudes of 1800 and 2700 m asl (Asfaw et al., 1994a).

A total of 577 accessions have been conserved in the Ethiopian Gene Bank. The collected germplasm material is mainly from Shoa and Gojam, and as well as Wello, Gonder, Tigrai, Gamo Gofa, Arsi, Bale and Hararge covering the altitudes from 1600 to 2900 m asl. Of the total collection, 433 accessions have been characterized for eight quantitative and two qualitative traits (Tables 1, 6 and 7).

STATUS OF GENETIC EROSION

Crop genetic resources, a reservoir of irreplaceable genes and gene complexes, are being lost at a rapid rate. Farmers discard old varieties in favor of the new ones, plant breeders displace lines that do not meet their immediate objectives, and government policies do not look seriously at the land use plans that lead to the destruction of plant habitats (IBPGR, 1984). Varietal displacement of landraces, introduction of genetically uniform improved varieties, dynamics of agriculture and land uses, destruction of natural habitat, and drought in the country are the important causes of genetic erosion in Ethiopia (Melaku and Hailu, 1993; FAO, 1996). Nevertheless, the extent of genetic erosion due to replacement by improved crop varieties for grain legumes is relatively low as compared to cereals. Moreover, artificial hybridization of pulses in Ethiopia including crossing them with their wild relatives are less attempted than cereal crops, and the existing improvement strategies are dominantly done through screening and selection. Thus, they are more genetically maintained/stabilized and less eroded than the cereals due to less advancement in crop improvement activities. This was also observed during the periodical exploration and collection trips conducted through out the country.

COLLECTION AND CONSERVATION

The initial and basic task of crop conservation at IBCR is collection expedition. It is an essential tool to capture the remnant diverse gene components of any crop's germplasm. Thus, in order to capture all plant genetic resources, germplasm collection exercise is done every year by the Field Crops Genetic Resources' Department of IBCR. Accordingly, out of the total accessions of 55, 800 of field crops in the Ethiopian Gene Bank, 7250 (13%) accessions belong to food legumes (Table 1).

In plant genetic resources conservation system, two important strategies are adopted and exercised: *ex situ* and *in situ* conservation systems. For an *ex situ* conservation system, a seed Gene Bank has been established in Addis Ababa for broadening the genetic base and to meet the demand for crop improvement. . The Ethiopian seed Gene Bank operates in the cold room at two temperature levels, -10^{0}C and +4^{0}C, where the germplasm materials are stored for long- and short-term conditions, respectively.

In Ethiopia, attention has recently been given to *in situ* (on-farm) conservation. Therefore, *in situ* crop conservation sites were established to allow the evolutionary processes of the crops and enable the farmers for sustaining conserving and utilizing their valuable germplasm while keeping the diversity alive (Frankel et al., 1995; FAO, 1996). These include 12 *in situ* on-farm crop conservation sites in 12 *woredas* of four regional states of Ethiopia. These *in situ* sites have been used to conserve and maintain the natural habitats of a number of farmers' varieties of seven grain legumes (faba bean, field pea, chickpea, lentils, haricot bean, grass pea and fenugreek). Moreover, all the 12 Crop Conservation Associations (CCAs) that were organized in all the 12 *woredas* have annually distributed the conserved seed in the Community Gene Bank (CGB) as a loan to the farmers. . Through this process, the system has ensured the supply of planting seed material to the farming communities.

CHARACTERIZATION AND DIVERSITY STUDY

A total of 5320 accessions of grain legume germplasm have been characterized at different research stations in the country, which were suitable for each of the pulse crops. A total of seven to eight quantitative characters (Tables 2-6), and some qualitative traits (Table 7) were analyzed for five grain legumes. The results of characterization (Tables 2-7) revealed different levels of variations in different agronomic traits that were studied for various accessions collected from different provinces and altitudes. Chickpea and grass pea collections across former provinces, for instance, showed wider mean values for number of pods per plant, which ranged from 38 to 90 and from 25 to 121, for chickpea and grass pea, respectively (Tables 2 and 6). On the other hand, high level of variation was observed for 1000-ssd weight of the crops; field pea (155-920 g), grass pea (89-1256 g) and haricot bean (797-2149 g) across the former provinces. Also, grain weight variation that was observed among accessions within provinces for these three pulse crops was also remarkable (Tables 2, 3 and 6). The highest and lowest values for variation (mean $\pm$SD), for instance, were $\pm$ 713 g (Bale) and $\pm$ 0.6 g (Wellega), both of them being for grass pea. Such variability, which would be due to the genetic diversity of the crops under consideration, could be useful for crop improvement.

Similarly, variation in number of seeds per pod across provinces for cowpea (11.2-13.4) showed almost twice that of field pea (4-5) and/or haricot bean (5.3-8.5), and almost eight-fold to that of chickpea (1.3-1.7) (Tables 2-5). In line with this agronomic trait, the observed variability revealed that all the studied pulse crops showed a wider option of genetic diversity for use in crop improvement program.

As far as length of maturity is concerned, the characterization results showed the existence of wider variation across provinces and among accessions for the trait (Tables 2-6). For instance, various haricot bean accessions collected from Sidamo matured in 78 days, whereas those collected from Shoa, Hararge, Gojam, Illubabor, Arsi and Bale matured within a narrow range of 82-86 days (Table 4). Likewise, among the 190 haricot bean accessions characterized for maturity, early-maturing accessions reached their physiological maturity in 73 and 74 days. These are accessions collected from Gojam province of Bure and Dibate *woredas* whose vernacular names are *Yeba* and *Ashoterie*, respectively.

The diversity index computed for few qualitative traits for each of the five grain legumes showed different magnitudes and trends of variability (Table 7). For instance, as indicated by the low value of diversity index (0.01), seed color in grass pea was almost homogenous in 358 of 359 plants that produced seeds whose color was uniformly grayish brown. On the contrary, seed shape in cowpea, growth habit and localization pattern of anthocyanin in haricot bean, and seed uniformity in chickpea significantly varied across different variables used to describe the traits. Generally, it has been observed from Simpson diversity index (S') shown in Table 7 that 10 of the 12 values of diversity index proved the presence of genetic diversity in six of the eight traits studied. In general, the study of variability among the qualitative traits (Table 7), and among the agro-morphologic traits observed across former provinces, altitude ranges and among accessions (Tables 2-6) showed that most of the traits under consideration had remarkable variability. This variation ascertained the existence of desirable genotypes, which could be used for further crop improvement and research. It also helps the expected promotion of the production and productivity of grain legumes in Ethiopia.

EVALUATION

The collected accessions of pulse crops with their full passport data and some morphological descriptions were subjected to characterization and diversity study, and then passed on for evaluation study. Hence, the characterized data need to be subsequently assessed in depth and confirmed by evaluating them in field for the specific traits. In this context, further assessment and screening of traits using molecular markers also become important and useful for crop improvement.

UTILIZATION OF GERMPLASM

The germplasm accessions conserved *in situ* in the Ethiopian Gene Bank have been utilized in various forms within the country and at the global scale. The increasing demand of local germplasm for national crop improvement program, the growing interest of land races/primitive cultivars for research inputs and the local farmers' varieties at *in situ* sites have received a remarkable attention. For the last few decades, the Ethiopian PGRC/E and/or IBCR has distributed a total of 11,181 locally collected accessions of grain legumes to research institutions, universities and development organizations, which constitute about 21% share of the total germplasm of field crops distributed. However, there is either no or poor feedback system and/or willingness of the recipients of these germplasm materials to provide information on their use. This has seriously limited the institute to document and analyze the utilization aspects of the supplied germplasm.

However, some information received does indicate that the supplied germplasm has been successfully used by the national breeding program. For instance, local collections of faba bean had provided the variability needed to develop high yielding cultivars adapted to mid-altitudes (Kasa and NC-58) and to high-altitudes (CS-20 DK and Kuse 2-27-33) (Asfaw et al., 1994b). Improved varieties of chickpea, viz., DZ-10-4 and Dubie which were released for production were selected from the Ethiopian chickpea collections (Geletu and Yadeta, 1994a). Several accessions of lentils designated as PGRC/E and ACC were identified as resistant to rust, tolerant to drought and early-maturing (Geletu and Yadeta, 1994b). Preliminary observations of grass pea accessions of PGRC/E showed great variability in grain yield and yield components as well as β-N-oxalyl amino-L-alanine (BOAA) content with a range of 0.072-0.098% (Asfaw et al., 1994a).

CONCLUSIONS AND FUTURE DIRECTIONS

In the past, conservation activities have received good attention, and in future should target both the dwindling and unexploited but potential genetic resources of the country. Collection expeditions, for instance, would focus on genetically eroded, marginal and relatively neglected areas. In addition to the cultivated grain legumes, their wild relatives would also be assessed in depth. It should also focus on other studies such as drought tolerance, and searching historical evidences and defining the volume and extent of genetic diversity in grain legumes.

Further work is needed on characterization to study diversity across locations and seasons. Appropriate utilization programs should also be designed in a much comprehensive way to enlarge its domain from restricted research perspectives to direct provision of evaluated germplasm to the farming communities. Another important task to be addressed is to establish and/or strengthen the feedback channels of the delivered local germplasm materials. This will enable the institute to document and analyze the contributions of the delivered accessions. Indeed, it would be worthwhile to integrate and coordinate all the efforts.

REFERENCES

Asfaw Telaye, Asgelil Dibabe, and Bekele Hunde. 1994a. Genetics and breeding of grass pea. p. 183-195. *In* Asfaw Telaye et al. (Eds.) *Coo-lseason Food Legumes in Ethiopia*. Proc. First National Cool-season Food legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. IAR/ICARDA), ICARDA, Aleppo, Syria.

Asfaw Telaye, Tesfaye Getachew, and Beyene Demtsu. 1994b. Genetics and breeding of faba bean. p. 97-123. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes in Ethiopia*. Proc. First National Cool-season Food legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. IAR/ ICARDA, ICARDA, Aleppo, Syria.

Barulina H. 1930. Lentils of the USSR and other continents [in Russian]. *Bull. Appl. Genet.and Plant Breed.,. Leningrad Supplement* 40: 1-319.

Baudoin, J.P., T. van der Borght, P.M. Kimani, and A.W. Mwang'ombe. 2001. Common bean. p. 317-333. *In* Romain H. Raemaekers (Ed.) *Crop Production in Tropical Africa*. D.G.I.C., Brussels. 1540 pp.

Bermudez T.K., Q.N. Robeledo, H.Z. Martinez, A. Tie, M. Wink, E.V. Santen, M. Wink, S. Weissman, and P. Romer

. 2000. Lupine, an ancient crop of the new millennium. p. 294-296. *In* E.V Santen et al. (Eds.) Proc. 9th International Lupine Conference, 20-26 June 1999. .Klink Muritz, Germany.

Cubero J.I. 1974. On the evaluation of *Vicia faba* L. *Theoret. App. Gene.* 45: 47-51.

Cubero J.I. 1981. Origin, taxonomy and domestication, p. 15-38. *In* C. Webb and G. Hawtin (Eds.) *Lentils.* C.A.B., London, U.K.

Dawit Taddesse, Asfaw Telaye, and Geletu Bejiga. 1994. Genetic resources in Ethiopia. p. 79-96. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes in Ethiopia.* Proc. First NationalCool-season Food legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. IAR/ICARDA, ICARDA, Aleppo, Syria.

Eshetayehu Tefera, Tesema Tanto, and Teshome Hunduma. 2002. Rescue collection missions of field crops in drought affected regions of Ethiopia (Unpublished). Institute of Biodiversity Conservation and Research (IBCR), Addis Ababa, Ethiopia.

FAO (Food and Agricultural Organization). 1996. Report on the status of the plant genetic resources for food and agriculture. International Technical Conference on Plant Genetic Resources. 17-23, June 1996, Leipzig, Germany

Frankel, O.H., A.H.D., Brown, and J.J, Bordon. 1995. The Conservation of Genetic Diversity: The Dynamics of Genetic Diversity. Cambridge University Press, Cambridge.

Gabriel J.N. 1984. Legumes and their position in the national dietary of Egypt. p. 19-28. *In* M. M. El-Fouly (Ed) *Proc. of Grain Legumes Workshop.* National Research Center, Cairo.

Geletu Bejiga, and Yadeta Anbessa. 1994a. Genetics and breeding of chickpea, p. 138-161. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes in Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. IAR/ICARDA, ICARDA, Aleppo, Syria.

Geletu Bejiga, and Yadeta Anbessa. 1994b. Genetics and breeding of lentil, p. 162-182. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes in Ethiopia.* Proc. First National Cool Season Food legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. IAR/ICARDA, ICARDA, Aleppo, Syria.

Harlan J. 1968. Ethiopia: A center of economic diversity. *Botany* 23: 309-314.

Hedberg I., and S. Edwards. 1989. Flora of Ethiopia. Addis Ababa and Uppsala. 689 pp.

Lawes D.A., D.A. Bond, and M. H. Poulsen. 1983. Classification, origin, breeding method and objectives. p. 23-76. *In* P.D. Hebblethwaite (Ed.) *The Faba Bean (Vicia faba L.): A Basis for Improvement.* Butterworth.

Melaku Worede, and Hailu Mekbib. 1993. Linking genetic resources to farmers in Ethiopia. p. 78-84. *In* W de Boef, K. Amanor and K. Wellard (Eds.) *Cultivating Knowledge.* London: Intermediate Technology Publications.

Muehlbauer F. J., Cubero, and R.J. Summerfield. 1985. Lentil (*Lens culinaris* Medik.). p. 266-311. *In* R. J. Summerfield and E.H. Roberts (Eds.) *Grain Legume Crops.* Collins, London, UK.

Onwueme, I.C. and T.D. Sinha. 1991. Field Crop Production in Tropical Africa. Principles and Practice. The Technical Centre for Agricultural and Rural Co-operation (CTA), Wageningen, The Netherlands. 480 pp.

Planchuelo A.M. and G.D. Hill. 1999. Biodiversity of lupine in South America. p. 394-400. *In* Proc. 8th International Lupine Conference, May 11-16, 1996, Asilomar, California, USA.International Lupine Association, Canterbury, New Zealand.

Purseglove, J.W. 1987. Tropical Crops: Di-cotyledons. Longman, Singapore.

Singh L., S.N. Silim, J.P. Baudoin, P.M. Kimani, and A.W. Mwang'ombe. 2001. Pigeon pea (*Cajanus cajan* L.). p. 260-373. *In* Romain H. Raemaekers (Ed.) *Crop Production in Tropical Africa.* D.G.I.C., Brussels, Belgium.

Swiecicki W.K., Cowling W.A., and Buirchell B.J. 2000. Databases and genetic resources evaluation in Lupinus collections. p. 132-137. *In* Lupin An Ancient Crop for the New Millennium. Canterbury, New Zealand, International Lupin Association.

Vavilov N. I. 1951. The origin, variation, immunity and breeding of cultivated plants. *Chronica Botanica* 13: 1-366.

Yadav D.S. 1992. Pulse Crops Production Technology. Kalyani Publishers. New Delhi, India.

Yohannis Degago. 2000. Faba bean (Vicia faba L.) in Ethiopia. Institute of Biodiversity Conservation and Research (IBCR), Addis Ababa, Ethiopia.

Zohary D. 1977. Comments on the origin of cultivated broad bean, *Vicia faba* L. *Israel. Bot.* 26: 39-40.

Breeding Concepts and Approaches in Food Legumes: The Example of Common Bean

Steve Beebe, Idupulapati Rao, Henry Terán and César Cajiao

Centro Internacional de Agricultura Tropical (CIAT), A. A. 6713, Cali, Colombia

ABSTRACT

Legumes are in a crisis of stagnated production compared to cereals, and their production has increased much slowly than that of cereals during the past three decades. This could be attributed mainly to internal competition for photosynthate between plant parts, intensity of diseases, and demand for very specific commercial types. The main causes for low yields in common bean (*Phaseolus vulgaris* L.) fields are diseases and insect-pests, drought and low soil fertility, the last one is often the primary limitation on bean yields in realizing the yield potential of the crop on farmers' fields. There appear to be excellent opportunities to improve the abiotic stress tolerance in bean, which may permit us to increase yield potential as well, as per the experience in other grain legume species such as soybean. Marker-assisted selection (MAS) can be a valuable tool in breeding, and in the short-term can be used to maintain biotic stress resistance genes in breeding populations, while other breeding objectives are pursued such as abiotic stress tolerance and higher mineral content in grain.

INTRODUCTION

Grain legumes are an important component of agricultural and food systems in practically all over the world, and serve to complement the cereal crops in several aspects (Graham and Vance, 2003). First, in terms of human nutrition, legumes supply a higher percent of protein while cereals are the primary source of calories. The amino acid profile of legume protein tends to complement that of cereals, adding lysine to the diet while cereals are a better source of sulfur containing amino acids. Furthermore, legumes are better source of minerals, presenting two or more times the levels found in most cereals (Wang et al., 2003).

Agronomically, legumes serve as rotation crops with cereals, reducing soil pathogens and supplying nitrogen to the cereal. Finally, legumes tend to fetch better prices in the market and in some regions are more profitable due to this reason. Legumes usually enjoy a 2- to 4-fold price differential over cereals, although this depends greatly on which legume and which cereal are being compared. In East Africa, bean and maize are the legume-cereal combination that lends itself to this comparison most readily, and here this price differential is maintained, with seasonal variations (Ugandaidea, 2002). Maize tends to be the cheapest cereal the world around, and soybean the cheapest legume, though seldom for human consumption outside of Asia.

PRODUCTION AND YIELD

Legumes are in a crisis of stagnated production compared to cereals, over a 30-year period. While production of cereals has doubled or tripled in most regions of the world, equaling or exceeding population growth, increases in legume production scarcely exceed 30% (FAOSTAT 2003). With a doubling of population, this necessarily leads to declining per capita consumption. Faced with declining real prices of cereals and scarce legumes, poor consumers naturally gravitate toward consumption of cereals, with important implications for human health. In India, for example, a significant rise in anemia in the last 30 years has been attributed to declining legume consumption (UN-ACC-SCN, 1992).

The lag in production of legumes is paralleled by, and in large part caused by, a lag in yield increases in relation to cereals. While plant breeding has dramatically increased yields of cereals, no such increase has been registered in legumes. Soybean is the legume for which breeding has been practiced most intensely over many widespread breeding programs, with significant investment of resources, and for which progress has been most systematically documented. Thus, soybean is the legume that best lends itself to a comparison with cereals (especially maize), and to an analysis of the problems inherent in breeding legumes. Specht et al. (1999) have presented such a comparison in the case of yields in the state of Nebraska, USA, and have reviewed other literature in a similar vein.

Yields of soybean in Nebraska have traditionally presented a much lower baseline compared to maize, by a factor of about 2.8. Besides initiating at a lower level, yield increases of soybean have also been slower, both in the long-term and more recently. Between 1972 and 1998 on-farm yields under irrigation increased 35 kg $ha^{-1}yr^{-1}$ for soybean versus 98 kg $ha^{-1}yr^{-1}$ for maize. Similar results were reported in Canada by Voldeng et al. (1997) who studied soybean yields over a 58-year period. When the entire six decades were considered, yield gains of about 11 kg $ha^{-1}yr^{-1}$ were calculated, but most gain in fact occurred in the last 20 years, at a rate of 30 kg $ha^{-1}yr^{-1}$. In one sense this indicates that breeding is becoming more successful in recent decades, but in any case the slope of the yield curve for soybean is far below that of maize and the absolute difference in yields of the two crops continues to widen.

When the underlying causes of yield increases of maize are studied, it appears that most increase has been obtained due to higher planting density (Duvick, 1984). The genetic component of this agronomic practice is a capacity of the crop to withstand higher densities, which is essentially an expression of stress tolerance, especially tolerance to competition for light, soil nutrients and water (Tollenaar and Wu, 1999). In other words, maize yields in the temperate zone, an environment that we usually do not think of as stressful with regard to nutrients and water, have increased precisely due to tolerance to relatively lower water and nutrient supply per plant. In this sense, the gains that have been registered in temperate maize breeding for favorable environments are similar to those that are needed in stressful environments in the tropics or elsewhere.

Although yield increases in soybean are much more modest, the essential story is similar. Changes associated with greater yield are greater photosynthetic rate during grain fill, greater N_2 fixation, and greater stress tolerance, again expressed as the ability to respond to greater plant densities (Specht et al., 1999). While it is tempting to attribute a causal role to photosynthetic rate and N_2 fixation in yield, in fact both are readily influenced by a host of other plant attributes, and an increase in either or both of these traits can also be symptomatic of more general and ill defined factors which are acting through them. Be that as it may, a common thread in the breeding of soybean and maize is the correlation of high yields with improved tolerance to high plant densities and its associated abiotic stresses. It is interesting that this correlation contradicts a widely held view of some 20 to 30 years ago, that breeding for stress tolerance would lead to stable but low yields.

WHY IS YIELD IMPROVEMENT OF LEGUMES SO DIFFICULT?

There are many fundamental differences between cereals and legumes, some of which impinge directly on yield potential and the ease or difficulty of yield improvement. In particular, legumes are physiologically much more complex than cereals in the management and use of nitrogen and its relation to photosynthesis.

All plants experience some sort of internal competition for photosynthate between plant parts, for example, top growth versus root growth, but legumes express additional internal competition between growth of different plant parts and the fixation of nitrogen. Nitrogen fixation is an additional sink or demand for energy in legumes that the plant must confront. An investment of energy in nitrogen fixation ought to result in greater nitrogen (N) availability and subsequently greater leaf production and more photosynthesis, but the balance between investment of photosynthate and output of N and more photosynthate is necessarily complex.

Subsequent to obtaining N for photosynthesis, legumes also face greater competition for N to form protein. While all seed producing plants remobilize leaf nitrogen to seed to form proteins as a mechanism of N nutrition for the following generation, the intensity of N remobilization in legumes is greater than in cereals, due to higher level of protein in seed. As seed fills and protein is deposited, this results in a drain on leaf N, and early stress on the rate of net photosynthesis. This is another likely cause of the lower yield potential of legumes, and might well contribute to frequently observe negative correlations between yield and seed protein or N concentration. Whether one considers N metabolism from the standpoint of nitrogen fixation or protein, the conclusion is similar: N and protein represent a special cost for the plant that limits yield potential.

Another possible cause of the slow progress in legumes, and certainly in common bean (*Phaseolus vulgaris* L.), is the intensity of diseases. This might be due in part to legumes being a more nutritious substrate for pathogens, again given their favorable balance of N and carbon. As a result, many breeding programs have been dedicated primarily to resistance breeding, with relatively less emphasis on yield *per se,* (although this phenomenon is not unique to legumes).

Finally, in the case of common bean, demands for very specific commercial type (color, shape and especially size) have slowed progress significantly. Negative correlations of seed size and yield have often been observed, and the necessity of meeting seed size demands of the market might well have inhibited exploiting higher yielding, small–seeded types that were discarded over the years.

All of the foregoing discussion has revealed a slower progress in the yield improvement of legumes and common bean in particular. Now let us consider our successes, especially in resistance breeding, and the implications of these for yield levels. For the rest of this review we will focus on common bean as an example of grain legume breeding, although we think that much of what we will say could be relevant for other grain legumes as well.

OUR SUCCESSES AND THE CAUSES OF LOW YIELDS

A lack of breakthroughs in yield potential has not meant that there have not been successes in breeding of common bean. Given the emphasis on biotic stress resistance breeding, the more dramatic successes are in the production of disease- and insect-resistant varieties. We shall refer to two examples.

A problem, which is largely absent in Latin America but has come to the forefront in Africa, is that of Pythium root rot. Pathologists in Uganda and elsewhere have determined that the problem involves several species of Pythium. Selection among populations and lines brought from CIAT-Colombia proved to be highly resistant to the pathogen, and these are being promoted in targeted regions of Kenya, among other countries. Adoption rates as high as 80% are recorded in selected communities.

In Central America a new virus appeared in the 1970's, which was subsequently designated as bean golden yellow mosaic virus (BGYMV). CIAT and national programs of Guatemala, El Salvador, Puerto Rico, and Mexico among others, and the Pan-American School in Zamorano, Honduras collaborated to produce more than 15 varieties resistant to this gemini virus. Resistance levels have increased gradually as new sources were incorporated into the breeding program, and even though populations of the white- fly vector have increased and exacerbated disease pressure, today's varieties are capable of withstanding the heaviest attack witnessed to date in the region.

One can note in both of the previous cases that the disease in question had a proven destructive capacity over the crop. Total yield losses to BGYMV, while not the rule, are a real possibility and an occasional reality. Root rots likewise can impact dramatically on yield. But in any given region, there are seldom more than two diseases or pests with this capacity for yield reduction. Breeding for resistance requires self-discipline in recognizing which diseases are in fact serious threats to yield, and which ones are occasional nuisances.

However, biotic stress resistance breeding is often more of a defensive breeding strategy and does not necessarily raise yields dramatically. For example, even in Central America, in spite of the fact that BGYMV is a potentially devastating disease, regional average yields over a 25- year period from the mid-70s to the late-90s only increased from 550 kg/ ha to 650 kg/ ha (Viana, 1998). Percentage-wise this is about 18% but in absolute terms an increase of 100 kg/ ha is quite modest, and still far off the potential yield of the crop.

This invites an examination of the different possible causes of low yields in common bean. Let us contrast the several generic causes of low yields according to their frequency, intensity and risk that they represent to farmers (Table 1), remembering that national and continental average yields are usually in the range of 600-800 kg/ ha. What causes can account for this low level of yield, year in and year out, over widespread areas, compared to the known potential of the crop that exceeds 3000 kg/ ha?

Table 1: Production constraints and their frequency, intensity and risk in lowering grain yields in common bean.

Production constraints	Frequency	Intensity	Risk
Diseases and pests	***	**	***
Drought	**	****	*****
Poor soil fertility	*****	***	**

= low; * = moderate; ***** = very high.

Diseases and pests are an ever-present threat to the crop, and there are few fields that are totally free of symptoms. But on any given year, disease intensity varies greatly from one field to the next, or even within a single field. Diseases such as anthracnose or common bacterial blight often occur as foci within the field, and do not cover a wide area. Small minorities of fields present uniformly severe symptoms throughout the field. If one calculates the area infected by disease by the likely yield loss, it is difficult to account for as wide a yield gap as we are seeing.

Drought on the other hand, does not affect most production regions year after year, but when it does strike, it can affect entire regions very dramatically and with great intensity, occasionally to the point of inducing famines. Instead of reducing yields sporadically across the landscape as diseases usually do, drought can affect a majority of farms over large regions, but on occasional years.

Low soil fertility on the other hand is widespread across the landscape and thus occurs with high frequency. It also occurs every single year, and also with intensity that reduces yields significantly. As an indicator of the yield reduction due to soil fertility, one need only to look at yield responses in fertilizer trials, or at the difference between on-station and on-farm trials where the difference in the environments is largely fertility management. Soil fertility is the most important single factor to explain the vast gap between real yields across a continental landscape, and the yield potential of the crop.

However, it is also important to view these yield limitations in terms of risk that they represent, because risk is a factor that is especially worrisome to the farmer. Diseases, pests and drought, while they do not cause losses that can explain a vast yield gap on a national or continental level, are also important risk factors that introduce uncertainty in the life of the farmer and his family. Poor soil fertility, on the other hand, while it is the primary factor in reducing yields, does not represent much risk for the farmer, because he knows what to expect from his plots based on long term experience. Low soil fertility is a very serious problem, but it is more a given than a risk.

We do not with these reflections mean to cast aspersions on the very fine work that has been done in resistance breeding, but we do mean to drive home two points. First, much of what we have done in the past in the realm of resistance breeding has been addressing risk, and this is no trivial question for farmers. We have done a great service to the farmers in reducing risk from diseases, and they have been very grateful in the cases where we have been able to demonstrate the value of resistant materials. But this has not served to raise yields dramatically. Second, if we are to meet the challenge of raising bean yields significantly, we must address the question of soil fertility, and in some degree, drought, as factors that reduce yields by a wide margin.

BEANS AS AN EXAMPLE OF LEGUME BREEDING IN THE TROPICS

What are our perspectives for increasing yield in bean, and where will increases come from? In light of the yield increases in maize and soybean that originated in stress tolerance, we must ask: What is the potential to improve tolerance to physiological stress in common bean? We will refer to two important stresses that occur with some frequency: low soil phosphorus availability, and drought (Rao, 2001). Both of these efforts have been going on for more than two decades, and both are now showing positive results.

Low Soil P Availability

Since the inception of CIAT, breeding lines were screened for their reaction and relative tolerance to low soil P, although these lines had not been selected specifically for this tolerance (Lynch and Beebe, 1995). Gradually, breeders adopted the challenge of increasing levels of tolerance through conscious efforts including: screening of germplasm from the gene bank, creating crosses among superior accessions, and selection of populations. At the outset, little or no progress was registered, and it was necessary to explore the gene bank more thoroughly to reveal additional genetic variability. On the other hand, reducing levels of inputs in breeding nurseries led to a gradual increase in levels of tolerance, and a few unusually tolerant materials resulted, in particular A 774 (released in Brazil as BRS Marfim) and VAX 1 (an advanced line from interspecific cross), developed for resistance to *Xanthomonas axonopodis*. Both A 774 and VAX 1 display abundant shallow roots that exploit intensively the nutrients in the upper soil horizon where organic matter (litter) accumulates and degrades. On the other hand, germplasm accessions such as G 21212 and some Mexican varieties, especially in the 'flor de mayo class', express greater capacity to fill grain under stressful environments. This is an important physiological trait that reflects the capacity to transport photosynthate under conditions of stress when transport is normally inhibited. This trait complements the abundant shallow roots of VAX 1 and A774, and offers the possibility to combine mechanisms for higher levels of stress tolerance.

In yield trials of lines bred for tolerance to low P, VAX 1 significantly out-yielded the commercial check, and at least one line (progeny of VAX 1 and RAB 655, the latter derived from flor de mayo-type) in turn out-yielded VAX 1. Superior lines express as much as 80% yield advantage over commercial varieties in the small red-seeded class. This demonstrates graphically our strategy for breeding for low P stress. A good root system is the foundation of tolerance, since this contributes not only to P nutrition but to the acquisition of all other essential nutrients. Once a vigorous root system is selected, improved grain filling can increase tolerance further more.

Drought

Breeding for drought tolerance has a history at CIAT similar to that of breeding for low soil P availability (Beebe et al., 2003). Initially, advanced genetically fixed breeding lines were evaluated without any prior selection for drought tolerance. Subsequent evaluation of germplasm led to identification of additional sources, especially among accessions of race Durango from the dry highlands of Mexico. Similar to the story of breeding for low soil P, two general types of mechanisms have been recognized: vigorous roots, especially deep roots; and the ability to transport photosynthate and fill grain under stress. Indeed, some of the genotypes express this capacity to fill grain under drought stress as well as under low P stress, such as G 21212 and flor de mayo-types.

Breeding focused for many years on increasing levels of tolerance to drought without reference to commercial grain type or other agronomic characters, but in 2001 we initiated the first set of crosses to combine drought tolerance with other characters desired by farmers. Emphasis was placed on the small black-seeded class, and on the small red-seeded class that is popular in Central America and in many parts of Africa. It was possible not only to recover previously known levels of tolerance to drought with commercial grain and acceptable plant habit, but also to surpass the levels of tolerance previously obtained.

Multiple Abiotic Stress Resistance

The question remains, what happens under farmer's conditions when the crop is subjected to multiple abiotic stresses? It has been observed many times that the combination of drought and fertility stress is especially damaging to the crop and reduces yields far more than either stress alone. How can multiple stresses be dealt with? In fact we are attempting to combine tolerance to both low P and drought stresses, but this may have some intrinsic contradictions, in particular regarding roots. In a situation of multiple abiotic stresses, which are more valuable: shallow roots to tolerate poor fertility or deep roots for drought tolerance? We have only one experience so far, but this one field trial suggests that better plant nutrition early in plant development (as observed in low P tolerant materials) might contribute to better general plant vigor, and better roots to resist drought later in the season. This remains a hypothesis to be explored.

Another more general question is associated with the species, and is this: Why do beans have weak root systems? We think that this is a trait inherited from the wild ancestor, when the wild bean had to grow vigorously upward to survive in a competitive environment of weeds, shrubs, and small trees. The wild bean appears to invest its photosynthate preferentially in top growth as a survival mechanism, at the expense of roots. Thus, weak roots could well be a trait that continues with cultivated bean to this day.

Biofortification

To this point we have referred primarily to yield and its determinants, and what can be done to improve common bean in its quantitative dimension. Now we want to introduce a topic that is concerned with the qualitative dimension: that of nutritional value from the standpoint of micronutrient content, and specifically iron and zinc for human nutrition.

Several international research centers of the CGIAR (Consultative Group on International Agricultural Research) system are embarked on an effort to raise micronutrient content of major staple crops, under the broad banner of bio-fortification, a concept that has been defined as "the use of conventional and novel plant breeding techniques to increase the mineral and vitamin density in crop varieties in ways that improve the micronutrient status of the people who consume them". Besides common beans, other "first phase" crops for which an incipient knowledge base exists include maize, wheat, rice, cassava, and sweet potato. Other efforts are just initiating with a series of "second phase" crops: yams, barley, millet, sorghum, pigeon pea, cowpea, peanut, lentils, potato, banana and plantain. The three micronutrients that have been chosen as breeding objectives are iron, zinc and vitamin A, according to the potential of a given species to serve as a source of one or more of these micronutrients. This is a diet-based approach, whereby we seek to address the potential nutritional role of several components in the diet (for example, maize and beans in East Africa), thereby maximizing the potential impact on human health. We do not see biofortification as a substitute for more traditional approaches such as supplementation or fortification during food processing. Rather, bio-fortification is complementary to these approaches, and has the potential to reach certain populations who have reduced access to supplementation or fortified processed foods.

As complements to cereals within diets, legumes often play an important role as sources of minerals due to their higher initial content (Wang et al., 2003). Depending on the legume and cereal being compared, legumes often present about double the iron and zinc concentration of cereals. Furthermore, cereals like rice and wheat are usually polished and lose a significant portion of mineral in the process, but most legumes and certainly common bean are not hulled before eating. However, legumes have the disadvantage of containing significant levels of polyphenolic compounds that result in lower bioavailability.

With regards to mineral concentration in common bean, we have found an average of about 55 mg kg^{-1} iron in commonly used varieties while in the gene bank we have detected materials with over 100 mg kg^{-1}. Our goal is to increase iron content by at least 80%. Variability in zinc concentration is more modest in *P. vulgaris*, with an average of about 35 mg kg^{-1}, and a maximum of about 50 mg/kg. We hope to raise the level of zinc by about 40% based on existing intraspecific genetic variability. However, a sister species, *P. coccineus* or the scarlet runner bean, presents rather higher levels of zinc, and it may be possible to transfer these levels to the common bean through interspecific crosses. A large number of interspecific progeny of common bean and scarlet runner bean already exist and can be screened for this purpose.

The Role of Molecular Markers

It is difficult to speak of plant improvement these days without making some reference to the role of molecular markers (Mackay, 2001). DNA marker serves as a biotechnological tool that permits detecting the presence of a gene by a particular DNA sequence in close proximity to the gene. The advantages of marker technology have been cited often: selection of genes independently of the environmental effect that can mask gene expression; the opportunity to select recessive genes in early generations; the opportunity to pyramid resistance genes; etc. We will not dwell on these aspects, or on the technical aspects of DNA markers. Rather, we will refer to a few practical considerations that receive little attention in the literature but that must be addressed in the implementation of Marker-Assisted Selection (MAS).

The topic of MAS is in fact closely allied to the previous topics of improvement of abiotic stress tolerance, and bio-fortification. We stated previously that normally, no more than two pests or diseases have high destructive capacity in any given region, and for those priority pests or diseases, we need to assure that we are selecting the appropriate resistance genes in our breeding populations and lines, at the same time that we are selecting for tolerance to drought or low soil fertility, or for mineral content. It is in this context that markers have great potential in the short-term: in focusing on a few key resistance genes, while we broaden our scope to attend to other breeding objectives. At present, we are using markers to recognize important resistance genes that otherwise would be difficult for us to screen in CIAT. In particular, the most important bean virus in the western hemisphere, BGYMV, cannot be screened effectively in CIAT in the field, and so marker technology permits selection in the absence of the pathogen.

While marker technology is usually considered "high tech," we want to refer to the "low tech" side of markers - what is necessary to implement MAS effectively in a breeding program.

Well-selected genes: The first criterion is to focus on priority genes for priority traits. One can find many examples of gene tagging in the literature that have never come to practical use, largely because the traits or the genes were in fact not so interesting as to be worth the investment in implementing MAS. Before entering upon the effort to tag genes, one must ask, if I had a marker in hand, would I use it? Does it respond to one of those critical diseases or pests that can cause significant yield loss?

Choosing those priority genes as the focus of tagging requires a detailed characterization of those genes by specialists in allied disciplines, such as pathologists and entomologists. Much of this work represents "conventional" studies of the effectiveness of a given gene to a range of pathogen races, for example. While this sort of research is not necessarily "cutting edge," it nonetheless, is "strategic" and forms the basis for identifying the genes that merit intensive attention in gene tagging.

High quality markers: The second indispensable factor in the implementation of MAS is high quality markers. This usually implies going beyond the mere tagging of a gene, and obtaining markers that are generated by Polymerase Chain Reaction (PCR) and that respond to a series of requirements: stability across laboratories and time; good expression using DNA of variable and often poor quality, as is normally the case when one must extract DNA massively from hundreds or thousands of individuals; markers that are unique to the source of the gene, among the several parents that figure in the breeding program, so as not to confuse the marked gene with any other. It is in fact quite laborious to develop such markers, and often the work of tagging genes stops short of creating markers of sufficient quality that lend themselves to use in MAS.

Field logistics: A third factor in the implementation of MAS that is never cited in literature is the simple logistics of managing tissue samples of field grown plants, assuming that large-scale MAS demands planting populations or families in the field. An important part of the logistics is maintaining the relation between a DNA sample in the laboratory and a plant in the field. We have developed a system of identifying plants individually in the field with the number of a cell in a titer plate; sampling leaf tissue in the field with a paper punch and transferring directly to the titer plate; massive screening with a reliable SCAR (Sequence Characterized Amplified Region) marker; compilation of data in relation to field numbering scheme; and selection of plants based on the presence of bands.

A well-conceived plan: Markers must be applied in on-going breeding plans such as backcross breeding, pedigree, etc. The cost of markers and the labor involved in MAS does not permit using markers universally on all plants, thus the breeder must identify those points in his breeding program where cost effective information about the presence or absence of a gene permits useful decisions and effective selection. For example, in CIAT we work with many complex crosses with three to five parents. The F_1 plants of such complex crosses are genetically variable, and offer the possibility to practice selection, before creating large F_2 populations. We have found this to be a cost effective way to use markers, and in a typical season we reduce the number of F_1 plants that advance to the F_1 generation by about 40%, with a corresponding savings in land and resources. In other situations, we sample families or lines to determine the presence of the gene, and to discard entire families. However, we never evaluate F_2 populations due to the very large numbers of plants involved. It is also important to remember that the number of plants discarded and the corresponding savings depends on the frequency of the gene in the populations under selection. Once the frequency is very high, MAS may no longer be cost effective, because the percent of plants discarded becomes minimal.

More generally, the application of MAS requires a combination of technology with some simple common sense, and the input of the breeder on certain critical decisions: What genes are worth the effort and cost effective to select by MAS? What breeding scheme should I use? And at what point in the breeding scheme do I employ MAS? It also requires some thought of how to set up a simple yet effective scheme for managing hundreds or thousands of tissue samples, and maintaining plant identity. These are elements that are often overlooked in the discussions of MAS but are just as important as the more technical aspects.

CONCLUSIONS

Production of grain legumes has increased much more slowly than that of cereals during the past three decades. Abiotic stress factors and especially soil fertility is often the primary limitation on bean yields in realizing the yield potential of the crop on farmers fields. There appear to be excellent opportunities to improve the abiotic stress tolerance in bean, which may permit us to increase yield potential as well, as per the experience in other grain legume species such as soybean. Marker-assisted selection (MAS) can be a valuable tool in breeding, and in the short-term, can be used to maintain biotic stress resistance genes in breeding populations while other breeding objectives are pursued, such as abiotic stress tolerance and higher mineral content in grain.

REFERENCES

Beebe, S., I. Rao, H. Terán, C. Cajiao, J. Ricaurte, and J. Beltran. 2003. Progreso en Aumentar Tolerancia a Estrés Abiótico en Frijol Común. Paper presented in the XLIX Meeting of the PCCMCA, Programa Cooperativo Centroamericano de Mejoramiento de Cultivos y Animales. La Ceiba, Honduras. April 27-May 3, 2003.

Duvick, D.N. 1984. Genetic contribution to yield gains of U.S. hybrid maize, 1930 to 1980 p. 1-47. *In* W.R. Fehr (Ed.) *Genetic Contributions to Yield Gains of Five Major Crop Plants*. CSSA Spec. Publ. 7. ASA and CSSA, Madison, WI.

FAOSTAT. 2003. http://apps.fao.org/cgi-bin/nph-db.pl?subset=agriculture.

Graham, P.H., and C.P. Vance. 2003. Legumes: Importance and constraints to greater use. *Plant Physiol.* 131: 872-877.

Lynch, J., and S. Beebe. 1995. Adaptation of beans (*Phaseolus vulgaris* L.) to low phosphorus availability. *Hort Sci.* 30: 1165-1171.

Mackay, T.F.C. 2001. The genetic architecture of quantitative traits. *Ann. Rev. Genet.* 35: 303-339.

Rao, I. M. 2001. Role of physiology in improving crop adaptation to abiotic stresses in the tropics: The case of common bean and tropical forages. p. 583-613. *In* M. Pessarakli (Ed.) *Handbook of Plant and Crop Physiology*. Marcel Dekker, Inc., New York.

Specht, J.E., D.J. Hume, and S.V. Kumudini. 1999. Soybean yield potential – a genetic and physiological perspective. *Crop Sci.* 39: 1560-1570.

Tollenaar, M., and J. Wu. 1999. Yield improvement in temperate maize is attributable to greater stress tolerance.

Crop Sci. 39: 1597-1604. Ugandaidea. 2002. http://www.ugandaidea.org/ugandagrains/02Oct41&42.pdf.

UN-ACC-SCN. 1992. United Nations Administrative Committee on Coordination-Subcommittee on Nutrition. Second Report on the World Nutrition Situation. Vol. I. Global and Regional Results. 1992; Geneva, Switzerland: United Nations Administrative Committee on Coordination, Subcommittee on Nutrition.

Viana R., A. 1998. Flujo de germoplasma e impacto de PROFRIJOL en Centroamérica. Período 1987-1996. Programa Cooperativo Regional de Frijol para Centroamérica, México y el Caribe. Guatemala, Guatemala.

Voldeng, H.D., E.R. Cober, D.J. Hume, C. Gillard, and M.J. Morrison. 1997. Fifty-eight years of genetic improvement of short-season soybean cultivars in Canada. *Crop Sci.* 37: 428-431.

Wang, T.L., C. Domoney, C.L. Hedley, R. Casey, and M.A. Grusak. 2003. Can we improve nutritional quality of legume seeds? *Plant Physiol.* 131: 886-891.

Participatory Plant Breeding with Women and Small-scale Farmers: A Case Study in Haricot Bean in Ethiopia

Habtu Assefa[1], Daniel Dauro[2], Meklit Tariku[3], Setegne Gebeyehu[1], Asrat Asfaw[2], Bulti Tesso[3] and Paul Kimani[4]

[1]*Melkassa Agricultural Research Centre, PO Box 436, Nazareth, Ethiopia,* [2]*Awassa Agricultural Research Centre, PO Box 6, Awassa, Ethiopia,* [3]*Alemaya University, PO Box 138, Alemaya, Ethiopia,* [4]*University of Nairobi, Nairobi, Kenya*

ABSTRACT

The Ethiopian national haricot bean program traditionally followed conventional approaches in bean improvement for smallholder farmers. The relative effectiveness and efficiency of participatory plant breeding (PPB) compared to conventional approaches is not fully understood. Among other things, the study was initiated to evaluate participatory plant breeding in bean improvement to target and disseminate more acceptable and productive bean varieties for poor women and men farmers. The study was conducted in Awassa, Melkassa and Alemaya in southern, central and eastern Ethiopia, respectively. Breeders and farmer selectors evaluated and then selected lines on-station from a diverse germplasm pool. The breeders followed a conventional approach, while farmers evaluated their selected lines on their farm. Breeders' and farmers' final selections were evaluated by other small farmers (farmer-evaluators) and by the breeders in multi-location trials. The Alemaya site included climbing beans in its selections, whilst other project locations focused on more traditional bush growth habit types. The selection process demonstrated that farmers were capable of making significant contributions in identification of superior cultivars within a relatively short period. They effectively evaluated and selected from large numbers of fixed lines. They applied up to 40 distinct selection criteria indicating the complexity of the user needs and production conditions. However, yield, tolerance to biotic and abiotic stresses and drought, earliness, marketability, cooking characteristics, seed color and size, and growth habit were considered key criteria across sites. Involving farmers in the selection process had several impacts, not only on farmer perceptions and skill building but also on the formal breeding process, farmer acceptance, farmer production and income, farmer-held diversity, farmer breeding and seed processes, farmer empowerment and costs. A new formal-led breeding scheme incorporating farmer participation is also developed. Lack of an effective seed delivery system and supporting policy is likely to constrain release and rapid dissemination of PPB varieties.

INTRODUCTION

Major production increases through genetic improvement and high inputs have been achieved in the more agriculturally favored areas in Ethiopia. In contrast, subsistence systems, which today exist principally in less favored and heterogeneous environments, have mostly been bypassed by the green and post-green revolution (Trutmann and Pyndji, 1994). Conventional breeding programs are seldom designed to meet the specific requirements of different types of farmers and ecologies who due to many reasons may have contrasting preferences, which might require different breeding approaches.

The history of formal breeding and genetics has roots in farmers' practices, and in the past, researchers have shown appreciation for farmers' practices and knowledge (Richards, 1985; Kimmelmann, 1987). Farmers' innovations have made significant contributions in their own right, either in experimenting and disseminating introduced crop types (Fowler, 1994) or in the identification and isolation of valuable lines (Martin, 1936). However, in recent years, there has been a sustained level of international interest in farmer participatory research (Sperling and Loevinsohn, 1996; Eyzaguire and Iwanaga, 1996; SWP/PRGA, 1997; IPGRI, 1996). In crop breeding, participatory plant breeding (PPB) is thought to have the potential to develop crop varieties better adapted to farmers' local environmental conditions (Sthapit et al., 1996; Ceccarelli et al., 1996) or quality requirements (Kornegay et al., 1996) or enhancing bio-diversity (Voss, 1996) through farmer involvement.

In Ethiopia, haricot or common bean (*Phaseolus vulgaris* L.) production areas differ greatly: the central Rift Valley is distinct in having been for long an area where small-scale commercial bean production predominates; the southern Rift Valley produces mostly for subsistence; while the Hararghe highlands are intermediate. The haricot bean genetic diversity on farm is much lower in Ethiopia, and until the 1990s only a few new varieties had been released for farmers' cultivation. Typically, the Ethiopian lowland pulses breeding program takes about 10 years to release an improved variety. Of this, about 70% of the time is spent on breeding activities from nurseries to yield trials. Even then, the result may be disappointing as the rate and extent of adoption of the released varieties are often quite low.

Participatory research can help to reduce the time involved, reduce the number of unacceptable varieties and increase the number of options available to farmers. More decentralized breeding approaches are also needed that exploit genotype x environment interaction, making use of specific adaptation, and the active participation of farmers. Advantages and disadvantages of involving farmers in the early stages of bean breeding strategy were not critically assessed. Moreover, debates still continue on the role of PPB in the NARS (National Agricultural Research System). Aware of this, the Ethiopian National Lowland Pulses Improvement Program (ENLPIP) had in 1998 commissioned research that was the first attempt at comparing PPB approaches to the conventional breeding scheme used in the country. PPB project was initiated in 1998 to develop more client-oriented products in a participatory approach. The project was carried out in three regions in six communities to compare PPB and the conventional breeding approach.

MATERIALS AND METHODS

Site and Farmer Selection

In April 1998, breeders and agricultural economists in collaboration with the experts from the Bureau of Agriculture from district offices at Melkassa, Awassa and Alemaya conducted a survey to identify potential sites, which could host the PPB project. The criteria considered during site selection were relative land area allocated for bean growing, number of bean growers, accessibility, and engagement in other research projects. Based on the above criteria, two farming communities from each of Melkassa and Awassa, and three communities from Alemaya were selected (Table 1). These were Bofa and Wolenchiti from Melkassa; Remeda Peasants' Association (PA) and Korangogie PA from Awassa; and Tinke PA, Ararso PA and Efabate PA from Alemaya. Participating farmers in Alemaya were classified as rich at Efabate, average at Ararso, and poor at Tinke. Following the site identification, using PRA techniques and interview with key informants, researchers and development agents of Bureau of Agriculture selected participating farmers at all the sites. Selection of farmers was based primarily on position of resources, soil variation and willingness to participate in the research.

Research Design

Research designs for comparing conventional and PPB were developed during an initial workshop in 1998 and reviewed for all teams during another workshop in March 2000. The standard breeding design used at each site was adopted as the conventional design and applied by the breeder. Farmer-selectors (FS) followed the PPB design.

Characteristics of Initial Germplasm Pool

The gene pool for the initial study was constituted from the 1996 haricot bean nursery (VEF96) that included 595 entries. Lines from this initial gene pool were selected based on preliminary studies made earlier with farmers where some information was collected on their preferences either for export types or other beans used for local consumption (Table 2). At Melkassa, based on these criteria the conventional breeder selected fixed lines of 241 food type beans and 32 export-type bean lines, constituted the initial gene pool, that possessed different colors, sizes and types. The initial germplasm pool at Awassa comprised of eight climbers, 36 large-seeded and 103 small- and medium-seeded bush bean lines. All four-growth habits (Type I, II, III and IV) were represented. Most of the entries were red and red-mottled. A few had cream, purple and yellow seed colors. The initial germplasm pool at Alemaya was separated into three nurseries (PPB I, II and III) based on growth habit, seed size and color, and potential for use in cropping systems (Table 3).

Selection Procedures

Farmers were invited to research centers located in different sites during the first year. Subsequently, FS decided the type of materials to be grown on their farms. In Melkassa, 273 lines of beans were planted in 1998 at Melkassa Agricultural Research Center in a single-row nursery. The nursery was researcher-managed. Recommended cultural practices were followed. Male farmers visited the trial three times; at early vegetative crop growth, at flowering, and finally at maturity. Farmers chose the timing of their visits. Farmers were explained that these stages were selected to compare the performance of the lines at the different growth stages. Visits by Bofa and Wolenchitti farmers were scheduled at different dates. Farmers were informed about the range of color groups included for the evaluation, and seed samples were displayed during the third evaluation. The same 273 lines were sown again on-station in July 1999 for female farmer evaluators. Female farmers evaluated the lines twice, late in August and September to coincide with the flowering and maturity stages, respectively (Table 4).

Table 1. Characteristics of the experimental sites.

	Melkassa		Awassa		Alemaya		
Characteristic	Bofa	Wolenchetti	Remada	Korangogie	Tinke	Ararso	Efabate
Soil	Three major types (Shakite, Koticha, Gombore); Medium fertility	Two soil types (Koticha, Gombore); medium fertility	Nitosols	Andosols	Regosols	Vertisols, Cambisols	Fluvisols
Mean annual rainfall (mm)	700	700	1200	1000	790	790	790
Altitude (m asl)	1500	1500	1900	1500	2000	2000	1900
Temperature (max °C)	27-30	27-30	16	20	25	-	-
Cropping system for bean	Sole-crop, one season/year	Sole-crop, one season/year	Inter-crop with maize in first season; sole in second season		Maize-bean-chat inter-cropping; Vegetable production (potato, cabbage, etc)		
Productivity	Low to medium	Low to Medium	Medium to high	Medium to high	Low to medium	Medium to high	Medium to high

Table 2. Number of entries and categories of initial germplasm pool at experimental sites.

Site	Bush	Climbers	Total
Melkassa	273	0	273
Awassa	139	8	147
Alemaya	238	25	263

At Awassa, 22 male and female farmers from each of the two villages were invited to evaluate 147 bean genotypes sown on-station to make selections for on-farm testing. They selected lines based on pod load, seed color, and growth habit in three cycles of selection (Table 5). The team members recorded farmers' selection criteria during visits to latters' plots. In Alemaya, farmers were invited to Alemaya University Research Center (AURC) to evaluate and select from a germplasm pool of 250 lines at flowering, podding and at harvesting stages during the 1998 main season (Table 6). The breeder also made his selections from the same pool for comparison. The germplasm pool comprised of climbers with red and cream seed types, and red, cream and black colored bush bean lines. The three farmer user-groups were invited to evaluate the germplasm pool. Farmers sowed the initial germplasm pool in communal plots in 1998.

During the first and second season of 1999, each of the three user-groups (identified through diagnostic methods) selected lines from the communal plot for sowing in one farmer's field in the group. In subsequent seasons, each farmer selected lines for evaluation in his/her individual plot. Open-ended evaluation was employed to identify farmers' selection criteria. Breeders selected lines from on-station in replicated trials from the same germplasm pool as the farmers and advanced them following the conventional breeding scheme. Non-selector farmers evaluated breeders' and farmers' selections at all the sites in the year 2001.

RESULTS AND DISCUSSION

Selection of Acceptable and Productive Varieties by Farmers

In Melkassa, the FS from Bofa and Wolenchitti made their on-station selections in 1998. Based on their own selection criteria, they selected a wide range of varieties. The selections by each farmer varied from a minimum of seven to 30 lines. A total of 165 lines were selected in 1998 from a germplasm pool of 273. Of these, 59 were selected both by Bofa and Wolenchitti farmers. Fifty-one selections were unique for Bofa, and 55 for Wolenchitti. Lines selected by at least 10 farmers included Roba (18), DOR 522 (14), A 262 (11), DOR 562 (10), EMP 389 (13), DOR 715 (11), DFV 18 (10), Centralia (10), ACC No 1207 (23) and Mexican 142 (16). All farmers selected both red and white colors; 76% selected cream types, and 62 % selected speckled beans. For food bean types (colors other than white), lines selected by farmers gave a yield range of 178 and 709 g per plot, while for the export beans it ranged between 135 and 611 g per plot. In the descending order of importance, the principal selection criteria applied were earliness, yield, stress tolerance and seed color.

In 1999, 22 male FS in each of the villages of Bofa and Wolenchitti planted 63 and 42 bush bean lines, respectively, on their own farms following on-station selections. Bofa male FS selected five to 30 selections per farmer. Wolenchitti male FS selected 12 to 24 lines per farmer. The selectors evaluated their beans at least three times during the growing period. At the end of the crop season, Wolenchitti and Bofa male FS selected 93 lines (40 from Wolenchitti and 50 from Bofa) to be advanced for the next stage of testing. The number of selections for each farmer ranged from two to eight lines. Of the 40 selections in Wolenchitti, only seven lines were commonly selected by participating farmers. A white pea bean, Mexican 142, was selected by 40% of the farmers. In Bofa, 11 lines were commonly selected and the rest were selected only once. Female farmers selected 28 lines for sowing in 1999. As opposed to male farmers, they had a large number of (50%) common selections. The most notable one was MAM 48, which was selected by 90% of the female farmers, followed by Roba and UTT 24-131, which were selected by 60% of the female farmers.

In 2000, male FS in the two villages planted 77 lines selected from the 165 lines sown in 1999. At Bofa, the selectors planted 40 lines (28 red, 9 white and 3 of mixed colors), whereas the Wolenchitti male selectors planted 31 red, 12 white and seven of mixed colors. At the end of the crop season, the male FS retained 45 lines; 28 at Bofa and 23 at Wolenchitti. Lines selected in the two villages were predominantly red or white. At Bofa 57.4% of selected lines were red and 32.1% were white. A similar trend was observed at Wolenchitti (69.6% red and 21.7% white). Number of lines retained by male FS varied from one to three. About 62% male FS retained two lines per farmer. Number of lines sown by female FS was drastically reduced from 273 in 1999 to 31 in 2000. Female FS showed similar preferences to those of male FS but most of the lines sown and retained were red or white. At the end of the crop season, female selectors retained 16 lines (10 red, four white and two of other colors). They retained one to three lines per farmer. Sixty percent of the female selectors retained two lines. Number of lines retained by each group of selectors was reduced further after post-harvesting testing for cooking quality, compatibility with local dishes, physical appearance and taste.

The year 2001 was the period for final cycle of evaluation and selection. Participating and non-participating farmers in the two villages conducted the evaluation of FS and breeder selections. The test materials were evaluated during the vegetative and harvest stages in the field, and after cooking. The male FS planted 27 lines in 2001; 17 at Bofa and 16 at Wolenchitti. Female FS planted 12 lines for the final evaluation. Non-participating farmers planted both breeder and farmer selections. Three types of selections were made: (i) individual selections: those

Table 3. Characteristics of the three bean nurseries used in the conventional and participatory breeding programs at Alemaya.

Character	Nursery PPB-I	PPB-II	PPB-III
Growth habit	Climbers (type IV)	Bush (types I and II)	Bush (types 1 and II)
Seed color	Mixed, red and cream	Mixed colors, cream and black	Red
Seed size	Large and medium	Large, medium and small	Large, medium and small
Current production	Low	High	Very high
Importance in farming system	Around home yards, can be array cropped in *chat* (*Chata edulis*) and coffee (*Coffea arabica*)	For intercropping with sorghum and maize; bean sole crops	For intercropping and relay cropping with sorghum and maize; bean sole crops
Cropping season	Main (*Meher*)	*Belg* and main season	*Belg* and main season
Number of lines	25	59	183

selected by individual participating FS, reflecting the specific adaptation to a farmer's field and user preference, (ii) group selections by participating FS, reflecting the wider adaptation to several farmers' fields and wider communal user preferences, and (iii) communally selected lines by non-participating farmer-evaluators (FE), which reflected not only wider and specific adaptation but also unbiased assessment of the potential of these lines to meet wider user needs. Thirty-two lines at Bofa and 25 at Wolenchitti were selected by individual farmers. Awash-1 and Atndaba were the most frequently selected lines in Bofa village. Awash-1 was selected by 10 of the 17 male FS, and Atndaba by seven male FS. In Wolenchitti, Dresdan and Mexico 142 were the most popular lines selected. Four farmers selected Dresdan, whereas three selected Mexico 142. All other lines were selected by only one or two farmers at the two villages indicating diverse preferences and probably adaptation to specific microenvironments. Number of lines selected varied from two to four per farmer. About 32% of male FS at Bofa selected four lines, 57.9% selected three lines, and 10.5% selected two lines per farmer. In Wolenchitti, 75% of male FS retained three lines, and 25 % retained 2 lines.

The female FS at the two villages finally selected 14 lines. At Bofa, 60% of the female selectors retained four lines per farmer and 40% retained three lines per farmer. At Wolenchitti, all female selectors retained three lines each. Roba-1 and MAM 48 were the most popular lines selected in the two villages. Group selections and selections by non-participating FE are shown in Table 7.

Table 4. Number of farmer-selectors (FS) and non-selector evaluators during the selection and evaluation stages at Melkassa, Rift Valley region, Ethiopia.

Cycle (C)	Bofa Male	Bofa Female	Bofa Total	Wolenchitti Male	Wolenchitti Female	Wolenchitti Total
C_1 (1998)	20	0	20	20	0	20
C_2 (1999)	20	5	25	18	5	23
C_3 (2000)	20	5	25	15	5	16
C_4 (2001)	18	5	23	13	5	18
Evaluators (2001)	10	2	12	7	3	10

Table 5. Number of farmer-selectors (FS) and non-selectors evaluators during the selection and evaluation stages at Awassa, southern Ethiopia.

Cycle (C)	Remada Male	Remada Female	Remada Total	Korangogie Male	Korangogie Female	Korangogie Total
C_1 (1999)	17	5	22	17	5	22
C_2 (2000)	14	4	18	12	3	15
C_3 (2001)	13	4	17	7	3	10
Evaluators (2001)		5			5	

Table 6. Number of farmer-selectors (FS) and non-selector evaluators during the selection cycles at Alemaya, eastern Ethiopia.

Cycle	RPF[1]	RRF[2]	WF[3]	Type of selection[4]
C_1 (1998)	22	10	18	Communal
C_2 (1999A)	6	6	10	Communal
C_3 (1999B)	6	6	10	Communal
C_4 (2000A)	6	6	10	Individual
C_5 (2000B)	6	3	6	Individual
C_6 (2001A)	7	2	6	individual

[1]RPF= Resource-poor farmers; [2]RRF= Resource-rich farmers; [3]WF= Women farmers., [4] Communal selection= Group selection in a jointly owned plot; individual = a farmer evaluating lines selected by him/herself. Season A is the *Belg* season (February to April) and season B is the main season (July to October).

At Bofa, few lines were selected in group selections and also by non-participating farmers (Table 7). DOR 526 was the only line selected by all groups and evaluators at Bofa. However, most lines were group and site specific, a trend, similar to the one observed at Wolenchitti as well. This indicates that few lines can be expected to meet adequately the wide range of user preferences and production environments.

The number of selected lines reduced further after cooking and taste assessments by non-participating farmers and FS. Lines that met the participating and non-participating male and female farmers' criteria at Bofa were: DOR 527, DOR 517, DOR 526, RAB 593, MAM 48 and XAN 310. At Wolenchitti, these were DOR 710, XAN 310, DOR 705, DOR 711, NZBR 2-5, RAB 580, DOR 517, DOR 527, RAZ 54 and DOR 794. Of these, selections DOR-527, DOR-705, XAN 310, RAZ 54 and DOR554 were also selected by the breeders based on the conventional breeding. DOR 554 was officially released in 2002.

Table 7. Lines communally retained at the end of the fourth cycle of selection by farmer-selector (FS) groups and non-participating farmer evaluators (FE) in two villages, Melkassa, Ethiopia.

	Group Selections		FE Selections	
Community	Male FS	Female FS	Male FE	Female FE
Bofa	DOR 716, G4638		DOR 527, DOR 526	DOR 554, DOR 526
	EMP 385,DOR 527		DOR 517, DICTA 109	G4638, RAZ 54
	DOR 526, DOR 517		DOR 567, DOR 531	DOR 567, EMP 385
	DOR 560, DOR 715		RAB 593, XAN 310	NZBR 2-8, STTT 165-72
	NZBR 2-8, UTT 24-137		XAN 316, PAN 182	PAN 182, DOR 711
	STTT 165-72		MAM 48, FEB 194	DOR 364, DOR 716
Wolenchitti	DOR 711, DOR 517	DOR 705	RAB 580, RAZ 54	DOR 710
	RAB 580, NZBR 2-5	POA 4	VAC 73, DOR 517	UTT 27-24
	EMP 212, UTT 24-131	UTT 24-131,	EMP 212, ROBA-1	XAN 310
	ACC 1207, RAB 580	DOR 710	DOR 811, NZBR 2-8	LOCAL
	RAZ 54	XAN 310,	DOR 794, DOR 548	DOR 705
		DOR 764	DOR 527, FEB 183	UTT 24-131

In Awassa in the first season of 1999, 22 FS in each of the villages of Korongogie and Remada individually made selections from diverse germplasm pool sown on-station and on-farm in the second and principal bean growing season of 1999 (1999b). Number of lines per FS in the first year ranged between eight and 52 at Korangogie and six to 17 at Remada. In both villages small- and medium-seeded lines dominated their selections (Table 8), most of which were red-seeded, similar to Melkassa, where the red-, small/medium-seeded, popular local variety, Red Wolaita, is grown for food. During the 1999b season the FS evaluated their chosen lines and made selections for the second season of 2000 (2000b).

In 2000, the FS in Remada and Korongogie selected a greater proportion of large-seeded lines (90% and 88%, respectively), compared to small/medium-seeded lines (79% and 84%, respectively), indicating a change from the earlier preference for the latter (Table 8). This trend was reinforced by the provisional selections made by FS for season 2001b. In both villages, all the large-seeded lines were retained compared to only 68% and 71% of the small-seeded lines for Remada and Korongogie, respectively. On an average, large-seeded bean lines were 2.5 times more likely to be selected than small/medium-seeded ones. This shift in preference occurred even though their previous experience of bean types was limited to medium-seeded Red Wolaita and small-seeded and white Mexican 142, cultivated for cash.

At the end of 2001 evaluation, each FS retained an average of 4.9 lines in Remada and 7.9 in Korangogie. Eighty-two of the original 147 lines were retained by at least one FS indicating a substantial increase in genetic diversity in the region. In Remada, female FS retained 4.5 lines compared to 5 lines for males. Korangogie males retained 8.5 lines compared to 7.9 of female FS.

In Alemaya in 1998, in contrast to the other locations in Ethiopia, the initial selection phases were conducted communally, as is the normal practice in the preliminary assessment of the 'new technologies' in this region. Three user-groups, initially comprising 22 resource-poor farmers (RPF), 10 resource-rich farmers (RRF) and 18 women farmers (WF), initiated communal selection in a germplasm pool in two nurseries comprising of 25 climbers and 239 lines of bushy growth habit. From these, breeders selected 24 bushy lines and eight climbers for the conventional breeding program.

In the two seasons of 1999, the three groups respectively evaluated 39, 31 and 52 lines (Table 9), all showing a marked preference for the bushy types (Table 10). In the first and second season of 1999, the FS in each user-group communally evaluated their selected lines on one farmer's field of the group. As crop growth in first season was poor due to little and poorly distributed rain, the FS re-evaluated all lines in the second (main rainy) season in which the resource-poor group individually selected 40 lines, ranging from 19 to 27 lines per farmer, for evaluation on their own farms in the first season of 2000. Farmers in the resource-poor and women's groups communally selected 12 and 14 lines, respectively, for joint communal evaluation.

Table 8. Number of large- and small/medium-lines selected by farmer-selectors and sown on-farm in 1999b and 2000b and provisionally[1] selected for 2001 in Remada and Korongogie, near Awassa.

	Large-seeded		Small-medium seeded	
Parameter	Remada	Korongogie	Remada	Korongogie
Number of lines sown in 1999b	29	34	48	82
Number of lines sown in 2000b	26	30	38	69
Number of lines provisionally[1] selected in 2000b	26	30	26	49
Percentage of lines selected in 2000b	100%	100%	68	71
Range in selection frequency of individual lines in 2000b	1 to 8	1 to 11	1 to 4	1 to 5
Mean frequency of selected lines in 2000b	3.3	3.9	1.3	1.6

[1] Lines which farmers provisionally selected at physiological maturity for sowing in the 2001.

Table 9. Number and growth habit of lines sown for evaluation by farmer-selectors in three user groups and on-station by the breeders in 1999/2000, and selections for 2001 at Alemaya.

Year / Season	Resource-poor (6)		Resource-rich (6)		Women (10)	
	Communal[1]	Individual[2]	Communal	Individual	Communal	Individual
1999A	39	None	31	None	52	None
1999B	39	None	31	None	52	None
2000A	None	40	12	None	14	None
2000B	None	29	None	9	None	13

[1]All farmers in a user-group undertake communal evaluation on one of the group's farms, [2] Evaluation of the selected lines by an individual farmer him/herself.

Table 10. Frequency of bushy and climbing haricot bean lines selected by different categories of farmers, 1999-2001.

Growth type	1999A			2000B			2001		
	Poor	Rich	Women	Poor	Rich	Women	Poor	Rich	Women
Bush	35	28	44	33	10	12	33	8	11
Climbing	4	3	8	4	2	2	4	2	2

In 2000A, the six resource-poor selectors chose a mean of 13 lines, ranging from eight to 16 per farmer, from the progenies of their individual selections planted on their own farms (Table 11). The resource-rich and women's groups sowed fewer lines than the resource-poor farmers, but proportionally selected more and rejected fewer lines. Results showed that RPF selected one common line, compared to five and three lines by the RRF and women farmers, respectively, among their individual selections. Grain yield, drought tolerance, seeds per pod, pods per plant, pod filling and seed color were the major selection criteria. In the second season of 2000 (2000B), however, the RPF had selected 29 bushy lines compared to nine of RRF and 11 of WF; the climbing lines selected by the three groups for 2000b were four, *one* and two, respectively.

In 2001A, farmers conducted the last individual selection and ranked their final selections for color, seed size, cooking time and taste (Table 12). They also ranked their selection criteria. In descending order of importance, the RPF group ranked grain yield, marketability, drought tolerance, disease resistance and eating quality as the most important selection criteria. The WF group ranked (in descending order of importance) grain yield, eating quality, marketability, and forage yield and drought tolerance as their most important criteria. Climber beans were not preferred because they lodged when intercropped with maize. Farmers are now evaluating them in sole stands. In the conventional breeding program, three climber bean lines, three colored- and four red-seeded lines were selected in 2001A. Selections from both breeders' and farmer-user groups were sown on-station and on-farm in 2001B for evaluation by FS and non-selector farmer evaluators.

Farmers' Selection Criteria

In Melkassa, the principal selection criteria applied by WF in the two villages are shown in Table 13. Grain yield, earliness, drought tolerance, seed color and marketability were the most important criteria. Among the male selectors, grain yield was ranked as the most important criterion by 26% of the farmers at the two sites. Other important criteria were marketability (21%), '*nifro*' quality; the perceived quality of a line for preparing the local dish '*nifro*' (boiled mixed grains of maize and beans) (14%), earliness (5%), even germination (5%), vigor (5%), pod load (5%), plant architecture (4%), and '*wot*' quality (4%).

Depending on location and gender farmers applied several selection criteria. In 1999 male and female farmers identified 16 and 17 traits, respectively, as their selection criteria. High grain yield, drought tolerance, earliness, vigor remained the most important criteria for many farmers. Red was the most preferred color identified by all selectors, followed by white and carioca/cream types. More than 60% of the varieties selected by male and female farmers both from Bofa and Wolenchitti were red. Preference for size was strikingly uniform across locations and for both group of farmers. Beans having medium-seed sizes were the most preferred groups as more than 70% of the lines selected were medium in seed size.

Table 11. Number of lines sown and selected (Sel) in the first season of 2000 by farmer-selectors (FS) in the three-user groups1 at Alemaya.

RPF			RRF			WF		
Farmer name	Sown	Sel	Farmer name	Sown	Sel	Farmer name	Sown	Sel
Mohammed	21	8	Mahadi	12	10	Rumia Umer	13	9
Abrahim	24	16	Hasan Mume	sown	10	Annisa Mussse	sown	10
Jemal	27	12	Tili Sadiq	communally	10	Rumia Adem	communally	9
Elias Abdurahman	26	13	Adam Usman		10	Mardia Abdulah		9
Idris Bakar	19	13	Aliy Abdi		10	Deneba Abrahim		10
Ibsa Aliy	27	15	Usman Kamal		5	Rumia Musse		13
						Mako Yusuf		6
						Kimia Ali		7
						Hindia Mume		9
						Fatuma Umer		8
Total	144	77			55			90
Mean	24	13			9			9

[1]RRF, RPF, WF: Resource-poor, resource-rich and women farmers, respectively.

Table 12. Ranking of lines selected by resource-poor farmers (RPF) and women farmers (WF) groups in 2001A in Alemaya.

RPF					WF				
Genotype	Color	Seed size	Cooking time[1] (h:min)	Taste	Genotype	Color	Seed size	Cooking time (h:min)	Taste
DOR 575	5	8	1:24 (1)	3	SUG-137	7	6	1:22 (2)	1
DOR 564	2	1	1:47 (8)	6	AND 1051	4	5	1:48 (8)	10
DOR 761	9	9	1:34 (6)	11					
SUG-136	8	4	1:51(9)	9	AFR 722	1	1	1:40 (4)	6
812-BRC-28	6	2	1:51 (9)	10	DRK 137	3	3	1:47 (7)	4
DICTA-105	3	7	1:45 (7)	4	AND 1066	5	7	1:45 (6)	5
DOR 711	10	10	1:32 (5)	7	CAL 160	6	2	1:30 (3)	2
AFR 707	4	5	1:32 (5)	5	DOR 564	10	9	1:55 (9)	9
XAN 314	1	6	1:31 (4)	2	849-BRC-6	9	8	1:30 (3)	7
DAF 47	7	3	1:28 (2)	8	874-BRC-12	2	4	1:12 (1)	8
Red Wolayta (check)	11	11	1:29 (3)	1	Red Wolayta	8	10	1:43 (5)	3

[1]Cooking time ranks are in parenthesis.

Table 13. Criteria applied by female farmer selectors at two villages in Melkassa, Ethiopia.

Criterion	Bofa (%)	Wolenchitti (%)
Yield	31	37
Drought	29	8
Earliness	19	23
Color	7	7
Marketability	1	10
Vegetative vigor	7	2
Physical appearance	2	3
Adaptation	1	4
Cooking quality	<1	2

In Awassa, the most important criteria mentioned by farmers for selection of lines from the germplasm pool in 1999 were growth habit, plant height, pod load, pod length, pod height, early maturity, seed color, and size. Subsequent interviews with the farmers revealed that the critical selection criteria (decision-making criteria) were seed color and grain yield. Other criteria such as pod clearance from the ground, pod load, pod length, seeds per pod, growth habit, stem strength, plant height, seed size, taste, cooking time, digestibility and reduced flatulence problems, swelling ability during cooking ('puffing up'), and earliness were also important attributes of a good cultivar. Farmers ranked their individual selections sown in a communal plot in 2001. Yield of the best lines communally selected were 1961, 1427, 683, 576 and 1228 kg/ha for DCB-97, LSB-14, LSB-19, LSB-27 and LSB-34, respectively. Based on replicated preliminary and regional yield trials in 2000 and 2001, the breeders also selected LSB-14 and LSB-34.

In Alemaya, the selection criteria, elicited from all the farmer-selectors and user-groups in the first season of 2000 and 2001, emphasised grain yield and yield components (pods/plant, seeds/pod, seed size) across user groups. Drought tolerance ranked as the next criterion. Within user-groups, 83% or more of FS rated these criteria in the top five. Cooking quality, market value and cooking time ranked 10th, 14th and 24th, respectively, across user-groups, reflecting their relative lack of importance to both the male-dominated groups. These criteria are, however, of importance to women FS with 70%, 80% and 40%, respectively, considering these criteria as important. Farmers did not value some criteria usually of importance to breeders.

Comparison of Methods, Activities and Relative Costs of Conventional and Participatory Plant Breeding

Information on activities and outputs by both farmers and breeders collected during the project period was used in computing the overall costs in the Year Three. Data were collected on operation costs (farmers' and researchers' time, travel, materials used), type of benefits obtained each year, recipients of these benefits or outcomes, types of costs involved each year (both costs incurred and costs avoided), and who bore the burden of these costs. Qualitative and quantitative cost data were collected for each of the activities carried out in conventional and participatory schemes. A comparison of the nature of research costs for conventional and participatory breeding for project sites are shown in Tables 14 and 15.

Results from both the sites showed that PPB was less costly compared to the conventional breeding. However, at one site PPB was more expensive. Qualitative costs varied with activity. These costs were considered as indicative rather than absolute because actual costs are likely to vary with program objectives, activities, relative efficiencies and several site- specific factors, both predictable and un-predictable. Programs should be purpose-oriented and incorporate desirable features from both the conventional and participatory approaches.

Strategies for Multiplication and Dissemination of Seeds

Strategies were developed at each site for application as farmer selections became available for dissemination in late 2001. The strategy envisaged involved the activation of community-based system with the Ethiopian Agricultural Research Organization (EARO), which is expected to supply basic or breeders' seed to farmers. In the proposed scheme, male and female farmers will multiply seeds supported by a quality control system to ensure that farmers produced seeds that met the required standards. Seeds produced by farmers will be either sold to cooperatives for cash or exchanged with other farmers in kind. Cooperatives may in turn sell the varieties they purchase from farmers to other farmers. This way, the relationships of various parties may be maintained in order to multiply seeds continually. Nevertheless, the formal system may play a role after many farmers accept the varieties or after the demand created is more attractive. Moreover, in order for the strategy to materialize, the existing seed policy, which favors only the formal seed system, should be modified.

Table 14. Comparison of methods, activities and relative costs of conventional and participatory plant breeding at Melkassa.

Activity	Conventional breeding	PPB
Survey	Method: No survey required, assumes researcher is familiar with research problem Cost: None Pros: Cons: Assessing farmers' needs and identifying constraints regularly is important	Method: (i) PRA to assess the potential & constraints of bean production with major emphasis on varieties & objectives of production; (ii) key informants to define user groups Cost: Researcher time, travel expenses, training and allowances for development agents Pros: Farmers' need and production constraints identified Cons: An additional cost
Site selection and characterization	Method: None undertaken as work is done in existing research sites or field stations Cost: Saves researchers' time Pros: Cheap, less time required and better expression of genetic potentials Cons: May not be representative of on-farm conditions	Method: Meeting and discussions with local agricultural development department staff and other key informants, previous PRA results. Cost: Organization & implementation of meetings, researcher's time, travel expenses, DAs and farmers' time. Pros: Better participation of stakeholders, better representation of agro-ecologies & socio-economic factors; better chance for extrapolation of results Cons: Costly, takes more time. Costs may limit number of sites used and hence extrapolation of research results
Germplasm collection and seed preparation	Method: Selection from introductions, collections and crossing blocks; multiplication of seeds, packing and dispatching to different sites across the nation. Cost: Researchers' time, mailing and quarantine costs, seed production, packing and dispatch Pros: Wide genetic variability Cons: Costly, time consuming	Method: Same as for conventional breeding except that farmers are not involved in crossing activity, choice of parents and acquisition of materials if from outside the experimental site Cost: Same as for conventional breeding Pros: Wider genetic variability, seeds of better quality Cons: Limits farmers' skills of seed maintenance & preparation
Selection of participating farmers	Method: None Cost: None Pros: Better identification of varieties of farmers' preference Cons: Costly, time consuming	Method: Contacts were made with local DAs; recommendations of the community & village of trials; on volunteers Cost: Researchers' and technicians' time, travel expenses, agents' time Pros: Inclusion of farmers' resources or characteristics and women farmers Cons: Since selection is based on recommendations and volunteers, marginalized farmers might be neglected, thereby reducing effectiveness of results & rate of adoption
On-station visit and exposure to large number of germplasm	Method: None Cost: None Pros: Cons:	Method: Selected participating farmers and DAs were invited to the research centre and were oriented to the diversity of bean germplasm. They undertook evaluations at three growth stages. Final selections were made at pod harvesting. Cost: Farmers *per diem*, travel allowance, lunch, researchers' time, Pros: Creation of awareness of farmers about the availability of diverse bean germplasm; reduction in number of entries to be handled by program to a manageable size Cons: Costly, farmers may have difficulties in differentiating among a large number of bean germplasm accessions.
Field management or operations	Method: Mechanized land preparation, hand weeding and cultivation, manual harvesting and threshing, packing and storage Cost: Labor and operations from land preparation to harvesting Pros: Better field establishment, germination and growth; facilitated pre & post-harvest data collection Cons: High labor & material requirement	Method: Manual land preparation, weeding, cultivation, harvesting and threshing Cost: Family or hired labor from land preparation (traditional) to harvesting Pros: Same as for conventional breeding; can be slow and area sown depends on labor availability Cons: Adds cost to farm operations
Evaluation of genotypes	Method: Collection of quantitative and qualitative data at vegetative and reproductive stages and post-harvest Cost: Researchers' and technicians' time Pros: Identification of varieties with desirable characteristics set by researchers Cons: Tedious	Method: Visual observation of genotypes at seedling, flowering & maturity stages and after cooking Cost: Participating and non-participating farmers' time, travel expenses Pros: Identification of varieties with desirable characteristics set by farmers Cons: Tedious, requires additional skills

Activity	Conventional breeding	PPB
Training	Method: In service training on trial management & data collection and analysis for junior researchers, technicians & other technical staff Cost: Trainees travel expenses and allowances, trainers' time and allowances, stationeries & other consumable items Pros: Skill up grading Cons: Costly	Method: Invited farmers & DAs to the centre for oral presentations and field practices on improved crop & data management Cost: Farmers & DAS allowances, training & travel expenses, researchers' time, stationeries Pros: Awareness creation, improving farmers' indigenous technical knowledge on improved crop (bean) production techniques and data management Cons: Costly, time consuming
Workshop	Method: Research review meetings at different levels; society meetings to present new results Cost: Researchers' time, travel expenses, stationeries Pros: Presentation of finished, ongoing and new activities Cons: Costly, time consuming	Method: Meetings to discuss progress and plan held at Awassa & Melkassa; exchange of experiences among scientists held at Ivory Cost (March 2000). Final workshop on process impact held at Alemaya Cost: Travel expenses and allowances for national and international scientists, experts, stationeries, and accommodation Pros: Present results to farmers, share experiences among researchers, present results to donors, policy makers, better researcher-farmer interaction Cons: Costly, time consuming.
Data collection, entry and analysis	Method: Take measurements for quantitative traits and subjective judgment for qualitative ones; -Subject to appropriate statistical analysis and obtain the required outputs. Cost: Researchers' & technicians' time, travel expenses & allowances to visit several locations, stationery including computer consumables. Pros: Make valid comparisons among genotypes, and draw precise conclusions. Cons: Tedious, costly	Method: Farmers-researcher joint data collection traits of farmer's interest; subject data to appropriate statistical package and obtain the required output. Cost: Farmers', researchers' and technicians' time; travel expenses & allowances for researchers; stationeries, computer consumables Pros: Farmers gain knowledge that helps them in making better decisions, and in making valid comparisons and conclusions on genotypes Cons: Tedious, costly, data analysis complex, statistical packages not available to analyze the data

Table 15. Cost comparisons (US $) of conventional and participatory breeding programs at Melkassa and Awassa.

	Melkassa		Awassa	
Year	CB*	PPB*	CB	PPB
1	18.6	0	971.3	4939.0
2	78.3	18.6	6192.0	3688.0
3	2626.6	1030.2	10320.0	4546.7
4	3830.5	1030.2	10320.0	1040.0
5	5214.4	1030.2	-	-
Total (US$)	11,768.40	3,109.2	27, 803.25	14, 213.75

*CB= Conventional breeding; PPB=Participatory bean breeding.

Relative Gains of the PPB Approach

The project activities had considerable process impacts at all sites. Involving farmers in the selection process had several impacts, not only on farmer perceptions and skill building but also on the formal breeding procedures. Experiences and data collected at the project sites indicated that each breeding approach had its own advantages and disadvantages. The following were the main advantages associated with participatory breeding:

Increased genetic diversity: Farmers and communities were exposed to a wider range of bean genetic diversity at all sites. In general, farmers tended to select and retain a larger number of lines than the conventional program. At Alemaya, the breeders selected 32 lines in each season, without distinction of potential user groups, against the range of 12 to 52 selected by the different user groups. When these data were disaggregated by bean growth habit, it became clear that FS selected more lines than the breeders only in the case of the bushy types, and appeared less interested than the breeders in climbing beans. In Awassa, the number of lines farmers retained for planting increased from 1 to 6. Number of small- and medium-sized bean lines retained by farmers increased from 1 to 2 and that of large-seeded bean increased from 0 to 4. Farmers in Ethiopia have limited exposure to diversity of bean germplasm compared to other countries in the region. Other effects were improved access to bean germplasm in participating communities, and more intra- and inter-varietal diversity. Farmers selected and maintained a larger number of lines to meet a wide range of uses and adaptation to several production microenvironments.

***Production increases in difficult environments*:** Selection at multiple sites leads to identification of lines better adapted to local constraints. PPB provided for localized selection. On-station selection focuses on wider adaptation partly due to the larger mandate of the breeding programs. Such lines are not necessarily adapted to local environments. This partly explains the observation that both breeders and FS selected few lines in common.

Farmers' selection criteria and preferences adopted, and positive interactions increased: The farmer selection criteria are now better understood and are being utilized in research. These were elicited by involving farmers in participatory selection program. For example, seed color, seed shape, seed size, vegetative yield and pod clearance were included as additional criteria in breeding program in Ethiopia. In Awassa, the program objectives were revised to include redder kidney and red-mottled lines in breeding program to meet the farmers' demands.

Crosses with red kidney and red-mottled parental lines started. The programs at Melkassa, Alemaya, and Awassa are now targeting more micro niches. Interactions between researchers and farmers have increased. Researchers now visit farmers' fields three times in every cropping season. Farmers are also showing increased interest in PPB. In Awassa, 30 farmers requested support to start their own PPB trials. In Alemaya, farmers requested researchers to initiate programs for sorghum and other important crops.

Improved farmer acceptance of new varieties: Perhaps one of the most severe limitations of conventional breeding is low acceptance and adoption of released varieties. This has been attributed to the fact that farmers and other end- users are not involved early enough in the selection process. Consequently, their preferences are not known until too late. In this program, farmers rated highly some of the lines selected in the program and expressed interest to adopt them. In Alemaya, threePPB lines were rated excellent for color and seed size by RPF compared to the local variety. Farmers regard PPB lines as their own and expressed interest in their multiplication and dissemination. In Awassa and Melkassa, farmers expressed interest to increase seed of the selected lines in bigger plots. However, regulations will have to be changed to facilitate informal seed increases and dissemination. This study also showed that male and female farmers might have different preferences. In Awassa region, women showed greater interest in large-seeded bean lines which are preferred for home consumption, while men preferred small- to medium-seeded because of their higher demand in local markets.

Farmer production and income: Participating farmers recorded production increases at the three sites in Ethiopia. In Awassa, grain yields of participating farmers, on an average, increased by 38%. A participating farmer sold grain of a PPB line at a price higher by 20 Birr (about $2.5) compared to the local variety. PPB lines were more acceptable to other farmers and consumers partly because of their higher yield potential and seed characteristics. Wider dissemination and adoption of these lines will contribute to increasing food availability and incomes. Participating farmers showed willingness to increase their investment (time and land) to the research process. However, one farmer in Alemaya demanded payment for his land.

Capacity building: Farmer variety selection and trial management skills were enhanced through practical training during on-station and on-farm visits. Communities got wider access to information, selection skills and better agronomic practices during the PRAs and meetings, and during visits to the stations. In Alemaya, RPF and WF farmers learnt and applied matrix ranking of varieties for different criteria. In Awassa, Nazareth and Alemaya, farmers also learnt how to evaluate a new variety and compare it with the local on a research plot. Farmers could differentiate several red- seeded beans for different quality traits. Farmers raised many issues on disease pathogens, fertility and cropping systems. In Awassa, a farmer designed his own trial to study the effect of different fertilizer rates on a bean variety. Farmers also disseminated seed of the PPB lines. About 30 farmers requested to be assisted in conducting PPB trials.

Empowerment: Internal capacities of communities to work together were strengthened. Farmers were able to listen to each other and argue positively during group-work. Relations and attitudes between communities and formal research improved because of regular contacts, sharing of experiences and materials. In Melkassa, farmers agreed to try up to 30 lines in future PPB trials. In Alemaya, farmers decided the number of lines they could accommodate in future PPB trials for effective selection: 6-8 lines for WFs and 10-15 lines for RPFs. All PPB lines were selected based on farmers' own decisions. They also named the lines. In Awassa, selected were lines were given names such as *'Ibada Ado'* (i.e. 'fresh milk'), *'Bussuke'* (i.e. a well-fed calf), 'meat without blood' – a name given to large-seeded types, which tasted like meat when eaten with a local dish *'wassa'*. Other farmers reported some of the lines tasted like fish when cooked. Others had low flatulence compared to local varieties. Fast cooking varieties were described as 'food for the hungry' (children).

Shorter time to release varieties: It takes about 10 years to develop and release cultivars at the three project sites. Results of this study showed that the period could be reduced considerably to about six years. This implied that farmers could access high yielding, disease-and pest-tolerant new materials with desirable seed and plant characteristics faster than with conventional approaches. This has major implications in improving food availability and food security particularly for marginalized people with few other options.

Cost comparisons: Results showed that at two sites PPB was less costly compared to the CB. Qualitative costs varied with activity. These costs were considered as indicative rather than absolute because actual costs are likely to vary with program objectives, activities, relative efficiencies and several site-specific factors, both predictable and un-predictable. Programs should be purpose-oriented and incorporate desirable features from conventional and participatory approaches.

Drawbacks of the PPB Approach

Drawbacks associated with participatory program included farmers difficulties in competition with other activities for farmers' time and resources, farmer's expectations for payment, lack of official recognition for farmer's varieties and supportive policy environment for PPB.

CONCLUSIONS

Results of the study demonstrated that farmers were capable of making significant contributions to identification of superior cultivars within a relatively short period. They effectively evaluated and selected from large numbers of advanced lines by applying up to 40 distinct selection criteria indicating the complexity of the user needs and production conditions. The farmer selection criteria are now better understood and are being utilized in research. For example, seed color, seed shape, seed size, vegetative yield and pod clearance were included as additional criteria in breeding program. In Awassa, the program objectives were revised to include more red-kidney types.

Farmers rated highly some of the lines selected in the program and expressed interest to adopt them. For example, farmers in Awassa regard PPB lines as their own and have expressed interest in multiplying and disseminating seed of XAN314 and DICTA 105, and five farmers expressed interest to increase seed of the selected lines in bigger plots. However, lack of an effective seed delivery system and supporting policy is likely to constrain release and rapid dissemination of PPB varieties. However, efforts are underway to seek solution to this problem.

Participating farmers recorded production increases at the three sites in Ethiopia. A participating farmer sold grain of a PPB line at a price higher by 20 Birr (about $2.5) compared to the local variety. PPB lines were more acceptable to other farmers and consumers partly because of their higher yield potential and seed characteristics. Farmers in Ethiopia had limited exposure to diversity of bean germplasm compared to other countries in the region. Farmer-held bean diversity increased at all project sites.

The study conducted at the three locations implied that there was a need to combine the two approaches for efficient use of resources, effectiveness and to addressing farmers' diverse needs. Thus, a new formal and participatory breeding scheme is proposed that incorporates farmer participation (Fig 1) in the existing breeding scheme.

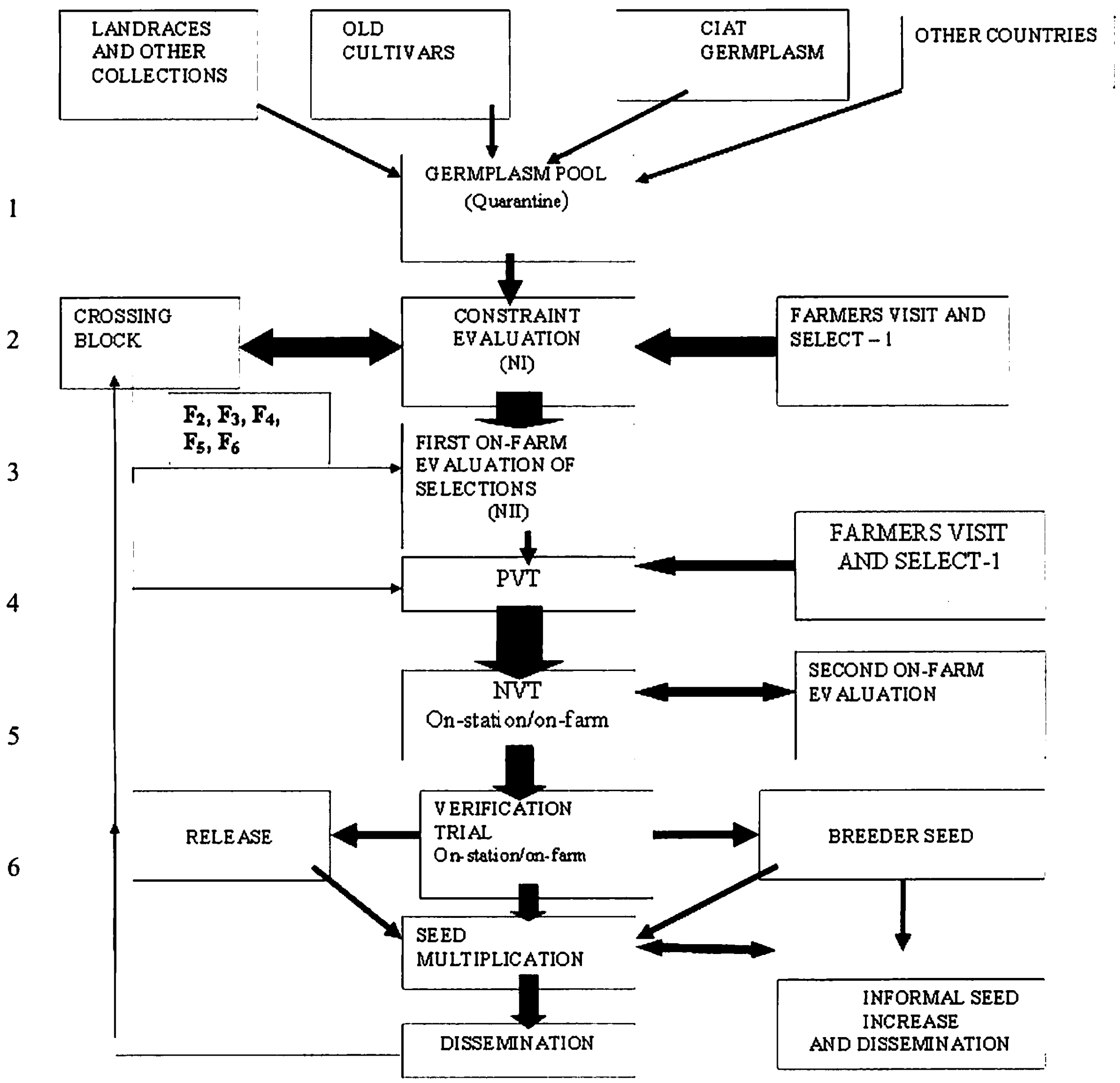


Fig 1. A generalized scheme linking formal and participatory haricot bean breeding.

REFERENCES

Ceccarelli, S., S. Grando, and R.H. Booth. 1996. International breeding programs and resource-poor farmers: Crop improvement in difficult environment. p. 99-116. *In* P. Eyzaguirre and M. Iwanaga, M. (Eds.) *Participatory Plant Breeding.* Proc. Workshop on Participatory Plant Breeding, 26-29 July 1995, Wageningen, The Netherlands.

Eyzaguirre, P., and M. Iwanaga. 1996. Farmers' contribution to maintaining genetic diversity in crops, and its role within the total genetic resources system. p. 9-18. *In* P. Eyzaguirre and M. Iwaanaga (Eds.) *Participatory Plant Breeding.* Proc. Workshop on Participatory Plant Breeding, 26-29 July 1995, Wageningen, The Netherlands.

Fowler, C. 1994. Unnatural selection: Technology, politics and plant evolution. International Studies in Global Change, 6. Switzerland: Gordon and Breach.

IPGRI. 1996. Strengthening the scientific basis of *in situ* conservation of agricultural biodiversity. A global collaborative project prepared by the International Plant Genetic Resources Institute, June, 1996. Rome: International Plant Genetic Resources Institute.

Kimmelmann, B.A. 1987. A progressive Era Discipline: Genetics at American agricultural colleges and experimental stations, 1900-1920. Ph. D. Dissertation, Univ. of Pennsylvania.

Kornegay, J., J. A. Beltran, and J. Ashby. 1996. Farmer selections within segregating populations of common bean in Colombia. p. 151-159. *In* P. Eyzaguirre and M. Iwanaga (Eds.) *Participatory Plant Breeding.* Proc. Workshop on Participatory Plant Breeding, 26-29th July 1995, Wageningen, The Netherlands.

Martin, J.H. 1936. Sorghum Improvement. p. 523-559. *In Year Book on Agriculture.* Washington: US Government Printing Office.

Richards, P. 1985. Indigenous Agricultural Revolution: Ecology and Food Production in West Africa. London: Allen and Unwin.

Sperling, L., and M. Loevinsohn (Eds.). 1996. Using diversity: Enhancing and maintaining genetic resources on-farm. Proc. Workshop held on 19-21 June 1995, New Delhi, India. IDRC: New Delhi.

Sthapit, B. R., K.D. Joshi, and J.R. Witcombe. 1996. Farmer participatory crop improvement. Participatory crop improvement, a case study of high altitude rice from Nepal. *Experimental Agriculture* 32: 479-496.

SWP/PRGA (System Wide Programme on Participatory Research and Gender Analysis). 1997. A Global programme on participatory research and gender analysis for technology development and organizational innovation. ODI Agricultural Research and Extension Network Paper No. 72. London: Overseas Development Institute.

Trutmann, P., and M.M Pyndji. 1994. Partial replacement of local common bean mixtures by high yielding angular leaf spot resistant varieties to conserve local genetic diversity while increasing yield, *Ann. Appl. Biol.* 125: 45-52.

Voss, Joachim. 1996. Participatory breeding and IDRC's biodiversity program. p. 3-8. *In* Pablo Eyzaguirre and M. Iwanaga (Eds.) *Particpatory Plant Breeding.* International Plant Genetic Resources Institute, Rome.

Faba Bean (Vicia faba L.) Genetics and Breeding Research in Ethiopia: A Review

Gemechu Keneni, Mussa Jarso and Tezera Wolabu

Holetta Agricultural Research Center, P.O. Box 2003, Addis Ababa, Ethiopia

ABSTRACT

Faba bean (*Vicia faba* L.) is the most important pulse crop in Ethiopia in terms of area coverage and total annual production. The crop is of manifold merits in the economic lives of the farming communities in the highlands of the country. It is a source of food, feed and cash to the farmers. It also plays a significant role in soil fertility restoration as a rotation crop. The productivity of the crop is far below the potential due to several yield-limiting factors. The commencement of faba bean breeding to ameliorate the main production problems contributed to low productivity in Ethiopia dates back to the early 1960's, as a result of which a number of improved varieties have been released to farmers. Research and development efforts prior to the early 1990's in Ethiopia were reviewed during the first national workshop in 1993. Breeding efforts since then have gone some steps forward and the outputs of these efforts and their implications for future research have not been properly reviewed and documented. The paper is based both on analyses of primary records from screening nurseries and variety trials, and secondary sources from literature. The paper, therefore, reviews breeding efforts made since 1993 to alleviate problems associated with faba bean production in Ethiopia, and to summarize the outputs of these efforts in terms of both scientific information and physical outputs. Finally, based on the foregoing discussions, opportunities, challenges and implications for future directions of faba bean breeding in Ethiopia have been discussed.

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the major pulse crops grown in the highlands (1800-3000 m asl) of Ethiopia, where the need for chilling temperature is satisfied. It is believed that the crop was probably brought to Ethiopia from Middle East through Egypt (Yohannes, 2000) around the 5th millennium B.C., immediately after domestication (Asfaw et al., 1994). Ethiopia is now considered as one of the centers of secondary diversity for faba bean (Asfaw et al., 1994; Yohannes, 2000). The crop takes the largest share of the area and production of the pulses grown in Ethiopia. It occupies close to 370,000 hectares of land with an annual production close to 450,000 tons (Ethiopian Agricultural Sample Enumeration, 2002). The crop is grown in several regions of the country with annual rainfall of 700-1000 mm.

Faba bean is a crop of manifold merits in the economic lives of the farming communities in the highlands of Ethiopia. It serves as a source of food and feed with a valuable and cheap source of protein. It plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen. It is also a good source of cash to the farmers, and generates foreign currency to the country. Despite the importance, however, the productivity of the crop is far below the potential. Production has been constrained by several yield limiting factors. The inherent low-yielding potential of the indigenous cultivars is among the most important production constraints (Asfaw et al., 1994; Yohannes, 2000). Moreover, diseases like chocolate spot (*Botrytiss fabae*), rust (*Uromyces viciae-fabae*) and root rot (*Fusarium solani*) and abiotic stresses like water-logging are important production constraints that deserve priority as breeding objectives (Asfaw et al., 1994; Dereje and Tesfaye, 1994).

It is obvious that the genetic modification of crops to the interest of the community is preferred to the continual manipulation of the growing environment because of environmental concerns and cost, particularly to the resource-poor farmers who cannot afford the purchase of production inputs. The commencement of a comprehensive breeding program in Ethiopia dates back to the early 1960's. The main objective was to improve the productivity of the crop through the development of varieties tolerant/resistant to different constraints and suitable for cultivation under different agro-ecologies of the country. As a result, a number of improved varieties were developed and released to farmers before 1993 as summarized and documented by Asfaw et al. (1994). Similar efforts continued after, but results have not been systematically summarized and documented despite the absolute importance of such information for further improvement of the crop. The theme of this paper is, therefore, to review breeding efforts made since 1993 to ameliorate problems associated with faba bean production in Ethiopia and summarize the outputs of these efforts in terms of both physical outputs (varieties) and scientific information that are of use for further crop improvement. Finally, based on the foregoing discussions, opportunities, challenges and implications for future directions of faba bean breeding in Ethiopia have been discussed.

GERMPLASM DEVELOPMENT

Sources of Germplasm

Sources of genetic variation for genetic improvement of faba bean in Ethiopia include germplasm collections from important production areas of the country through the Biodiversity Conservation and Research Institute (IBCR) and target collections by breeders, introduction and acquisition from foreign sources like the International Center for

Agricultural Research in the Dry Areas (ICARDA), and crossing of selected parents from both sources. On an average, more than 2500 germplasm accessions/lines and breeding materials were evaluated every year between 1994 and 2002. Of these, more that 60% have usually been from hybridization, more than 20% from collections, and more than 15% from introductions (Figure 1). Among the introductions, some were received at their earlier filial generations to select better-performing segregants under the Ethiopian conditions.

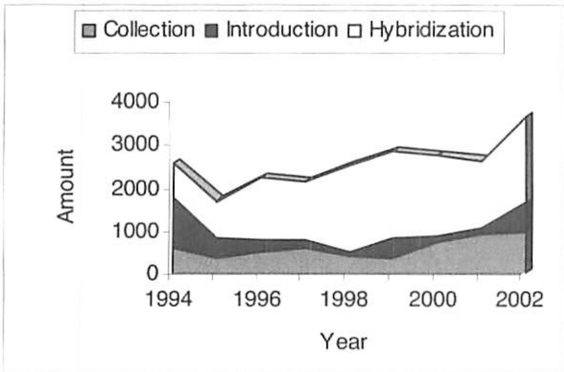


Figure 1. Comparative contributions of collection, introduction and hybridization as sources of germplasm to faba bean breeding program in Ethiopia (1994-2002).

Currently, the hybridization programs focus mostly on the large-seeded, chocolate spot (*Botrytis fabae*) resistance, and high-yielding types. Rather than starting breeding work afresh which takes a longer period, conversion of the otherwise well-adapted varieties into their large-seeded, chocolate spot-resistant and high-yielding counterparts is followed as a first priority to achieve the desired goal within a short period of time. In addition to the bi-parental crosses, population improvement with recurrent selection method using honeybee as a crossing agent is also underway. Sources of genes for large-seeded and chocolate spot-resistant types have been identified from introductions of ICARDA (Dereje and Tesfaye, 1994). The recovery percent from hybridization (i.e. number of effective pods harvested divided by total number of flowers crossed and then multiplied by 100) in Ethiopia between 1997 and 2002 ranged from 13 to 33%, which is significantly low as compared to both 50% success under field and 50-70% under greenhouse conditions at ICARDA (ICARDA, 2000). The lower recovery percent could be attributed to the shading effect of the mesh cages, which might reduce the light intensity and might enhance vegetative growth at the expense of reproductive growth, and flower and pod shedding. The investigation of optimum environment for crossing, and proper times of emasculation and pollination specific to Ethiopian conditions may be needed for better recovery.

Segregants from hybridization and germplasm from collection and introduction are grown inside insect-proof cages to keep pollinating-insects out. Artificial inoculations with the virulent isolates of chocolate spot pathogen (*Botrytis fabae*) and a sick-plot of black root rot (*Fusarium solani*) have been employed for screening in addition to the natural conditions.

Genetic Diversity in Ethiopian Landraces

Westphal (1974) reported that Ethiopian germplasm are uniform in that the small-seeded (var. *minor*) types dominate. Others consider the country to be a secondary centre of diversity (Bond, 1976; Singh, 1990) with both the small-seeded (var. *minor*) and the medium-seeded (var. *equina*) types (Amare, 1990; Asfaw et al., 1994). Some believe that the medium- and small-seeded types dominate in the northern and the southern parts of the country, respectively (Asfaw et al., 1994), while others consider the opposite to be true (Amare, 1990). The reports, however, do not emanate from scientific evidence based on a systematic study apart from some informal visual observations.

A study (Gemechu et al., 2003) on the extent and pattern of genetic diversity among the 160 faba bean accessions collected from north and south Wello, north Gonder, north Shoa and Arsi zones showed the existence of high genetic diversity that was not uniformly distributed across the regions. Accessions from the northern half of the country (north and south Wello, north Gonder and north Shoa) seem to be closely related regardless of their geographic origin and the rugged nature of the terrain which could have favored isolation among the accessions and, hence, distinct lines of evolution in each region. Accessions from this part of the country fell into clusters C_1 and C_2, which were non-significantly distant from each other (Table 1).

Most of the materials from the northern part of the country might have originally been introduced from the same source, followed by frequent exchange of seeds among farmers in these proximal regions of the country. There could also be a tendency, particularly among resource-poor farmers in marginal areas, of selecting for the same traits of interest like yield stability, resistance to diseases, insects and abiotic calamities and low dependence on the external inputs (de Boef et al., 1996). Although the original sources might vary, the crop might have also been forced to evolve in the same direction by this kind of local breeding for the same targets, which may emanate from similar economic, social, cultural and ecological reasons in the area.

Accessions from the southern part of the country (Arsi) were more diverse even though it is not possible to ascribe precise reasons. These might have originally been introduced from different sources. Also, there are indications that the *equina* and the *major* botanical varieties of faba bean were introduced to Ethiopia in the 19^{th} century after the first introduction of the small-seeded (var. *minor*) types immediately after the domestication of the crop (Westphal, 1974; Asfaw et al., 1994). However, the route of introduction was not clearly stated. The considerable genetic diversity in the southern part of the country might be explained in terms of the introgression into the *minor* types by the lately introduced *equina* and the *major* types. The crop also might have been forced to evolve in different direction through local breeding for different targets in the same region. Farmers could play an important role in the dynamics of genetic diversity by providing opportunities for hybridization by bringing together geographically and ecologically isolated landraces, and then by making selections for desirable agronomic traits (Teshome et al., 1997).

The accessions from Arsi were superior for most of the traits including lower chocolate spot infection level, larger seed size and higher grain yield (data not shown). Hence, the report that faba bean accessions from Wello and Shoa which were rather more diverse than those from other regions of the country including Arsi (Dawit et al., 1994), should carefully be re-examined. The small proportions of accessions from Arsi in the population they studied could be the main reason for the discrepancy rather than inadequacy of genetic diversity among collections from Arsi. Therefore, future collection missions and conservation strategies should prioritize Arsi to safeguard the tremendous genetic diversity from genetic erosion and ensure the sustainable perpetuation of these valuable resources. Breeding programs should also focus on effective and efficient exploitation of not only inter-regional diversity in the country as a whole but also intra-regional diversity in Arsi. It should be noted that an old but a long-lasting popular faba bean variety, CS 20 DK, was originally selected from collections of Arsi.

Genetic Variation in Faba Bean Germplasm

Most of the studies in areas with no water-logging problems in Ethiopia revealed the existence of a wealth of genetic variability among the population for most of the morpho-agronomic traits. Frequency distributions of 160 populations tested at Holetta and Kulumsa during the year 2001 clearly showed the existence of high levels of variation in terms of range among the population for most of the morpho-agronomic traits including the economic ones like grain yield and seed size (Figure 2). Previous reports from Ethiopia (Asfaw et al., 1994; Dawit et al., 1994; Getahun, 1998) also indicated the existence of considerable variation for morpho-agronomic traits in faba bean landraces.

Nevertheless, a study conducted simultaneously under waterlogged Vertisols on broad bed and furrow (BBF) and flatbeds showed lower broad-sense heritabilities and predicted genetic gains from selection particularly for grain yield and number of pods per plant on flatbeds as compared to those on BBF (Gemechu et al., 2001; Keneni and Jarso, 2002). Genotypes normally better express their genetic potential under favorable environments than the stressed ones (Rosielle and Hamblin, 1981; Buddenhagen and Richards, 1988; Singh, 1990). Normally, more favorable environment shows higher heritability estimate than a poor environment because heritability is concealed due to a greater genotype x environment interaction component under poor environments (Briggs and Knowles, 1967). Broad sense heritability for 1000-seed weight on both BBF and flatbeds was high and indicated that this trait was less affected by water-logging and efficiency for selection of this trait would be high. In general, the heritability was moderate for number of pods per plant (Table 2). Singh (1990) reported that efficiency of selection for traits with high (80% or more) heritability was fairly easy as compared to those with low heritability (less than 40%). Under conditions where the intensity of the stress is high, it is generally difficult to discriminate for yield differences among genotypes (Banziger and Edmeades, 1997). Despite the distinct relative differences in genetic variation for grain yield under the two conditions (BBF and flatbeds), the extent of genetic variation was generally very low under both conditions. It is obvious that genetic gain from selection depends on the extent of genetic variation and on the magnitude of the heritable portion of this variation. Therefore, there is no doubt that making genetic progress under both conditions would be very difficult having such low levels of heritabilities. However, one should not anticipate dramatic results from breeding efforts in stressed environments but only small gradual changes should be expected (Buddenhagen and Richards, 1988).

Table 1. Clustering pattern of faba bean accessions from different origins over seven clusters.

Origin	Number of accessions	No. of accessions in each cluster						
		C_1	C_2	C_3	C_4	C_5	C_6	C_7
North Wello	19	16	3	--	--	--	--	--
South Wello	10	9	1	--	--	--	--	--
North Gonder	40	28	12	--	--	--	--	--
North Shoa	41	38	3	--	--	--	--	--
Arsi	50	3	14	9	16	3	3	2

Source: Gemechu et al. (2003).

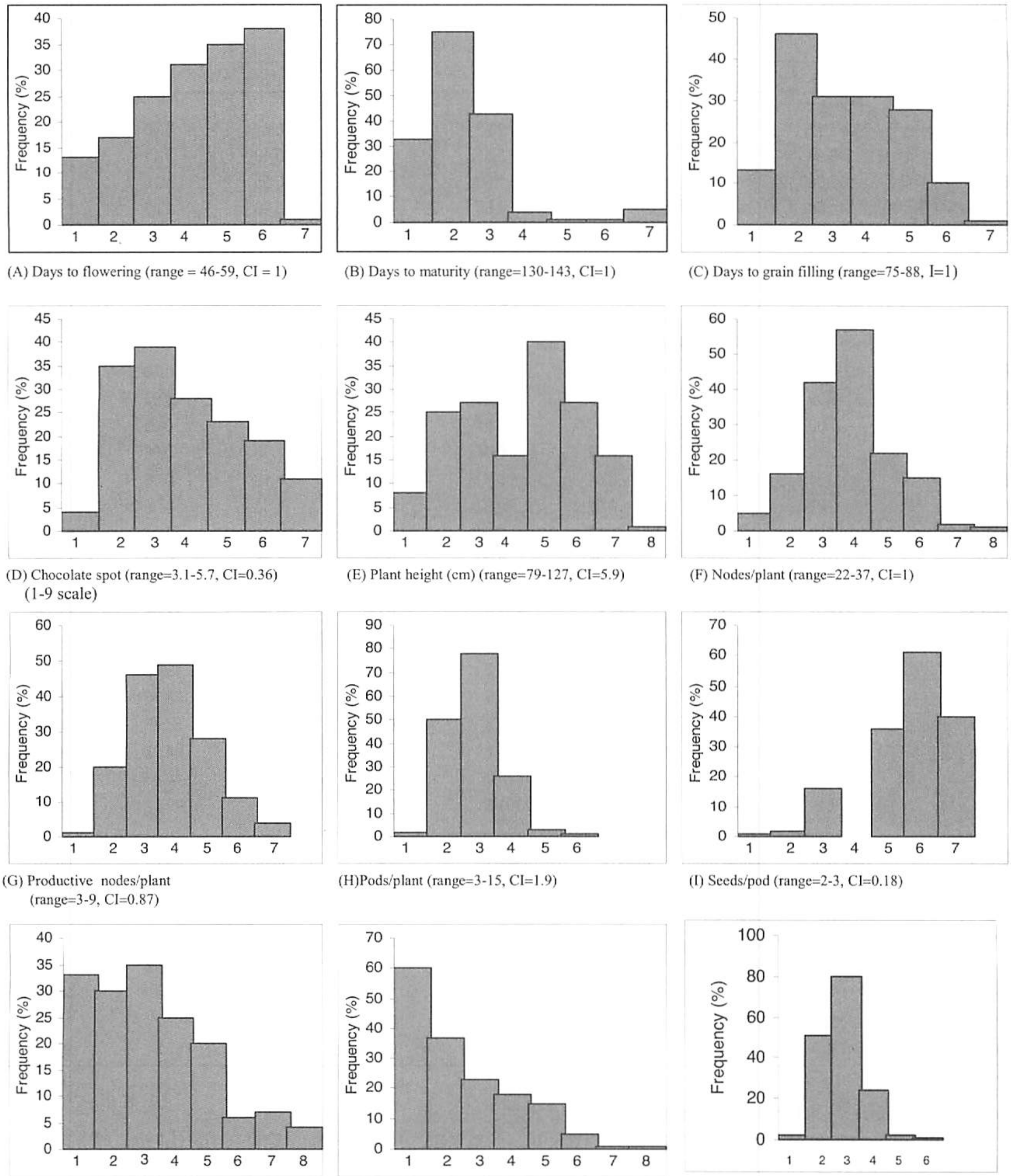


Figure 2. Frequency distributions for 12 characters in 160 Ethiopian faba bean landraces collected from different geographical regions. Sequential numbers represented classes but ranges with class intervals (CI) are given under each graph.

Table 2. Phenotypic (p2) and genotypic (g 2) variances, broad-sense heritability (h2) and predicted genetic gain (DR) from selection for grain yield and its determinants in faba bean variety trials conducted on BBF and flatbeds under waterlogged Vertisols (1996-1999).

	σ_p^2		σ_g^2		h^2		DR	
Experiment	BBF	Flat	BBF	Flat	BBF	Flat	BBF	Flat
	Number of pods per plant							
EXP 1	6.13	5.19	3.91	2.63	0.64	0.51	1.58	1.16
EXP 2	8.54	4.48	3.24	0.81	0.38	0.18	1.11	0.38
EXP 3	3.98	2.35	2.31	1.30	0.58	0.55	1.16	0.85
EXP 4	11.56	6.43	4.86	1.66	0.42	0.26	1.43	0.66
EXP 5	2.94	1.55	1.28	0.74	0.44	0.48	0.75	0.60
EXP 6	11.14	7.35	1.60	1.77	0.14	0.24	0.47	0.65
EXP 7	4.92	9.11	2.81	1.73	0.57	0.19	1.27	0.57
Mean	7.03	5.21	2.86	1.52	0.45	0.34	1.11	0.70
	Number of seeds per pod							
EXP 1	0.09	0.08	0.03	0.01	0.33	0.13	0.10	0.04
EXP 2	0.09	0.11	0.01	0.06	0.11	0.55	0.03	0.18
EXP 3	0.02	0.03	0.004	0.01	0.20	0.33	0.03	0.06
EXP 4	0.10	0.11	0.02	0.04	0.20	0.36	0.06	0.12
EXP 5	0.04	0.03	0.01	0.003	0.25	0.10	0.05	0.02
EXP 6	0.07	0.05	0.02	0.02	0.29	0.40	0.08	0.09
EXP 7	0.06	0.05	0.01	0.005	0.17	0.10	0.04	0.02
Mean	0.07	0.07	0.01	0.02	0.22	0.28	0.06	0.08
	1000-seed weight (g)							
EXP 1	637.9	764.0	216.5	164.5	0.66	0.22	11.95	6.02
EXP 2	2816.7	1955.2	2646.1	1745.0	0.94	0.89	49.87	39.41
EXP 3	2920.1	842.9	2643.5	750.2	0.91	0.89	49.05	25.84
EXP 4	8891.0	5262.4	8370.2	5015.5	0.94	0.95	88.70	69.03
EXP 5	4268.4	4070.0	3835.5	3725.3	0.90	0.92	58.75	58.54
EXP 6	3499.0	1721.0	2655.6	1535.2	0.76	0.89	44.93	36.96
EXP 7	2930.3	2244.7	2431.9	1775.0	0.83	0.79	44.93	37.45
Mean	3709.1	2408.6	3257.0	2101.5	0.85	0.79	49.74	39.04
	Grain yield (kg ha^{-1})							
EXP 1	108770.0	108584.2	22841.7	13439.1	0.21	0.12	69.26	40.16
EXP 2	168630.8	688955.1	50411.9	269078.7	0.30	0.39	122.98	323.95
EXP 3	66475.5	150712.8	19778.5	47952.8	0.30	0.32	77.03	123.88
EXP 4	98708.0	241512.2	17684.8	30408.2	0.18	0.13	56.42	62.87
EXP 5	230650.2	89886.8	39705.8	9617.3	0.17	0.11	82.16	32.53
EXP 6	873158.5	255097.1	252285.5	45631.4	0.29	0.18	270.49	90.63
EXP 7	608066.7	156753.3	386328.0	7801.2	0.64	0.05	497.24	19.75
Mean	307780.0	241643.0	112719.0	60561.0	0.30	0.19	167.94	99.11

Source : Keneni and Jarso (2002).

Secondary Traits as Selection Criteria

Grain yield, in general, is a complicated system that can be influenced by several components both in positive and negative directions. Grain yield has low heritability because of polygenic behavior and strong influences of environmental effects (Lawes et al., 1983). As a result, direct selection for yield *per se* is not very effective. Identification of secondary traits, which are positively associated with grain yield and possess high genetic variability and high heritability, helps in formulating efficient multiple trait selection index, as it provides means of direct and indirect effects of component characters (Lawes et al., 1983; Edmeades et al., 1997,1998).

It is logically expected that grain yield in faba bean is a function of number of nodes bearing pods, number of pods at each node, number of seeds per pod and seed weight, and improvements in any one of these traits may result in indirect improvement of grain yield (Lawes et al., 1983; Hardwick, 1988; Slinkard and Sindhu, 1988). However, indirect selection through any one or more of these yield components often reduced grain yield due to component compensation (Slinkard and Sindhu, 1988) despite the logical expectations.

In Ethiopia, a study at Bekoji sub-station showed that increased number of flowers and pods per plant were more important than seed size (Getahun, 1998) in faba bean. The same author reported that days to maturity was also positively associated with grain yield. Early genotypes that are able to complete their life cycle within a short duration could escape the effect of terminal moisture stress and may perform better than late genotypes in areas with short growing duration. Results of another study (Berhe et al., 1998) on 20 varieties at Denbi, Holetta and Bekoji showed that 8-9 different secondary traits out of the 14 studied had significant positive correlation with grain yield at different locations. However, they indicated that the traits were not independent and, as a result, only number of seeds per plant, and 100-seed weight were the major direct contributors to seed yield across the locations, while a number of other traits including number of pods per plant were indirectly important. Generally, the effects of yield components on seed yield do not appear to follow a simple trend, which may be due to the variation in nature of the testing environment and the genotypes.

A study on waterlogged Vertisols under BBF and flatbeds in Ethiopia showed the existence of significant positive associations between grain yield and number of pods per plant, and significant negative associations between grain yield and 1000-seed weight (Keneni and Jarso, 2002). This indicates that selection for more pods per plant will highly improve productivity. Selection for 1000-seed weight, on the other hand, could result in a negative response of grain yield. Therefore, for simultaneously improving 1000-seed weight and grain yield on BBF and flatbeds through selection, a compromise between selections for both traits must be made, or the breeder must set minimum standards for one trait while selecting for the other. The alternative option of following separate breeding programs for seed size and grain yield may be more effective from the breeding perspectives. Number of seeds per pod was weakly associated with grain yield in most of the cases, indicating that there is an independent genetic control between the two traits and that improvement in any one of the two would have little effect on the other (Table 3).

It is not sufficient for a breeder to identify secondary traits associated with primary traits but the breeding progress from simultaneous selection for the primary and secondary traits must be proven to be superior over the selection for the primary trait alone (Banziger et al., 1998). Both direct selections for yield *per se* and indirect ones through yield components have commonly been exercised in faba bean improvement in Ethiopia. The additional genetic gains due to simultaneous selection for grain yield and yield components over selection for grain yield alone need to be quantified.

The relative advantage of direct selection for grain yield as compared to simultaneous selection for grain yield and its important determinants (number of pods per plant, number of seeds per pod and 1000-seed weight) was studied under waterlogged Vertisols. The results showed that even though both direct selection for grain yield *per se* and simultaneous selection with number of pods per plant could improve grain yield, simultaneous selection with number of pods per plant seems to be more efficient than direct selection particularly as the level of stress increases (Figure 3). This is clearly revealed from the increasing values of the ratio of genetic gains from indirect selection to direct selection (IR/DR) as the level of stress increases. A value of 1.0 indicates that direct selection was predicted to be equally efficient as indirect selection. A value of less than 1.0 indicates that direct selection was more efficient. A value of greater than 1.0 indicates that indirect selection was more efficient (Banziger and Edmeades, 1997; Banziger et al., 1997).

Table 3. Correlation coefficients (r) of grain yield with yield determinants in faba bean variety trials conducted on BBF and flatbeds under waterlogged Vertisols (1996-1999).

	No. of pods/plant		No. of seeds/pod		1000-seed weight (g)	
Experiment	BBF	Flat	BBF	Flat	BBF	Flat
EXP 1	0.48*	0.62**	-0.29	0.01	-0.10	-0.56**
EXP 2	0.67**	0.41*	0.24	-0.04	-0.44*	-0.42*
EXP 3	0.50*	0.66**	0.13	0.24	-0.57*	-0.42
EXP 4	0.53**	0.77**	0.05	0.25	-0.18	-0.49*
EXP 5	0.80**	0.70**	0.14	0.42	-0.84**	-0.87**
EXP 6	0.55*	0.57*	-0.12	0.54*	-0.51*	-0.51*
Mean	0.59	0.62	0.03	0.24	-0.41	-0.36

* and ** denote significant (P<5%) and highly significant (P<1%) correlation between grain yield and the respective traits (Keneni and Jarso, 2002).

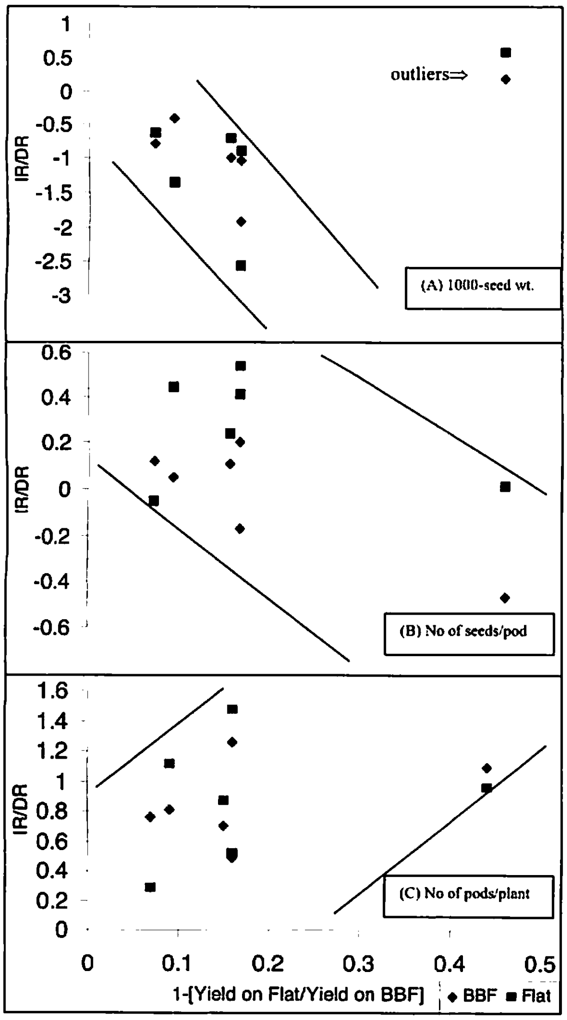


Figure 3. Interrelationships between relative yield reductions in (A) grain yield, 1-[yield on flatbed/yield on BBF] and relative efficiencies of indirect selection as compared to direct selection (IR/DR) in faba bean variety trials on BBF and flatbeds on Vertisols (1996-1999).

Effects of Tripping

The tripping of flowers by hand by releasing the stigma and style from the keel petals and by rupturing the stigmatic surface in the absence of pollinating insects is known to improve fertilization and seed setting since the early days (Hanna and Lawes, 1967). A study on 114 faba bean genotypes in 1994 at Holetta showed that different genotypes responded differently to tripping. Genotypes that need no tripping for fertilization are referred to as autofertile, while those that need tripping are called non-autofertile. Therefore, the existence of genetic variation among the genotypes may indicate the possibilities of developing autofertile cultivars through selection. Tripping improved grain yield by 30% as compared to the un-tripped counterparts, and this might show that pollinating insects have a significant role in faba bean production. A significant portion of this yield increment could be attributed to the relative changes in magnitudes of not only grain yield itself but also those in number of pods per plant (Table 4). On the other hand, it seems that number of seeds per pod is little affected by tripping.

Table 4. Comparisons of mean performances of tripped and un-tripped faba bean genotypes for number of pods/plant, number of seeds/pod and grain yield (g/plot) under honeybee-proof cage at Holetta, (1994).

Character	Tripped	Untripped	Relative reduction*
No. of pods/plant	17.0	13.8	0.19
No. of seeds/pod	2.0	1.9	0.05
Grain yield (g/plot)	105.3	73.8	0.30

* Relative reduction is calculated as 1-(value of untripped/value of tripped treatment). Source: Holetta Highland Pulses Breeding (unpublished data).

VARIETY EVALUATION

Selection Environment

Falconer (1989) was the first to suggest the concept of direct and indirect selection. Direct selection is made directly under the target production environment or under closely similar environmental situation as the target environment. Indirect selection is made under distinctly different environment from the actual target production environment but still to improve productivity under the latter.

Different reasons could be given to the need for indirect selection. Some believe that this approach is preferred by breeders because it is generally perceived that heritability and expected genetic gains from selection, and consequently the level of success is usually higher under favorable than that of the unfavorable conditions (Rosielle and Hamblin, 1981; Singh, 1990; Simmonds, 1991; Banziger and Edmeades, 1997). The practical importance of this concept emanates from an assumption that best genotypes under favorable conditions are also the best under the unfavorable ones (Banziger and Edmeades, 1997). Some also believe that the main reason for the need of indirect selection environment in the tropics is not necessary because it is the best approach but breeding methodologies in the tropics are influenced by experiences from breeding in the temperate areas, despite the fact that yield levels in farmers' fields in temperate areas are similar to experiment station yields (Hawtin et al., 1988; Banziger et al., 1998). Contrarily, crop production in the tropics is frequently stressed and yields in farmers' fields are very different from yields obtained under more favorable conditions at research stations.

It seems from the yield gap of selection and target environments in Ethiopia that there is a high level mismatch between faba bean selection and target production environments although systematic confirmation is needed. The breeding approach is based on the development of varieties on experiment stations under optimal management levels; the promising ones might then be verified finally under farmers' low input conditions.

The ultimate goal of breeders, though working on research stations, is to develop productive cultivars that suit the biotic and abiotic stresses in farmers' target environments. As there might be no mutual compatibility between the initial selection and the actual target production circumstances, it is logical to expect that the process of evaluating a few "finished" varieties eventually under farmers' circumstances can not make up for the useful genetic variation that might have already been lost when large number of genotypes that would have been suited to the target environment were discarded in the early stages (Banziger et al., 1998).

Differences between faba bean varietal selection and target production environments in Ethiopia are presented (Table 5). If G X E interaction between the two environments is large enough to the extent that it results in rank order changes among the performances of the genotypes, it means that the two environments are distinctly different and they do not represent one another. Although a number of varieties have been developed under favorable environments for unfavorable target environments in the tropics, this approach does not have sufficient scientific background particularly for truly marginal target environments, and it should be noted that many such varieties failed to succeed (Ceccarelli, 1989; Ceccarelli and Grando, 1996).

Complication by larger G X E interaction is a major challenge when the difference between the test (selection) and the target production environments is significant and thus the former may not represent the latter (van Oosterom et al., 1993), and hence the best genotype under selection environment may not in most of the cases be the best under the target environment to succeed under truly marginal conditions (Ceccarelli, 1989; Ceccarelli and Grando, 1996; Banziger and Edmeades, 1997; Banziger et al., 1998). According to Banziger et al. (1998), as it is normally not expected to breed pest-resistant genotypes in pest-free environments, drought-resistant genotypes in a drought-free environments, frost-resistant genotypes in frost-free environments and so on, breeders shall not commit the same mistake when they assume that varieties selected under high yield potential on research stations could be appropriate under farmers' fields, where very marginal management and different biotic and abiotic stresses prevail.

Another controversial aspect of selection environments in Ethiopia is that even though a significant portion of the produce comes from faba bean-field pea mixed culture (Hailu et al., 1994; Amare, 1996; Dereje, 1999), there was no planned breeding program existing for mixed cultures so far. It is controversial whether varieties developed under sole cropping system are likely to result in better yields than if selections were done under mixed cultures (Smith, 1986).

Despite the importance, however, systematic efforts made to establish optimum selection environments in Ethiopia are very limited. Of these, one was done on faba bean to determine if selection of genotypes under drained conditions is efficient for identification of genotypes for the undrained target environments on waterlogged Vertisols (Gemechu et al., 2001)

Another similar study was done on barley to determine the effectiveness of selection under high fertilizer input for low input target environments (Woldeyesus et al., 2002). Both studies clearly revealed the relative advantage of direct selection under the target environments compared with the indirect selections done under more favorable environments, although indirect selection as well may be useful to identify better genotypes.

The association of relative yield reduction in faba bean under flatbeds with the ratio of the predicted genetic gains from indirect selection under BBF to the predicted genetic gains from direct selection under flatbeds was positive and high. This indicates that both direct and indirect selections could bring about certain levels of genetic improvements in yield. However, indirect selections were less efficient than the direct ones within the current range of stress intensity, as the ratio of indirect to direct selection was always less than one (Table 6; Figure 4).

Table 5. Comparison of selection and target production environments for faba bean in Ethiopia.

Parameter of Comparison	Selection environment	Target environment
Implement used for land preparation	Tractor mounted (mold-board, disk plow, etc.)	Simple local implements (*maresha*, hoe, etc.)
Plowing frequency	2-3 plowings with local plow or one disc-plowing followed by two disc-harrowing	A single plowing plus another plowing to cover the seed in most of the cases
Fertilizer	Blanket application of 18-48 kg N-P_2O_5 ha^{-1} at most of the locations	No fertilizer in most of the cases
Weeding	Twice hand-weeding or sometimes weed-free particularly in breeding blocks	Not weeded in most of the cases or often weeded late
Cropping system	Sole cropping	Sole or mixed culture of faba bean with field pea
Type of farm	Mostly potential	Mostly marginal

Sources: Personal observations; Amare and Adamu (1994); Hailu et al. (1994); Rezene (1994); Amare (1996); Dereje (1999).

Table 6. Mean grain yields (kg/ha), broad-sense heritabilities and predicted genetic gains from direct (DR) and Indirect (IR) selections in a series of faba bean variety trials conducted under BBF and flatbeds on the highland Vertisols of Ethiopia (1996-1998).

	Grain yield (kg/ha) ± SE			Heritability			DR (kg/ha)				(IR)	
Trial	BBF	Flat	RYR[1]	BBF	Flat	RHR[2]	BBF	Flat	RGGR[3]	r_g	(kg/ha)	IR/DR
EXP1	1379±70	814±57	0.41	0.15	0.11	0.27	48.61	27.86	0.43	0.75	24.40	0.88
EXP2	2327±83	1647±178	0.29	0.49	0.38	0.22	220.71	189.43	0.14	0.23	49.48	0.26
EXP3	2557±155	1625±127	0.36	0.43	0.29	0.33	261.45	136.98	0.48	0.37	50.68	0.37
EXP4	2206 ±103	1368±101	0.38	0.28	0.19	0.32	151.55	112.68	0.26	0.55	75.23	0.67
EXP5	3852±178	1924±159	0.50	0.43	0.27	0.37	287.94	104.96	0.64	0.59	78.15	0.74
EXP6	1241±122	992 ±121	0.20	0.30	0.22	0.27	52.69	41.04	0.22	0.20	9.59	0.23
Mean	2260±119	1395±124	0.36	0.35	0.24	0.30	170.49	102.16	0.36	0.45	47.92	0.53

[1] RYR=Relative Yield Reduction; [2]RHR = Relative Heritability Reduction; [3] RGGR = Relative Genetic Gain Reduction (Relative reductions were calculated as 1-(values under flat beds / values under BBF)); r_g = Genotypic correlation coefficient between performances under BBF and flatbeds

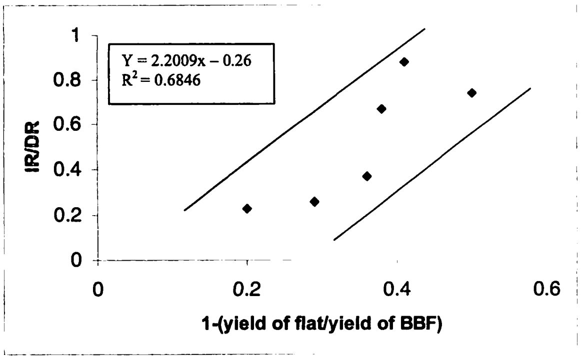


Figure 4. Relative efficiency of indirect selection under BBF (IR) as compared to direct selection under flatbeds (DR) for improving grain yield under flatbed target environments as a function of relative yield reduction, 1-[grain yield under flatbed/grain yield under BBF] in faba bean (Gemechu et al., 2001).

Integration of Genotypes and Drainage

Drainage of excess water under the Vertisols of the Ethiopian highlands using BBF resulted in dramatic yield increments compared to flatbeds (Getachew et al., 1988; Jutzi, 1988; ILCA, 1990; Srivastava et al., 1993). However, it is well established that better environment alone may not lead to better yields from inferior genotypes beyond a certain limit (Buddenhagen and Richards, 1988; Singh 1990). Production gains from the development of resistant genotypes to water logging may also not provide the required productivity under highly waterlogged environments.

Prospects for the integration of appropriate drainage of excess moisture and improved genotypes to solve this constraint were studied in faba bean (Gemechu et al., 2002a). Data from eight multi-location variety trials conducted under BBF and flatbeds from 1996 to 1999 were considered for the study. Results indicated that the drained environment was suitable for realizing the yield potential of the genotypes compared to the non-drained one. A mean grain yield increment of 46% was obtained with improved drainage using local cultivars. Improved cultivars developed for areas without water- logging problem showed a relative yield reduction on undrained sites and a 49% yield increment under BBF compared to local cultivars grown on flat beds.

The highest yielding genotypes grown on flat beds exhibited a mean yield increment of 66% relative to local cultivars on flat beds. The integration of improved drainage using BBF with the highest yielding genotypes resulted in a mean 106% yield increment (Table 7). Future improvement in productivity from this group of soils should, therefore, come from the integration of appropriate drainage and specifically adapted genotypes.

Analysis of Experiments under Waterlogged Vertisols

Analyses of a series of multilocation variety trials conducted simultaneously under BBF and flatbeds at Ginchi, Inewari, Ambo, Sinja and Bichena between 1996 and 2000 showed that experiments on flatbeds were usually characterized by higher coefficients of variation as compared to the ones under BBF (data not shown). Similarly, the interrelationship between grain yield and coefficient of variation in 10 different faba bean variety trials conducted in areas with no water logging problem between 1994 and 2000 showed the negative association between the two parameters (Figure 5). Some locations (Denbi, Holetta and Shambu) were characterized by higher CVs of more than 20% in some years. This shows the difficulties of blocking experimental units on flatbeds and under marginal environments compared to the potential ones. Means of minimizing errors and maximizing precision like the choice of leveled field, exposure of a limited number of genotypes per experiment so as to efficiently block the level of stress into homogenous classes and the use of moderate plot size could help a lot.

There is little experimental evidence whether components of variances calculated from separate analysis of variance under waterlogged condition is effective in estimating the extent of heritable variation and the effectiveness of selection. Analyses of a series of multilocation variety trials conducted simultaneously under BBF and flatbeds showed that heritability and expected genetic gains calculated from separate analysis averaged over locations were higher than those calculated from pooled analysis of variance over the same locations for grain yield. The relative precision improvement of pooled analysis of variance over separate analysis, calculated as 1-[Value of pooled analysis/Value of separate analysis], ranged from 57-83% for grain yield, and 7-25% for 1000-seed weight. Thousand-seed weight was more heritable than grain yield and heritability and expected genetic gains for both traits tended to decline with the increasing water logging stress as expected. There was weak association in almost all the cases between heritability and expected genetic gains calculated from separate and pooled analyses of variance for grain yield and strong positive association for 1000-seed weight. This indicates that genetic variation and effectiveness of selection for 1000-seed weight could more safely be calculated from separate analysis of variance than it is for grain yield. Thus, studies on genetic variability and effectiveness of selection for grain yield based on separate analysis of variance could be misleading under both drained and waterlogged Vertisols because of the potential danger of wrong conclusions that could be drawn from the confounding effects of genotype by environment interaction (Tables 8-9). Where genotype by environment interaction effects are great, care must be taken not to use statistical models that do not take care of the genotype by environment interaction effects. On the other hand, there were positively strong associations (r = 0.82-0.94) between the heritability and expected genetic gains calculated from separate and pooled analysis of variance for 1000-seed weight. Therefore, genetic variability and effectiveness of selection determined from separate analysis of variance could better be used for 1000-seed weight at least with certain levels of uncertainty. It also seems that heritability could be more safely determined from separate analysis of variance than expected genetic gains from selection.

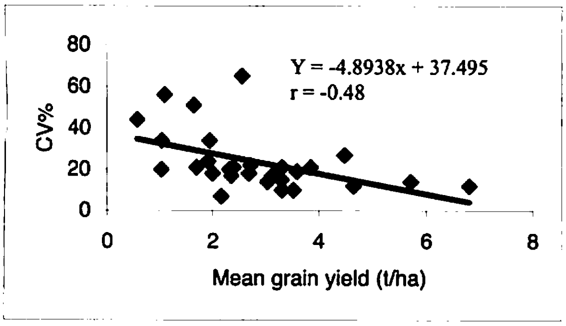


Figure 5. Interrelationship between grain yield and coefficient of variation (CV %) in 10 different faba bean preliminary variety trials conducted between 1994 and 2000 (Holetta Highland Pulses Breeding, unpublished data).

Participation of Farmers in Variety Selection

Farmers must be fully involved in the research process in general and variety selection and evaluation in particular as the ultimate users of the output. A farmers' participatory faba bean variety evaluation done in 1999 and 2000 showed that both farmers and researchers have their own unique and common selection criteria and different farmers within a location use more or less similar selection criteria to identify better varieties (Gemechu et al., 2002b). The selection criteria of male and female farmers also coincide except that female farmers are more interested in the seed size, cooking time and *kik* (de-hulled split for sauce making) making quality than the male farmers. Seed size is an indicative of the *kik* making quality, and female farmers also believe that large-seeded types have better market demand.

It was learnt that where the majority of the farmers are resource-poor and production is very subsistent, it could be realized that risk aversion, rather than yield maximization, may be the top priority since the economic potential of the farmers does not permit them to shoulder any level of failure. The risk aversion capacity of a variety should be proved in a short period of time as it goes with unfavorable climatic condition. It was also realized that farmers are interested in a system rather than a single commodity but the structural organization of research in Ethiopia is commodity based.

Important Achievements

Breeding efforts since 1993 resulted in the release of seven additional faba bean varieties at the national level (Table 10). A number of varieties have also been released regionally from different agricultural research centers. Of the varieties released nationally, two are suitable for highlands (2300-3000 m asl) and mid-altitude (1900-2300 m asl) areas of the country, two for the mid-altitude, two for waterlogged conditions, and one is a specific release for the West Shoa Zone.

Mussa and Yohannes (1999) reported that the variety Mesay was more stable than Bulga 70. Mussa et al. (2001) also reported that Wayu and Selale were consistently best performers both under BBF and flatbeds in most of the environments. A stratified ranking diagram (Figure 6) showed that, under BBF, Selale ranked in the top third at eight environments, and Wayu at seven out of 11 environments. Similarly, Wayu ranked in the top third at six environments, while Selale at five environments each under flatbed. Under waterlogged Vertisol condition, it was found that a stable genotype on BBF is not necessarily stable on flatbed and *vice versa* (Mussa and Gemechu, unpublished data). All faba bean varieties released so far belong to the conventional small-seeded and indeterminate types, and efforts made to develop determinate versions failed due to the fact that the latter were generally found to be low-yielders as compared to the former (Alem, 1998).

Table 7. Relative grain yield (t ha-1) due to improvements in moisture management (BBF), genotype, and the integration of moisture management and genotype as compared to local cultivars produced on flatbeds in eight faba bean variety trials conducted on Vertisols in the highlands of Ethiopia.

Exp.	Flat & LV[1] (check)	BBF & LV	RAOC (%)	Flat & RV	RAOC (%)	BBF & RV	RAOC (%)	Flat & BV	RAOC (%)	BBF & BV	RAOC (%)
EXP 1	1.16	1.89	62.9	1.86	60.3	1.73	49.1	1.98	70.7	2.09	80.2
EXP 2	1.36	3.06	125.0	1.50	10.3	3.55	161.0	2.62	92.7	3.94	189.7
EXP 3	0.89	2.07	132.6	0.68	-23.6	1.92	115.7	1.10	23.6	3.16	255.1
EXP 4	0.97	1.52	56.7	0.12	-87.6	0.89	-8.3	2.08	114.4	2.60	168.0
EXP 5	2.08	1.79	-13.9	1.33	-36.1	1.79	-13.9	2.59	24.5	2.61	25.5
EXP 6	1.82	1.44	-20.9	0.73	-59.9	1.43	-21.4	2.11	15.9	1.96	7.7
EXP 7	1.52	3.32	118.4	1.64	7.9	3.72	144.7	3.93	158.6	4.03	165.1
EXP 8	2.31	2.51	8.7	2.88	24.7	3.00	29.9	3.55	53.7	4.47	93.5
Mean	1.51	2.20	45.7	1.34	-11.3	2.25	49.0	2.50	65.6	3.11	106.0

[1]LV = local variety; RV = released variety for areas without water logging problem; RAOC = relative advantage over check; BV = best yielding variety in each trial. (Gemechu et al., 2002a).

Table 8. Broad-sense heritability (h2) and expected genetic gains (GA) for 1000-seed weight (g) and grain yield (kg ha-1) calculated from separate analysis of variance averaged over location and pooled analysis of variance in faba bean variety trials grown under drained (BBF) Vertisols.

Experiment	h^2 Separate analysis	h^2 Pooled analysis	h^2 RPI*	GA Separate analysis	GA Pooled analysis	GA RPI
			Thousand seed weight			
EXP 1	0.46	0.34	0.26	15	8	0.47
EXP 2	0.96	0.94	0.02	51	49	0.04
EXP 3	0.92	0.91	0.01	62	44	0.29
EXP 4	0.95	0.94	0.01	81	87	-0.07
EXP 5	0.96	0.90	0.06	86	52	0.40
EXP 6	0.80	0.84	-0.05	39	31	0.21
EXP 7	0.94	0.76	0.19	58	41	0.29
Mean	0.86	0.80	0.07	56	45	0.23
			Grain yield			
EXP 1	0.57	0.12	0.79	258	33	0.87
EXP 2	0.61	0.30	0.51	251	97	0.61
EXP 3	0.40	0.30	0.25	166	41	0.75
EXP 4	0.55	0.18	0.67	296	46	0.84
EXP 5	0.64	0.17	0.73	482	48	0.90
EXP 6	0.41	0.02	0.95	204	8	0.96
EXP 7	0.69	0.18	0.74	425	71	0.83
Mean	0.55	0.18	0.66	297	49	0.83

*RPI = relative precision improvement of pooled analysis over separate analysis of variance, calculated as 1-[Value of pooled analysis/ Value of separate analysis] (Holetta Highland Pulses Breeding, unpublished data).

Table 9. Broad-sense heritability (h^2) and expected genetic gains (GA) for thousand seed weight (g) and grain yield (kg ha^{-1}) calculated from separate analysis of variance averaged over location and pooled analysis of variance in faba bean variety trials grown under undrained (flatbed) Vertisols.

Experiment	H^2 Separate analysis	H^2 Pooled analysis	H^2 RPI*	GA Separate analysis	GA Pooled analysis	GA RPI
		---------------Thousand seed weight-----------------------				
EXP 1	0.51	0.22	0.57	18	5	0.72
EXP 2	0.91	0.89	0.02	43	38	0.12
EXP 3	0.86	0.89	-0.03	48	26	0.46
EXP 4	0.94	0.95	-0.01	71	69	0.03
EXP 5	0.88	0.92	-0.05	54	54	0.00
EXP 6	0.89	0.48	0.46	42	26	0.38
EXP 7	0.85	0.89	-0.05	37	36	0.03
Mean	0.83	0.75	0.13	45	36	0.25
		-----------------------Grain yield---------------------------				
EXP 1	0.57	0.21	0.63	270	55	0.80
EXP 2	0.77	0.39	0.49	613	261	0.57
EXP 3	0.58	0.32	0.45	379	31	0.92
EXP 4	0.78	0.13	0.83	469	47	0.90
EXP 5	0.53	0.11	0.79	377	19	0.95
EXP 6	0.54	0.32	0.41	395	232	0.41
EXP 7	0.49	0.29	0.41	606	163	0.73
Mean	0.61	0.25	0.57	444	115	0.75

Source: Holetta Highland Pulses Breeding (unpublished data).

Table 10. Description of nationally released faba bean varieties from Holetta between 1994 and 2002.

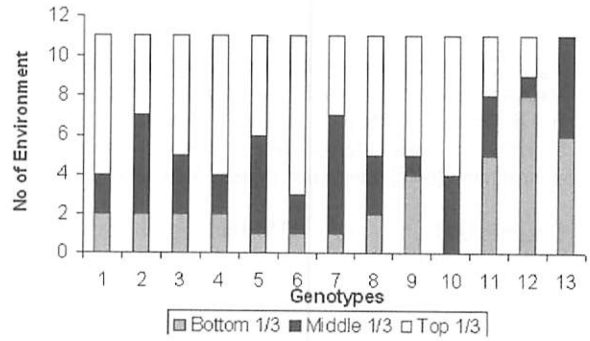
Variety	Pedigree	Year of release	Yield (t ha $^{-1}$)	% increase over check	Recommendation domain
Bulga-70	Coll 111/77	1994	4.4	10	Mid- and high-altitude areas of the country
Tesfa	75TA26026-1-2	1995	3.8	9	Mid-altitude areas of the country
Mesay	74TA12050 x 74TA236	1995	4.4	11	Mid-altitude areas of the country
Holetta-2	BPL 1802-2	2001	3.0	9.4	Specific release to West Shoa Zone
Degaga	R878-3	2002	3.2	17	Mid- and high-altitude areas of the country
Wayu	Wayu 89-5 with (BBF)	2002	3.0	52	Waterlogged Vertisols of the country
	Flat		2.9	100	
Selale	Selalekasim 91-13 (BBF)	2002	3.1	54	Waterlogged Vertisols of the country
	Flat		2.3	62	

G x E Interaction

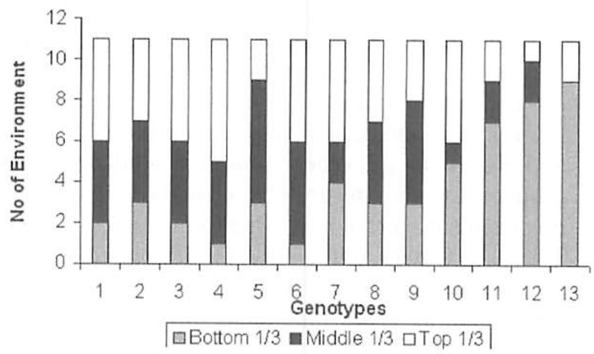
G × E interaction refers to the differential response of genotypes to different environments. High G x E interaction effect in faba bean has been reported by a number of authors (Mussa and Yohannes, 1999; Mussa et al., 2001). In most of these studies, environmental effects accounted for the largest part of the total variation, and the proportion of variation contributed by the genotypes was far less than that contributed by environmental and G x E interaction effects, particularly under waterlogged Vertisols. Change in rank orders or crossing over among the performances of the genotypes across the environments were clearly evident both under BBF and flatbeds (Fig. 6 and 7). Evidence of change in rank order among the performances of genotypes at different environments or existence of crossover type of interaction is believed to be an indicator of significant differences among environments (Ceccarelli and Grando, 1996; Ceccarelli, 1997).

Ethiopia is a country of great geographical diversity with environmental variation experienced both from one season to another and from place to place in the same season over a relatively small area (EMA, 1988), and faba bean is a crop highly sensitive to environmental changes. Where environmental differences are greater and the given crop is sensitive to environmental changes, it may be expected that the genotype by environment interaction will also be greater (Falconer, 1989; Van Oosterom et al., 1993). Complication due to larger G × E interaction is one of the major challenges that reduce progresses from breeding programs and complicates the task of plant breeding as a whole (Ceccarelli and Grando, 1996). If genotypes perform consistently across environments, breeders may be able to effectively evaluate genotypes with a minimum cost in a few environments for an ultimate use under wider areas. However, it is likely that genotypes selected for best performance under one set of condition may perform poorly under another (Singh, 1990; Romagosa et al., 1996; Ceccarelli, 1997).

Environmental conditions and management practices interplay to determine the extent and pattern of genetic expression of economic traits including yield potential in crops (Singh, 1990; Collaku et al., 2002). The environment for which breeding is undertaken should, therefore, be clearly defined and classified into similar categories in order to reduce the magnitude of G × E interaction, thereby maximizing gains from breeding efforts (Collaku et al., 2002). When GXE interaction is large to the extent that it results in rank order changes among the performances of the genotypes, it means that the environments are distinctly different and they do not represent one another. Hence, there may be no scientific base to go for wide adaptation in such cases but rather the breeding of alternate varieties with specific adaptation to local circumstances may ensure the sustainability of production (de Boef et al., 1996).

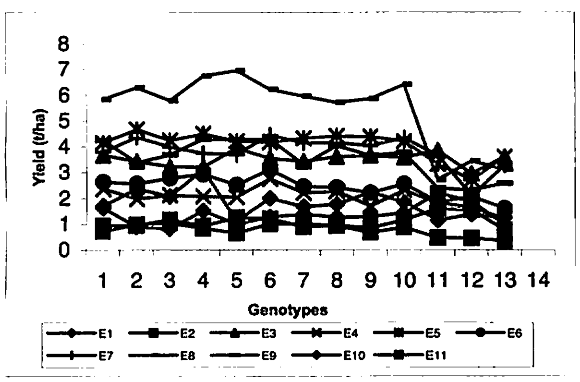


(A) BBF

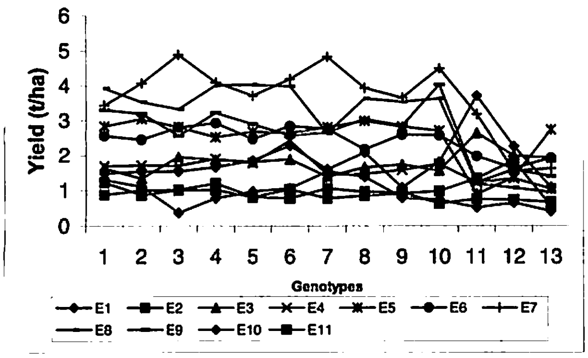


(B) Flat

Fig. 6. Stratified ranking diagram showing the relative performance for grain yield in 13 faba bean genotypes grown in 11 environments under BBF (A) and flatbeds (B). Numbers 4 and 6 in the figures represent Wayu and Selale, repectively (Mussa et al. (2001).



(A) BBF



(B)Flat

Fig. 7. Grain yield performances of 13 faba bean genotypes across eleven environments (E1-E11) each under (A) BBF and (B) flatbed conditions showing the existence of relative changes in ranks (cross-overs) due to genotype by environment (GXE) interaction (Mussa et al., 2001).

Categorization of Waterlogged Selection Environments

Classification of the environments into homogeneous groups to reduce the magnitude of G × E interaction was attempted based on data from a variety trial on 12 faba bean genotypes grown between 1997 and 2000 at multilocations on adjacent fields of BBF and flatbeds on waterlogged Vertisols.

The environments were grouped into three clusters (Fig. 8). The locations in the northern part of the country (Inewari and Bichena) on one hand and those in the central and southeastern (Ginchi, Ambo and Sinja) on the other showed a tendency to be grouped together regardless of years and moisture management techniques. Inewari 1998, Bichena 1999 and Ginchi 1999 and 2000 did not follow this general trend on BBF, indicating that geographical position was not the only factor influencing clustering. The classification of locations into two broad categories may indicate the need for a separate primary breeding station or testing location for each of the categories. Therefore, inter-cluster spatial replication of trials is more important than replications targeted to catch intra-cluster variations, temporal differences and those due to excess moisture management techniques. However, a comprehensive study involving both edaphic and climatic factors with more number of locations representative to Vertisols of the Ethiopian highlands was recommended to make more tangible conclusion at the national level.

OPPURTUNITIES, CHALLENGES, AND IMPLICATIONS

Faba bean is one of the crops listed in the "economically valuable crops" in the new development strategy of Ethiopia. As a potential export crop, it might apparently have a special opportunity in the few years to come. It is believed that more varieties will be expected from research and the demand for high quality seed is expected to increase through the current package program, as more farmers will realize the benefits of the use of quality seeds. There is no specific breeding program existing in Ethiopia for nutritive aspects particularly to improve protein content. Most literature on nutritive aspects fortunately show that, unlike cereals, protein contents in legumes are not as such negatively associated with grain yield but rather most of the essential amino acids seem to do so with protein content. The big challenge to faba bean breeders is the difficulty of serving multi-dimensional interests with limited financial, technical and material capabilities. In addition to the local needs emanating from the physical environments, farming systems and consumers' preferences, export qualities and standards may apparently deserve at least equal level of priority as breeding objectives.

It is expected that the genetic potential of improved faba bean varieties developed so far could not be exhaustively exploited as in some cereals even after a country-wide popularization of improved production packages which proved the superiority of the improved varieties over the old-age landraces for the major food crops (Takele, 1997). This could be attributed to the least priority given by the package program to pulses, least position farmers give to food legumes in general in terms of land and input allocation and poor crop management compared to cereals. Despite the release of a number of improved varieties, they are not yet sufficiently put under production and most of the cultivated areas in the country are still planted with local seeds. The national average yields are low and stagnant while yields of two- to three-folds are commonly recorded under research conditions.

In order to boost the productivity of faba bean in the country to the desired level, among others, the demand for varieties appropriate under farmers own circumstance need to be satisfied. The mismatch between selection and target environments could be of paramount importance for future considerations. Even though tangible scientific evidence from the Ethiopian context is scanty, the complaint that the varietal generation processes in developing countries do not take into consideration the target production systems that should be considered seriously (Hawtin et al., 1988). Depending on the practical situations existing in a given farming system, several options could be thought of to be more effective for the process of generation of such varieties.

Option 1. Farmers have to afford to take up the whole production packages along with the varieties. This option does not widely apply for an obvious reason that the majority of the resource-poor farmers may not afford the cost of production inputs. Among the key management inputs, commercial fertilizers are the most important but expensive. The rate of fertilizer applied by the farmers is either very low or none compared to the rate used under research stations as shown in Table 5. Unfortunately, the cost of fertilizer may continue to rise to the level that farmers in developing countries in general may not afford to purchase (FAO, 1984). As a result, production may mostly be based on the traditional approach despite the fact that farmers may realize the importance of using inputs like fertilizers.

It is advisable that breeding activities to address marginal areas should build on farmers' practices to complement them and not to substitute their practices. Landraces are believed to be more useful for breeding in marginal areas than introduced materials as they offer genes responsible for a more stable yield over a wide range of environmental conditions (Hawkes, 1983; Nachit et al., 1988; Ceccarelli, 1997; Bunders et al., 1996; Chahal and Gosal, 2002).

Option 2. The second option is that breeders must recognize farmers' unique situations and develop varieties based on their biophysical and socio-economic needs, as failing to do so may end up in shelving the varieties. With the rising price of fertilizers, therefore, the breeding of productive genotypes, which are suitable under low soil fertility levels and simulated farmers' circumstances, could prove one of the dependable approaches to address the problem of the majority of the resource-poor farmers in Ethiopia. However, this option has also its own limitations. The genetic gain under such circumstances, for instance, may limit grain yield improvements, and thereby, the national desire to double or triple productivity in order to feed the increasing population.

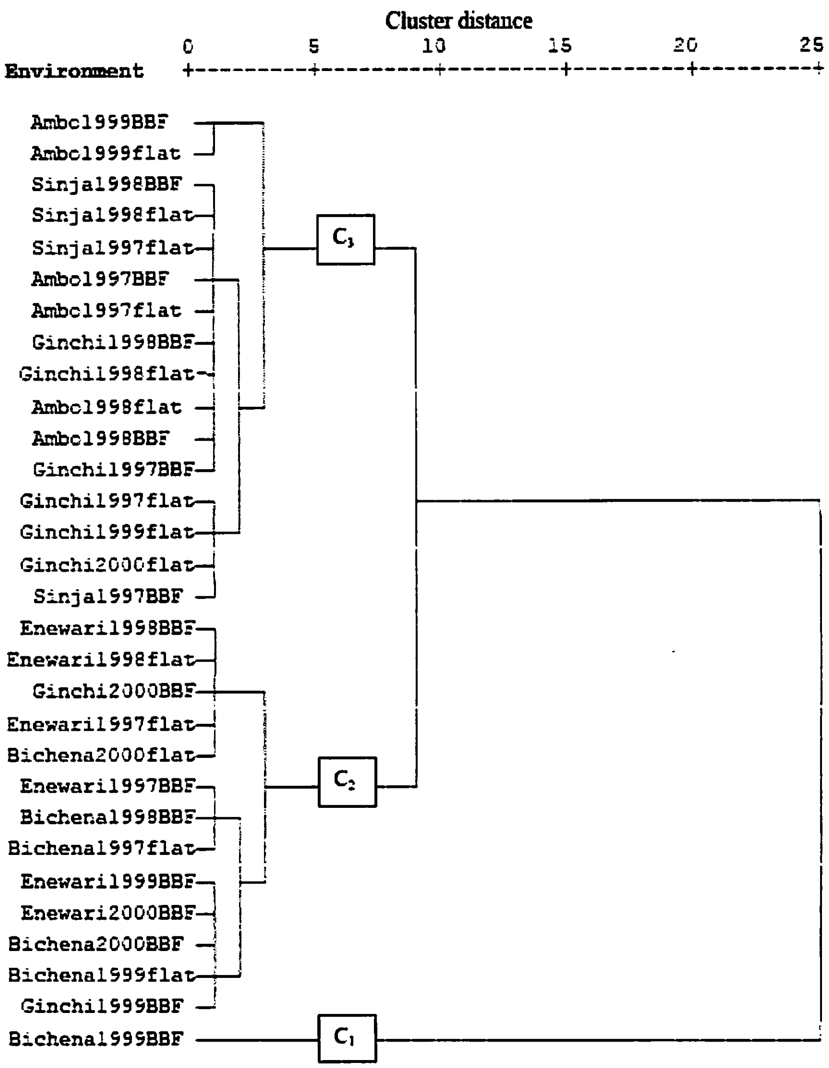


Fig. 8. Dendrogram of waterlogged environments based on mean grain yield of faba bean genotypes under drained and undrained conditions on waterlogged Vertisols.

Option 3. We have seen in options 1 and 2 that gearing both the breeding work towards the farmers' actual situation or gearing the production towards the research conditions have their own drawbacks. Another possibility that may mediate the two options is that there might be a compromise between researchers and farmers in such a way that researchers consider only those pertinent biophysical and socio-economic backgrounds of the farmers, while at the same time farmers also try to take up the most important but affordable components of the package. Testing of varieties under both optimal and sub-optimal conditions could be one of the stable alternatives to create alternative varieties that suit both conditions but the cost of germplasm evaluation would be greatly increased.

In conclusion, there is a need to revisit and redirect the scheme of variety development in order to make the future breeding efforts more objective and focused. The environment and the farming system for which breeding is undertaken, farmers' and consumers' preferences and characters to be modified under specific situations should be clearly defined, and accordingly, appropriate germplasm should be identified and proper breeding methods should be followed.

REFERENCES

Alem Berhe. 1998. Performance of determinate faba bean in Ethiopia. FABIS 41: 1-4.

Alem Berhe, Geletu Bejiga, and D. Mekonin. 1998. Association of some characters with seed yield in local varieties of faba bean. *African Crop Sci. J.* 6 : 197-204.

Amare Ghizaw. 1990. Evaluation of faba bean (*Vicia faba* L.) production packages on farmers fields in Arsi Administrative Region, M. Sc. Thesis, Alemaya University of Agriculture, Ethiopia.

Amare Gizaw. 1996. Mixed cropping of faba bean and field pea in Ethiopia. p. 56-63. *In* Woldeyesus Senebo et al. (Eds.) Proc. First and Inaugural Conference of Agronomy and Crop Physiology Society of Ethiopia (ACPSE), Addis Ababa.

Amare Ghizaw, and Adamu Mola. 1994. Faba bean and field pea agronomy research. p. 199-227. *In* Asfaw Tilaye et al.(Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

Asfaw Tilaye, Tesfaye Getachew, and Beyene Demtsu. 1994. Genetics and breeding of faba bean. p. 97-121. *In* Asfaw Tilaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

Banziger, M., and G.O. Edmeades. 1997. Predicted productivity gains from breeding maize under stressed vs. non-stressed conditions. p. 136-140. In J.K. Ransom et al. (Eds.) Maize Productivity Gains through Research and Technology Dissemination. Proc. 5th Eastern and Southern Africa Regional Maize Conference, Arusha, Tanzania, 3-7 June 1996. CIMMYT, Addis Abeba, Ethiopia.

Banziger, M., F.J. Betran, and H.R. Lafitte. 1997. Efficiency of high-nitrogen selection environments for improving maize for low-nitrogen target environments. Crop Science 37: 1103-1109.

Banziger, M., G. O. Edmeades, D. Beck, and M. Bellon. 1998. Breeding for drought and low N tolerance in maize. Regional workshop for breeders and agronomists of ASARECA member states, 1-14 September 1998, Arusha, Tanzania.

Bond, D.A. 1976. Field beans *Vicia faba*. p. 179-182. In N.W. Simmonds (Ed) Evolution of Crop Plants. Longman, London.

Briggs, F.N., and P.F. Knowles. 1967. Introduction to plant breeding. Reinhold Publishing Corporation, USA.

Buddenhagen, I.W., and R.A. Richards. 1988. Breeding cool season food legumes for improved performance in stress environments. p. 81-95. In R.J. Summerfield (Ed.) World Crops: Cool *Season Food Legumes.* Kluwer Academic Publishers, The Netherlands.

Bunders, J., A. Loeber, J.E.W. Broers, and B. Havertkort. 1996. An integrated approach to biotechnology development. p. 201-227. *In* J. Bunders et al. (Eds.) *Biotechnology; Building on Farmers' Knowledge.* MacMillan, London and Basingstoke.

Ceccarelli, S. 1989. Wide adaptation: how wide? *Euphytica* 40: 197-205.

Ceccarelli, S. 1997. Adaptation to low/high input cultivation. p. 225-236. *In* P.M.A. Tigerstedt (Ed.).*Adaptation in Plant Breeding.* Kluwer Academic Publishers, The Netherlands.

Ceccarelli, S., and S. Grando. 1996. Importance of specific adaptation in breeding for marginal conditions. p. 34-58. *In* Hailu Gebre and Joop Van Leur (Eds.) *Barley Research in Ethiopia: Past Work and Future Prospects.* Proc. 1st Barley Research Review Workshop, 16-19 October 2003, Addis Ababa. IAR/ICARDA. IAR, Addis Ababa, Ethiopia.

Chahal, G.S., and S.S. Gosal. 2002. Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches. Narosa Publishing House, New Delhi.

Collaku, A., Harrison, S.A., Finney, P.L., and D.A. van Sanford. 2002. Clustering of environments of southern soft red winter wheat region for milling and baking quality attributes. Crop Science 42: 58-63.

CSA. 2002. Report on the preliminary results of area, production and yield of temporary crops (*Meher* season, private peasant holdings). Part I. Ethiopian agricultural sample survey enumeration, 2001/2002. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Dawit Tadesse, Asfaw Tilaye, and Geletu Bejiga. 1994. Genetic resources in Ethiopia. p. 79-96. *In* Asfaw Tilaye et al. (Eds.) Cool-season Food Legumes of Ethiopia. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

de Boef, W.S., T. Berg, and B. Haverkort. 1996. Crop genetic resources. p. 103-128. *In* J Bunders et al. (Eds.) *Biotechnology; Building on Farmers' Knowledge.* Macmillan, London and Basingstoke.

Dereje Gorfu. 1999. Effects of mixed cropping of faba bean and field pea on disease development and yield. *Pest Mgt. Journal of Eth* 3 :61-67.

Dereje Gorfu and Tesfaye Beshir. 1994. Faba bean diseases in Ethiopia. p. 328-345. *In* Asfaw Tilaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

Edmeades, G.O., J. Bolanos, and S.C. Chapman. 1997. Value of secondary traits in selecting for drought tolerance in tropical maize. p. 222-234. *In* G.O. Edmeades et al. (Eds.) *Developing Drought and Low N-tolerant Maize*. Proc. Symposium, March 25-29, 1996, CIMMYT, El Batan, Mexico.

Edmeades, G.O., J. Bolanos, M. Banziger, J.M. Ribaut, J.W. White, M.P. Reynolds, and H.R. Lafitte. 1998. Improving crop yields under water deficits in the tropics. p. 437-451. *In* V.L. Chopra et al. (Eds.) *Crop Productivity and Sustainability - Shaping the Future*. Proc. 2nd Int. Crop Science Congress. Oxford and IBH, New Delhi.

Ethiopian Mapping Authority (EMA). 1988. National Atlas of Ethiopia, Addis Ababa. Ethiopian Agricultural Sample Enumeration. 2002. Report on the preliminary results of area, production and yield of temporary crops (*meher* season, private peasant holdings). Part I. Central Statistics Authority, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization of the United Nations). 1984. Fertilizer and plant nutrition guide. FAO Fertilizer and Plant Nutrition Bulletin, Rome.

Falconer, D.S. 1989. Introduction to quantitative genetics. 3rd Ed. Longman, London, England.

Gemechu Keneni, Belay Asmamaw, and Mussa Jarso. 2001. Efficiency of drained selection environment for improving grain yield in faba bean under undrained target environments on Vertisol. Euphytica 122: 279-285.

Gemechu Keneni, Mussa Jarso, and Belay Asmamaw. 2002a. The role of drainage and genotype in improving productivity of faba bean on waterlogged Vertisols. *Ethiopian J. Natural Resources* 4: 49-60.

Gemechu Keneni, Mussa Jarso, Belay Asmamaw, and Maaza Kersie. 2002b. On-farm evaluation of faba bean and field pea varieties around Holetta. p. 176-187. *In* Gemechu Keneni et al. (Eds.) *Towards Farmers' Participatory Research: Attempts and Achievements in the Central Highlands of Ethiopia*. Proc. of Client-oriented Research Evaluation Workshop, 16-18 October 2001, Holetta Agricultural Research Center, Holetta, Ethiopia.

Gemechu Keneni, Mussa Jarso, Tezera Wolabu, and Getnet Dino. 2003. Extent and pattern of genetic diversity for morpho-agronomic traits in Ethiopian highland pulse landraces II. Faba bean (*Vicia faba* L.). *Genetic Resources and Crop Evolution* (Accepted).

Getachew Asamenew, S.C. Jutzi, Abate Tedla, and J. McIntire. 1988. Economic evaluation of improved Vertisol drainage for food crop production in the Ethiopian highlands. p. 263-283. *In* S.C. Jutzi et al. (Eds.) *Management of Vertisols in Sub-Saharan Africa*. Proc. Conference, 31 August - 4 Sept., 1987. ILCA, Addis Abeba.

Getahun Mulat. 1998. Variation among Ethiopian faba bean landraces for seed yield and agro-morphological characters. *FABIS* 41: 5-8.

Hawtin, G.C., F.J. Muehlbauer, A. E. Slinkard, and K.B. Singh. 1988. Current status of cool season food legume crop improvement: assessment of critical needs. p. 67-80. *In* R.J. Summerfield (Ed.) *World Crops: Cool Season Food Legumes*. Kluwer Academic Publishers, the Netherlands.

Hailu Beyene, Workneh Negatu, and Shelemew W/mariam. 1994. Small holder practices and constraints in Ethiopian Bean. p. 19-30. *In* Asfaw Tilaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

Hawkes, J.G., 1983. The Diversity of Crop Plants. Harvard University Press, Cambridge, Massachusetts and London.

Hanna, A.S., and D.A. Lawes. 1967. Studies on pollination and fertilization in the field bean (Vicia faba L.). *Ann. Appl. Biology* 59: 289-295.

Hardwick, R.C. 1988.Critical physiological traits in pulse crops. p. 885-896. *In* R. J. Summerfield (Ed.) World Crops: Cool Season Food Legumes. Kluwer Academic Publishers, the Netherlands.

ICARDA . 2000. Hybridization techniques in faba bean. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.

ILCA (International Livestock Center for Africa). 1990. Annual Report 1989. ILCA, Addis Abeba.

Jutzi, S.C. 1988. Contribution of Vertisols to national food self-sufficiency, actual and potential. *Ethiopian J.Agricultural Sciences* 10: 67-70.

Keneni, G., and M. Jarso. 2002. Comparison of three secondary traits as determinants of *grain yield in faba bean on waterlogged Vertisols*. J. of Genetics & Breeding *56: 317-326*.

Lawes, D.A., D.A. Bond, and M.H. Poulsen. 1983. Classification, origin, breeding Methods and Methods and Objectives. p. 23-76. In P.D. Hebblethwaite(Ed.) The Faba Bean (Vicia faba L.). Great Britain, The University Press, Cambridge.

Mussa Jarso, Gemechu Keneni, Belay Asmama, Wuletaw Tadesse Wondafrash Mulugeta, and Tadele Tadesse. 2001. Performance of elite faba bean (*Vicia faba* L) genotypes for grain yield under waterlogged Vertisols of the Ethiopian Highlands. Paper presented at the 10th Annual Conference of the Crop Science Society of Ethiopia. 19-21 June 2001, EARO, Addis Ababa, Ethiopia.

Mussa Jarso, and Yohannes Degago. 1999. Genotype x environment interaction and grain yield in faba bean. p. 16-25. *In* Bedada Girma et al. (Eds.) *Sebil. Vol.8*. Proc. 8th Annual Conference of the Crop Science Society of Ethiopia, 26-27 Feb. 1997, Addis Ababa, Ethiopia.

Nachit, M.M., H. Ketata, and S.K. Yau. 1988. Breeding durum wheat for stress environments of the Mediterranean region. p. 297-304. *In*: G. Wittmer (Ed.) *Durum Wheat: The Future of Cereals for Human Feeding and Development of Biotechnological Research*, Proc. 3rd Int. Symposium. Publ. Chamber of Commerce, Foggia, Italy.

Rezene Fessehaie. 1994. Weed research in cool-season food legumes. p. 252-274. *In* Asfaw Tilaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

Romagosa, I., Ullrich S.E, Han F., and P. M. Hayes. 1996. Use of the additive main effects and multiplicative interaction model in QTL mapping for adaptation in barley. *Theoretical and Applied Genetics* 93: 30-37.

Rosielle, A.A. and J. Hamblin. 1981. Theoretical aspects of selection for yield in stress and non-stress environments. *Crop science*. 21: 943-946.

Simmonds, N.W. 1991. Selection for local adaptation in a plant breeding program. *Theoretical and Applied Genetics* 82: 363-367.

Singh, B.D. 1990. Plant Breeding: Principles And Methods. Kalyani Publishers, New Delhi-Ludhiana.

Slinkard, A. E., and J.S. Sindhu 1988. Role of physiology in pulse crop improvement: A plant breeding perspective. p. 931-939. *In* R.J. Summerfield (Ed.). *World Crops: Cool Season Food Legumes*, Kluwer Academic Publishers, The Netherlands.

Smith, M.E. 1986. Breeding for multiple cropping systems. p. 219-249. *In* C.A. Francis (Ed.) Multiple Cropping Systems. Macmillan Publishing Company, New York.

Srivastava, K.L., Abiye Astatke, Tekalign Mamo, Hailu Regassa, and Selamyihun Kidanu 1993. Land, soil and water management. p. 75-84. *In* Tekalign Mamo et al. (Eds.) *Improved Management of Vertisols for Sustainable Crop and Livestock Production in the Ethiopian Highlands: Synthesis Report 1986-92*. Technical Committee of the Joint Vertisol Project, Addis Abeba, Ethiopia.

Takele Gebre. 1997. The status of crop management technologies in the current extension package and their role in crop production in Ethiopia. p. 1-9. *In* Woldeyesus Sinebo (Ed.) *Crop Management Research for Sustainable Production: Status and Potentials*. Proc. 2nd Annual Conference of the Agronomy and Crop Physiology Society of Ethiopia (ACPSE). 30-31 May 1996. Addis Ababa, Ethiopia.

Teshome, A., B.R. Baum, L. Fahrig, J.K. Torrance, T.J. Arnason and J.D. Lambert. 1997. Sorghum [*Sorghum bicolor (L.)* Moench] landrace variation and classification in North Shewa and South Welo, Ethiopia. *Euphytica* 97: 255-263.

van Oosterom, E.J., Kleijn D., Ceccarelli S., and M.M. Nachit. 1993. Genotype-by- environment interaction of barley in the Mediterranean Region. *Crop Science* 33: 669-674.

Westphal, E. 1974. Pulses in Ethiopia: Their Taxonomy and Significance. College of Agriculture, Haile Sellessie I University, Ethiopia/ Agriculture University, Wageningen, The Netherlands.

Woldeyesus Sinebo, Ralph Gretzmacher, and Anton Edelbauer. 2002. Environment of selection in low fertilizer input barley. *Field Crops Research* 74: 151-162.

Yohannes Degago. 2000. Faba bean (*Vicia faba*) in Ethiopia. Institute of Biodiversity Conservation and Research (IBCR). Addis Ababa, Ethiopia.

Breeding Chickpea for Wide Adaptation

Geletu Bejiga[1] and Ketema Daba [2]

[1].Green Focus Ethiopia, P.O.Box 802, Addis Ababa, Ethiopia, [2].Debre Zeit Agricultural Research Center, P.O.Box 32, Debre Zeit, Ethiopia

ABSTRACT

Chickpea is one of the important pulse crops of Ethiopia that plays a key role in providing protein to the diets of the population. It has also helped to maintain the Ethiopian soils alive for centuries since it is the major pulse crop used in rotation with small cereals on Vertisols. The objective of this review is to compile all the results obtained on chickpea breeding since 1993 and indicate the future direction to meet the national food requirement. The National Chickpea Improvement Project has made a systematic effort to improve chickpea production in Ethiopia. The release of chickpea varieties DZ-10-4, DZ-10-11, Dubie and Mariye in the late 70s and early 80s was the key success in chickpea breeding in Ethiopia. Continued efforts after the 1993 resulted in the release of varieties Worku (DZ-10-6-2), Akaki (DZ-10-9-2), Shasho (Kabuli) and Arerti (Kabuli). Varieties ICCV-89303, ICCV-92318 and FLIP-88-42C were also proposed for release in 2003/2004 cropping season. The study of diversity in the Ethiopian chickpea population showed no significant variation between regions and altitude classes, as there is seed movement between regions and altitudes. However, there is diversity within the regions and altitude groups of Ethiopia. Cluster analysis showed that there was resemblance between populations of different regions. Study of drought response index (DRI) revealed that ICCL-89316, ICC-14156, ACC-41235 and ACC-209025 were highly tolerant to drought; and lines such as ICCL-83149, ICC89218 and ICCL-13974 were tolerant. The grain yield in the dry environment had significant positive association (0.54) with only root length. This suggests that in the dry environment, lines that develop deep roots at seedling stage have advantage over the others. Different sources of resistance to Fusarium wilt have been identified and are intensively used in the breeding program.

INTRODUCTION

Research achievements in genetics and breeding of chickpea (*Cicer arietinum* L.) during between 1972-1993 were reviewed and compiled by Geletu and Yadeta (1994). The objectives of this review are to assemble all the information generated since 1993 and set the future directions of research to further improve the productivity and quality of chickpea to meet the national food requirement and export quality.

Chickpea is one of the food legume crops grown in the tropics, sub-tropics and temperate regions of the world. However, its production is concentrated in South Asia, West Asia and North Africa, Central Asia, East Africa, and Latin America. It is also grown in southern Europe. There are two types of chickpeas: desi and Kabuli. Desi type accounts for about 85% of the world's chickpea area and production and is mainly grown in South Asia, Iran, Ethiopia, and Mexico (ICRISAT, 2000). In Ethiopia, desi-type chickpea accounts for more than 90 percent. Kabuli chickpea is only grown in small plots in some pocket areas or in mixture with desi-type chickpeas. It is mainly grown in the agro ecological zones of SM2, SM1, M1, M2, SH2, H2 and SH3. In 2001, chickpea occupied about 23% of the land allocated to the highland pulses and contributed 21.3% of the total grain production of the highland pulses (EARO, 2002). The area can be extended to the drier agro ecological zones under supplemental and full irrigation. There is also a great potential to expand its production to the humid and warm regions of Beni Shangul and Gambella provided that Ascochyta blight-resistant varieties are available. Ethiopia is considered as a center of diversity for chickpea. *Cicer cuneatum* is a wild relative of cultivated chickpea found in Tigrai region of Ethiopia. Chickpea is widely used in different forms as green vegetable (green immature seed), *Kollo* (soaked and roasted) and *nifro* (boiled seeds). The sauces made of shiro (powdered seeds) and *kik* (split seeds) are commonly eaten with injera (flatten bread made of tef cereal, wheat, maize, sorghum and other cereals). *Shimbera asa* (chickpea fish) is one of the popular dishes taken during the two months of fasting period, when Ethiopian Coptic Church followers do not take animal products and try to simulate fish by using chickpea due to its high protein. Mitad shiro (shiro made on pan) and butucha are the most popular dishes made from chickpeas in Gojam and Gonder regions. Chickpea is also one of the major export commodities and contributed 58.2% of the total pulses export of 282 million Birr in 2001/ 2002 (Ethiopian Herald, Nov 15 2002). The continuous requests coming from India, Pakistan, Egypt and Turkey to import Ethiopian chickpea are encouraging (EEPA, 2002a, 2002b, 2003a, 2003b, 2003c). It has an attractive demand both in the domestic and export markets and is a good value for money to farmers because it requires low input and management. Generally, it contributes to the soil fertility, environment and the health of the people because it fixes nitrogen, requires low pesticides and is a good source of cheap protein and some essential amino acids. However, the national average yield is still less than a ton. Non-availability of seed of improved varieties to the farmers is one of the major constraints to productivity.

Genetics

The National Chickpea Improvement Project (NCIP) has not given much attention to the genetic studies in chickpea since a good amount of information has been generated at the International

Agricultural Research Centers (IARCs) such as International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), in India and International Center for Agricultural Research in the Dry Areas (ICARDA), in Syria and other advanced institutions. However, the genetic information generated using the Ethiopian chickpea materials are briefly discussed below.

Correlations

Correlation studies undertaken by Feaven (2002) at Debre Zeit Agricultural Research Center revealed that grain yield of chickpea per plot had highly significant correlations with biological yield (0.538**), days to 50% flowering (0.125**), harvest index (0.286**), 1000-seed weight (0.084**), number of primary branches (0.248**), number of secondary branches (0.351**), number of seeds per plant (0.382**) and plant height at maturity (0.352**). The biological yield had the highest correlation with grain yield per plot and highly significant positive associations with all other characters studied except days to 90% maturity (Table 1). Biological yield, however, had highly significant and negative association with harvest index indicating that the lower the biological yield the higher the proportion of harvest index. Thousand seed weight had negative correlations with the number of days to 50% flowering and maturity, grain yield per plot, number of primary and secondary branches, number of seeds per plant and plant height indicating that this character was negatively affected by an increase in any one of these traits. Abebe (1985) also reported similar results in chickpea in Ethiopia. Correlation studies among 10 characters obtained from major chickpea producing areas (Shoa, Gonder, Gojam, Arsi-Bale, Tigrai, Wello, Gamo Gofa, Hararge and Sidamo) showed different association levels of grain yield per plot with other characters (Feaven, 2002). For instance, grain yield per plot had the correlation values of 0.106, 0.248**, 0.116, 0.470**, 0.379**, -0.072, 0.243** and 0.848** with harvest index at Shoa, Gonder, Gojam, Arsi-Bale, Tigrai, Wello, Gamo Gofa, Hararge and Sidamo regions, respectively. Biological yield had consistently high and significant positive association with grain yield per plot in seven regions had also negative and non-significant association with grain yield per plot in collections from Hararghe-Sidamo region. This indicates that selection criteria are influenced by the accessions collected from different regions.

Coefficient of Variation

Feaven (2002) indicated that the highest coefficient of variation was observed in number of seeds per plant, and ranged from 74.75% to 104.06% in the altitudes between less than 1500 to over 2300 m asl. However, the highest coefficient of variation was recorded in the collections made in less than 1500 m asl. Similar results were obtained for this character when it was determined for each region of origin of the accessions. Coefficient of variation was low for days to flowering and maturity and 1000-seed weight as compared to other characters at all altitude groups and origins of the accessions (Table 2). The lower the coefficient of variation, the lower would be the genetic gain from selection of that given character.

Heritability

The response to selection in any crop is dependant on its heritability of the characters under consideration. Thus, the heritability of a character determines the success of any breeding program. Feaven (2002) found the highest heritability estimate of 90% for days to maturity and 75% for days to flowering, and 72% for 1000- seed weight (Table 2). The lowest heritability was recorded for biological yield (13%), grain yield per plot (19%), and harvest index (26%). The low heritabilities indicate that these characters are highly influenced by the environment and make the selection very difficult for wider adaptation. Abebe (1985) also obtained the highest heritability for 100-seed weight, number of seeds per pod and plant height. The estimated genetic advance was relatively very low and ranged from 2.12% for days to maturity to 23.32% for number of secondary branches.

Diversity

Feaven (2002) estimated phenotypic diversity values for the characters studied, populations, regions, and altitudes of collections, and found that anthocyanin pigmentation was found almost homomorphism in Gamo Gofa, Gojam, Wello, Hararge and Sidamo regions. Other characters such as plant height, flower color, seed color, and seed surface and growth habit showed intermediate (0.50) to high diversity index (H') estimates (0.99). The highest phenotypic diversity index was revealed by the plant growth habit. This was true for both the origins of accessions and altitudes where they were originally collected. The overall diversity index reported by Feaven (2002) for all the accessions was estimated to be 0.64±0.08, indicating that considerable morphological variability exist in the Ethiopian collections.

Cluster Analysis

Cluster analysis is one of the tools for assessing variability in collections made from different environments or regions. It measures the genetic distance between the accessions or populations under consideration. Feaven (2002) clustered 50 Ethiopian chickpea populations collected from 10 regions. All these were grouped into 7 (A, B, C, D, E, F, G) clusters (Table 3). Among all the clusters, cluster C showed largest distances from clusters D (249.19), E (135.56), F (109.04) and G (144.42), respectively. Other clusters that had relatively large genetic distances are clusters A and C, A and D, B and C, and B and D. Cluster C, which contained only two accessions from Tigrai region was found to be unique and could produce good recombinants when crossed with clusters D, E, F and G.

Isozymes in chickpea

Several isozyme studies undertaken in chickpea revealed very low or no polymorphism (Oram et al., 1987; Gaur and Slinkard, 1990; Kazan and Muehlbauer, 1991; Tuwafe et al., 1998). It was only Feaven (2002) who could detect relatively good resolution for Aspartate aminotransferase, Esterase and Isocitrate dehydrogenase enzymes, while others showed poor resolution. Therefore, this study could not detect any polymorphism in the 50 Ethiopian chickpea populations.

CHICKPEA BREEDING

Germplasm Development

The success of any crop-breeding program is determined by the availability of variability in its genetic resources. The genetic variability can be obtained through collection of local germplasm, introduction, and hybridization. Since 1994, NCIP has introduced a large number of chickpea accessions (5000) from ICARDA and ICRISAT in the form of pure lines, segregating populations and breeding lines. It has also maximized the indigenous collections available at the Institute of Biodiversity Conservation and Research (IBCR) of Ethiopia. Wild Cicer species with resistance to different biotic and abiotic stresses were introduced from ICARDA. This has enabled the program to release Kabuli varieties that are now being used by the Ethiopian farmers.

Table 1. Correlation among ten different traits of fifty chickpea populations in Ethiopia.

Character*	DTF	DTM	GYPP	HI	TSW	NPB	NSB	NSPP	PH
BIY	0.091**	0.025	0.538**	-.463**	0.097**	0.115**	0.204**	0.220**	0.285**
DTF		-.094**	0.125**	-0.017	-.412**	0.125**	0.214**	0.066**	0.105**
DTM			0.040	0.024	-0.049	-0.041	-0.017	0.037	-0.009
GYPP				0.286**	0.084**	0.248**	0.351**	0.382**	0.352**
HI					-0.052*	0.098**	0.106**	0.094**	-0.015
TSW						-0.049	-.086**	-0.022	-0.021
NPB							0.671**	0.381**	0.216**
NSB								0.532**	0.449**
NSPP									0.577**

Significance level: ** + P<0.01, * + P<0.05, DTF = Days to 50% flowering; DTM= Days to 90% maturity; NPB= Number of primary branches; NSB= Number of secondary branches; PH =Plant height at maturity (cm); TSW= 1000-seed weight (g); BIY= Biological yield (g); GYPP=Grain yield / plot (g); NSPP= Number of seeds per plant; and HI = Harvest index. Source: Feaven, 2002.

Table 2: Estimates of phenotypic and genotypic coefficient of variation (PCV & GCV), broad sense heritability (h2) and genetic advance (GA) for ten traits in chickpea population.

Character	Mean	Vp	Vg	Ve	PCV%	GCV%	h2	GA (%of mean)
DTF	46.84	6.45	4.82	1.63	5.42	4.68	75	8.37
DTM	137.5	2.45	0.24	2.21	1.14	1.10	90	2.12
NPB	2.05	0.07	0.04	0.03	12.68	8.28	57	15.12
NSB	18.18	14.53	7.89	6.64	20.96	15.46	54	23.32
PH	33.13	7.79	4.43	3.36	8.42	5.52	43	7.46
TSW	124.33	82.91	59.38	23.53	7.33	6.20	72	10.87
BIY	730.35	28127.96	3714.44	24413.52	22.96	8.35	13	6.15
GYPP	171.02	1665.33	313.04	1352.29	23.86	21.50	19	9.34
NSPP	111.53	696.38	251.79	444.59	23.66	18.91	36	17.55
HI	25.23	36.16	9.51	26.65	23.82	12.21	26	12.76

DTF = Days to 50% flowering; DTM= Days to 90% maturity; NPB= Number of primary branches; NSB= Number of secondary branches; PH =Plant height at maturity (cm); TSW= 1000- seed weight (g); BIY= Biological yield (g); GYPP=Grain yield per plot (g); NSPP= Number of seeds per plant; and HI = Harvest index. Vp = phenotypic variance, Vg = Genotypic variance, Ve = Environmental variance. Source: Feaven 2002.

Table 3. Mahalonobis's distance (D^2) of the seven clusters of 50 chickpea accessions.

Cluster	A	B	C	D	E	F	G
A	-	9.63	77.71**	70.99**	19.97*	18.51*	22.99**
B		-	71.35**	72.24**	18.31*	21.63*	27.49**
C			-	249.19**	135.56**	109.04**	144.42**
D				-	30.61**	35.08**	39.89**
E					-	13.59	29.91**
F						-	18.60*

Significant level: ** = P <0.01, * = P <0.05. Source: Feaven (2002).

Varietal Development and Release

The average national chickpea yield in Ethiopia is less than one ton per hectare. The low yield is mainly attributed to the biotic and abiotic stresses. In the process of breeding chickpea to develop varieties of wider adaptation that relatively perform well across varying environments, the major production constraints were identified and a strategy to alleviate these constraints was designed. The key achievement in the history of the Ethiopian chickpea improvement has been the release of DZ-10-4, DZ-10-11, Dubie and Mariye in the late 1970s and early 1980s. Although it was not officially recommended, DZ-10-1 (Kabuli) variety was also popular and used to be grown by commercial farmers around Debre Zeit before 1974. After 1994, the NCIP developed two parallel sub-breeding programs to improve both *desi* and Kabuli chickpeas to meet the requirement of different markets. The two *desi*-type chickpea varieties, Worku and Akaki, and other two Kabuli chickpea varieties, Shasho and Arerti, were nationally released for Vertisols in the mid-altitudes ranging from 1800 to 2300 m asl (Geletu and Yohannes, 2000; Solh et al., 1998). Geletu et al. (1996) gave detailed descriptions of these varieties. Although these varieties are tolerant/resistant to one or more diseases, Arerti proved to have resistance to both Fusaruim wilt and Ascochyta blight. Varieties ICCV-89303, ICCV-92318 and FLIP 88-42C were proposed for official release in 2003/04 cropping season as they would be very useful particularly for export markets. Further efforts made by NCIP have shown that the genetic potential of chickpea yield in the Ethiopian highlands is over 5000 kg (Table 4). The highest yields were obtained in Chefe Donsa, Akaki and similar environments, where Vertisols are dominant and retain water for longer growth period with relatively cool temperature during cropping season. Accessions such as ICCV-91216, ICCV-91114 and ICCV-89212 yielded about 5584, 4459 and 4088 kg/ha, respectively, at Chefe Donsa, and over 3000 kg/ha at Akaki. These lines are very responsive to good environments. Many of the lines with high yield have smaller seed size than the released *desi* varieties Mariye and Worku. The results of the national yield trials of *desi* and Kabuli chickpea conducted over years clearly indicated that Akaki, Chefe Donsa and Debre Zeit were the best sites for selecting high yielding varieties for good chickpea growing environments, whereas Alem Tena, Goro, Minjar and Mekele are good for selecting varieties suitable for dry areas. Interestingly, the Kabuli lines ICCV-93512 and ICCV-93408 yielded also 5274 and 5118 kg/ha at Akaki, which indicated the genetic potential of Kabuli chickpeas for further improvement to exploit the demanding export markets. However, these are not suitable for the dry areas like Alem Tena, Goro and Mekele. Traditionally, Kabuli chickpeas were considered as low yielders, but our yield data indicated that Kabulis performed as well as *desi* chickpeas particularly in the highlands of Ethiopia (Table 5).

Chickpea for Non-Traditional Areas

Prospects for increasing chickpea production by introducing the crop to the non-traditional systems where cereals such as sorghum and maize are mono-cultured particularly in the semi-arid and arid areas has been indicated (Geletu and Million, 1996). This is justified by the results of the trials conducted at Alem Tena (Rift Valley), Goro (Bale) and Mekele (Tigrai) that have shown good prospects to expand chickpea in the dry areas provided that suitable varieties and their appropriate agronomic packages are developed and popularized. The results obtained from the trials conducted at Pawe Agricultural Research Center (in a non-traditional chickpea growing area) have been very encouraging. From the 2002/2003 National Yield Trial (Kabuli), eight lines yielded more than 1200 kg/ha with the highest yield of 1514kg/ha. Most of the desi lines gave yielded more than 1500kg/ha. It should be noted that these lines were selected for the mid- and high-altitudes, and thus they are not tolerant to the relatively high temperature during grain filling at Pawe. Hence, evaluation of a large number of germplasm accessions at Pawe will provide an opportunity to identify high yielding and adaptable genotypes for Pawe and similar environments. This requires an investment in human power and facility development to enhance the identification of suitable varieties and other technologies that will allow exploitation of the potential that exists in these regions.

Table 4. Mean seed yield (kg/ha) of *desi* chickpea genotypes selected form advanced yield trial, 1997/98.

No	Genotype	Locations			Mean
		Akaki	Chefe Donsa	Debre Zeit	
1	ICCV-91114	3428	4459	1229	3039
2	ICCV-91216	3290	5584	1145	3340
3	ICCV-89212	3597	4088	964	2883
4	ICCV-91128	3227	3900	1104	2744
5	ICCV-89205	2924	4020	1013	2652
6	ICCL-87533/85-DZ/2	3307	4004	949	2753
7	Akaki	2657	4049	1039	2582
8	Local Check	2246	3066	893	2068
	Mean	3085	4146	1042	
	SE±	445	701	112	

Table 5. Mean seed yield (kg/ha) of Kabuli chickpea genotypes in national variety trial, 1999/2000.

No.	Variety	Location			Mean
		Akaki	Chefe Donsa	Debre Zeit	
1	ICC-14808	4961	3682	3504	4049
2	ICCV-93512	5274	3601	3049	3974
3	ICCV-93506	4772	3142	3192	3702
4	ICCV-93-410	4863	3475	3401	3913
5	FLIP-89-84C	4608	3091	3844	3847
6	FLIP-91-75C	4735	3167	2440	3447
7	ICCV-93408	5118	3227	3770	4038
8	ICCV-92318	4778	3129	3171	3692
9	FLIP-94-78C	5057	2882	3722	3887
10	FLIP-88-42C	3795	3436	3560	3597
11	FLIP-93-64C	4364	2596	3153	3371
12	DZ-10-5	3892	2614	2057	2854
	Location mean	4603	3440	3229	3757
	C.V (%)	15.0	12.0	11.7	
	LSD at 5(%)	982	517	535	
	Total plot size (m2)	4.8	4.8	4.8	
	Harvested area (m2)	2.4	2.4	2.4	

Breeding for Irrigated Agriculture

Rained agriculture has become unreliable in the Ethiopian context since the country has suffered for over three decades due to recurrent droughts. On the other hand, the country has untapped water resources (many big rivers, streams and runoff) which could be used for irrigation. To exploit these natural resources, trials were designed and conducted to identify suitable chickpea varieties for irrigated agriculture. The results revealed that a yield of more than 3000 kg/ha can be easily obtained from varieties that are responsive to irrigation. Kabuli lines such as FLIP-88-42C, ICCV-92318, FLIP91-75C, ICCX-910406 and FLIP97-263C yielded more than 3000 kg/ha. Similarly, yields of about 3500kg/ha were obtained from *desi* varieties Akaki, ICCV-92069 and ICCV95615 in 2001/02. This suggests that NCIP also needs to focus on the development of varieties and packages for the irrigated areas.

Breeding for Taller Plants

One of the bottlenecks for the expansion of chickpea in Ethiopia is its unsuitability for mechanization. The plants are hand-pulled at harvesting and threshed by draught animals. The manual harvesting and threshing are not acceptable to the commercial farmers since they are labor intensive. Therefore, development of tall and compact plant type that is suitable for machine harvest is required to mechanize chickpea in Ethiopia. There are commercial farmers interested to grow chickpea for export markets, and development of such a plant type will promote chickpea production in Ethiopia. Geletu and Yadeta (1995) emphasized the strategy to use the resources of IARCs , and introduced Kabuli accessions with tall heights. This effort should further continue to get good yields.

BREEDING FOR MAJOR STRESSES

Drought

Recurrent drought and poverty have made Ethiopians to suffer from food shortages and malnutrition. The ongoing efforts of support of international communities towards mitigating the impact of drought situation are encouraging but a temporary. The long-term solution should come from research efforts to ensure food security through development of integrated crop production. One of these approaches is to identify crops and varieties that can be used in these areas. Chickpea is one of the potential crops for the drought prone environments. Drought is the most important abiotic constraint to chickpea production in Ethiopia, and the research initiated at Alem Tena would help to generate varieties and agronomic packages suitable for drought prone areas (Geletu and Million, 1996).

Efforts were made since 1991 to develop drought-tolerant chickpea varieties. Some drought-tolerant chickpea lines have been identified, and the selection criterion has been studied for drought tolerance (Geletu and Yadeta, 1994; Yadeta and Geletu, 2002). The observations recorded at Alem Tena showed that seed yield was correlated with root length, root mass, length of lateral roots, shoot/root ratio, shoot length and shoot mass. However, seed yield had significant positive association (0.54*) with only root length indicating that lines with deep roots had better tolerance since they could further absorb soil moisture in deeper zones than susceptible ones (Geletu and Yadeta, 1994).

Yadeta and Geletu (2002) found that drought tolerant lines have smaller leaf area with no further reduction under low moisture stress. Additionally, they have high dry root weight, root volume and rooting depth, which are not significantly reduced under low moisture stress as compared to the susceptible variety Mariye. ICC4958 (DRI= 0.624) as drought-resistant check was used to study drought response index (DRI). Genotypes like ICCL-89316, ICC-14156, ICCL-83149, ICCL-89218, ICC-13974 and ICC-13960 had better tolerance to drought. Among these ICC-14156, ICC-13974 and ICCL-89218 were high yielding lines. The DRI of these test entries is given in Table 6.

Table 6. Drought response index (DRI) for seed and biological yields in some chickpea genotypes in Ethiopia.

Genotypes	Seed yield	Biological yield
ICC-8582	-0.135	0.234
ICC-12703	-0.543	0.242
ICC-11942	-0.468	0.312
ICCL-89316	1.612*	0.367
DZ-10-11	-0.869	-3.479*
Mariye	-0.869	-3.479*
ICC-13960	0.740	0.287
ICC-13974	1.014	0.330
ICC-7336	-0.068	0.334
ICC-4934	-0.555	0.384
ICCL-820016/85-DZ/9-2	-0.730	0.309
ICC-4958	0.624	0.375
ICC-14156	1.496*	0.393
ICCL-83149	1.262	0.850
ILC-2325	-1.168	0.399
ICCL-89243	-1.058	0.363
ICCL-89218	1.277	0.233
ICC-7534	-0.662	0.233
ICCL-12337X ICC-1069/L-NO-132-1X ICCL-85216	-0.990	0.412
ICCL-84215	0.177	-1.454*

* Significant at 5% probability level. Source: Geletu and Yadeta (1994).

Water-logging

The Ethiopian farmers have grown chickpea for centuries on residual soil moisture due to its inability to stand water logging during the heavy rainy season of June to August. The problem is serious on Vertisols, and affects root aeration. It often causes a total kill of the crop plants and a total yield loss when it occurs at high intensity on the Vertisols. If water-logging-tolerant lines are available, an immense increase in chickpea yields can be made. For instance, Geletu and Abebe (1982) obtained a yield increase of 95%, 118% and 11% in three chickpea varieties (NEC756, DZ-10-2 and Dubie) in 1978 by advancing planting date from September to August. Therefore, identification of tolerant lines combined with good management could help to maximize this potential. To achieve this, Geletu and Yadeta (1995) evaluated about 100 chickpea lines by imposing 30-day-old seedlings in pots to water-logging (Table 7). This study showed that 74% of these accessions survived for more than 30 days, where the most susceptible line ICC-10450 survived for only less than 15 days. Combination of the tolerant lines with the improved management as recommended by Geletu *et* al. (1997) will help to advance sowing time to August and increase yield of chickpea in Ethiopia. Geletu (1999) and Geletu and Yohannes (2000) also recommended further strengthening of the screening work for tolerance to water logging to make use of good growing season.

Wilt and Root Rots

A regional network under the aegis of the Nile Valley and Red Sea Region of ICARDA was developed in 1995 to help the participating national research programs of Ethiopia, Egypt, Sudan and Yemen to coordinate their efforts and make use of trained human power and facilities within the region to manage the soil-borne diseases of food legumes. Ethiopia had the responsibility to coordinate the network because it had well developed sick plots of Fusaruim wilt for chickpea and lentil at Debre Zeit, and sick plot of black root rot (*Rhizoctonia solani*) for faba bean at Ambo.

Results of a 3-year survey done in Ethiopia, Sudan and Egypt revealed that Fusarium wilt caused by *Fusarium oxysporum* was the major soilborne disease of chickpea in the three countries. Dry root rot, caused by *Rhizoctonia bataticola*, was found as the second important soil borne disease on chickpea, except in Egypt where the stem rot was the second important after Fusarium wilt (Geletu et al., 1998 and Geletu et al. 2001). The sick-plot at Debre Zeit was used for the initial screening work and promising lines were sent out to the member countries to select suitable lines for evaluation under their conditions. An effort made at the national and regional levels yielded some promising results. At the national level, the two Kabuli varieties Shasho and Arerti that were released for commercial production, and ICC-12442 (*desi*) were resistant (Geletu et al., 1998). The results of the network revealed that H-68-170 and ICCV-89238 were resistant at Adet (Ethiopia), Beja (Tunisia) and Hudieba (Sudan). Other lines with the rating of 0, 3 and 7 at Adet and 0 rating at Beja were ICCV-91108, ICCV-91128 and ICCV-92034. None of these lines showed resistance or tolerance at Debre Zeit. During 1993 to 1995, ICC-1891 and ICC10592 were found resistant/tolerant to wilt and selected for the breeding work. However, there was no systematic work undertaken on the dry root rot, collar rot, wet rot and others under Ethiopian conditions.

MAJOR ACHIEVEMENTS

The crop improvement program has released relatively high yielding varieties that out-yielded the local cultivars by more than 100% (Table 8). The major advantages of these varieties are their tolerance to the major stresses like Fusarium wilt, terminal low-moisture stress and their abilities to maximize the available soil moisture during grain filling. Moreover, the development of their proper agronomic management such as planting date and seeding rate has helped to express their genetic potential.

CONCLUSIONS AND FUTURE DIRECTIONS

Significant increases in the demand for chickpea have been seen very recently. There is high demand for *desi*-type from the Indian sub-continent and for Kabuli chickpeas from Egypt, Israel, Turkey, and North Africa. However, the country could not meet the external demand although it was in a position to export reasonable quantity. Generally, Ethiopia has an advantage because of its location in a strategic region (near to the Middle East via Djibouti and through Sudan Port to North Africa) provided that efforts are made to produce chickpea of uniform seed size and color of local landraces or improved *desi* varieties and large-seeded Kabuli types. This is because presently the chickpea produced in Ethiopia is mainly mixture of black-seeded with yellow or brown seeded *desi*-type. Practically, no Kabuli chickpeas are produced in the country except in small plots in the central highlands. Value-added products of chickpea as sources of protein could also be locally processed. Therefore, special attention should be given to the high and medium priority research areas to meet the future increasing domestic and export markets of chickpea as shown in Table 9. Developments of varieties of high yield and quality (seed size and color), resistant to major diseases with wider adaptation are very critical for the chickpea improvement in Ethiopia. Other potential areas of research in the future are to develop varieties for irrigated agriculture and non-traditional regions.

Table 7. Chickpea lines that survived water logging for more than 30 days.

No. of days survived	No. of entries	Name of entries
31-35	11	ICC-14100, DZ-10-11, ICC-84204, ICC-13845, DZ-10-16-2(Worku), ICC-11320, ICC-12623, ICC-13959, ICC-3528, ICC-8594, ICC-12612
36-40	18	ICC-12668, ICCL-820028/85-DZ/4-1, ICC-13839, ICC-8597, ICC-13835, ICC-12582, ICC-13940, ICCL-84312, ICC13974*, ICC-8587, ICC-14126, ICC-14017, ICC-12684, ICC-4934, ICC-14139, ICC-13984, ICC-13890, ICC-12591
41-45	17	ICC-83232, ICC-12632, ICC-13930, ICC-14138, ICC-12665, ICC-14146, ICC-14028, ICCL-84227, ICC-12620, ICC-14156*, ICC-126330, ICC-14009, ICCL-7883/82-DZ/1, ICC-13976, ICC-12883, ICC-12707, ICC-14166.
46-50	14	ICC-4918, ICC-12795, ICC-7539, ICCL-820025/85-DZ5-1, ICC-12855, ICC-13896, ICCL-84202, ICC-14131, ICC-13829, ICCL-89225, ICC-14158, ICC-12635, ICC-12551, DZ10-4Xjg-79-23-88

Source: Geletu and Yadeta (1995)

Table 8. Performance of improved varieties of chickpea over local cultivars at Udie (near Debre Zeit).

	Mean seed yield (kg)				Percent increase over local		
Yield	Shasho (6)	Akaki (14)	Worku (5)	Local	Shasho	Akaki	Worku
Maximum	2040	2400	1600	868	135.0	176.5	84.3
Mean	1560	2263	1360	475	228.4	376.4	186.3
Minimum	240	1360	560	209	14.8	550.7	167.9

Table 9. Future priority areas of Research.

High priority research area	Medium priority research area	Low priority research area
Varietals development for wider & specific adaptation	Water logging	Frost
Wilt/root rots	Ascochyta blight	Stunt
Drought	African ball worm	Cutworm
Export quality (seed size, color, cooking, protein etc.)	Bruchids	Nematodes
Crop management (agronomy)		

Source: EARO (2002).

REFERENCES

Abebe Tullu. 1985. Correlation and variation studies on yield and some plant characters in indigenous and exotic chickpea varieties. M. Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

EARO 2002. Review of the cool season legume research program. Government of the Republic of Ethiopia and Royal Netherlands Embassy, Royal Tropical Institute, Amsterdam,

EEPA. 2002a. Pulses for India. Trade Point Newsletter Vol. 5. No.18. 4.

EEPA. 2002b . Pulses, lentils, beans, peas for India. Trade Point Newsletter Vol. 5. No. 20.3.

EEPA. 2003a. Pulses (beans, peas and lentil) for India. Trade Point Newsletter Vol. 6 No. 6.2.

EEPA. 2003b. White kidney beans and chickpeas for Turkey. Trade Point Newsletter Vol. 6. No. 2.2.

EEPA. 2003c. Chickpeas, red split lentils, green mungbeans, white kidney beans for India. Trade Point Newsletter Vol. 6. No. 2.3.

Feaven Workeye. 2002. Morphological and biochemical diversity analysis in chickpea (Cicer arietinum) landraces of Ethiopia. M.Sc. Thesis, School of Graduate Studies, Addis Ababa University.

Gaur, P.M., and A.E. Slinkard. 1990. Genetic control and linkage relations of additional isozyme markers in chickpea. Theoret. Appl. Genet 80: 648-656.

Geletu Bejiga.1999. Chickpea production in Ethiopia. *In* Crops of Ethiopia. Biodiversity Conservation and Research Institute, Addis Ababa, Ethiopia (unpublished).

Geletu Bejiga, and Abebe Tullu. 1982. The influence of planting dates on the yield of three chickpea (Cicer arietinum) varieties. Eth. J. Agric. Sci. 4: 61-66.

Geletu Bejiga, and Yadeta Anbessa.1994. Breeding chickpea for drought Resistance. p. 145-146. *In International Symposium on Pulses Research.* Abstracts. International Symposium, 2-6 April 1994, New Delhi. Indian Society of Pulses Research and Development. Institute of Pulses Research, Kanpur and Indian Agricultural Research Institute, New Delhi, India.

Geletu Bejiga, and Yadeta Anbessa .1995. Water-logging tolerance in chickpea. International Chickpea and Pigeon pea Newsletter No.2:23-24.

Geletu Bejiga, and Million Eshete 1996. Chickpea in Ethiopia. p. 137-153. *In* N.P. Saxena et al. (Eds.) *Adaptation of Chickpea in the West Asia and North Africa Region.* ICRISAT/ICARDA.

Geletu Bejiga, Million Eshete, and Yadeta Anbessa .1996. Improved cultivars and production technology of chickpea in Ethiopia. Research Bull.No.2. Debre Zeit Agricultural Research Center, Alemaya University of Agriculture, Debre Zeit, Ethiopia. 60 pp.

Geletu Bejiga, Abebe Tullu, Seifu Tsegaye, Million Eshete, and Yadeta Anbessa. 1997. Effect of improved soil surface drainage on the yield of chickpea grown on Vertisols. African Crop Sci. J. 5: 23-29.

Geletu Bejiga, Negussie Tadesse, M.B.Solh, W.Suliman, Nagi Abu-Zeid, and H.Halila. 1998. Resistance breeding for wilt and root rot diseases in chickpea, p. 267. *In* Opportunities for High Quality, Healthy and Add-value Crops to Meet European Demands. Abstract 3rd European Conference on Grain Legumes. 14-19 November 1998, Valladlid-Spain.

Geletu Bejiga, and Yohannes Degago.2000. Region 4. Sub-Sahara Africa, p. 99-105. *In* R.Knight (Ed.) *Linking Research and Marketing Opportunities for Pulses in the 21st Century.* Kluwer Academic Publishers, The Netherlands. (

Geletu Bejiga,N.Abou-Zeid, W.Suliman,S.Ahmed, and A. Hssanein.2001. Managing wilt and root rots of food legumes in the Nile Valley countries. ICARDA CARVAN15: 39-40.

ICRISAT.2000. Bringing hope to marginal environments: Chickpeas improvement at ICRISAT. ICRISAT, Patancheru, I ndia.

Kazan , K., and Muehlbauer, F.J. 1991. Allozyme variation and phylogeny in annual species of Cicer (Leguminosae). Plant Syst. and Evol. 175:11 - 21.

Oram, R.N., M.A.Q. Shaikh, K.M.S. Zaman, and A.H.D Brown. 1987. Isozyme similarity and genetic differences in morphology between Hyprosola, a high yielding, high protein mutant of chickpea (Cicer arietinum L.) and its parental cultivar. Env. Exptl. Botany 27. 455 – 462.

Solh, M.B. 1996. The Nile Valley Regional Program (NVRP): A Model for Technology Transfer. NVRP/ICARDA. 26 pp.

Solh, M.B, N. Hadad, and Hailu Gebre. 1998. Problem – solving regional networks on cool-season food legumes and cereals. ICADRDA/ NVRSRP, Cairo, Egypt.

Tuwafe Solomon, A.L. Kahler, A. Boe, and M. Ferguson. 1998. Inheritance and geographical distribution of allozyme polymorphism in chickpea (Cicer arietinum L.). J. Heredity 79: 170 – 174.

Yadeta Anbessa, and Geletu Bejiga 2002. Evaluation of Ethiopian Chickpea landraces for tolerance to drought. Genet. Resource and Crop Evolution. 49:557-564.

Review of Field Pea (Pisum Sativum L.) Genetics and Breeding Research in Ethiopia

Mussa Jarso, Tezera Wolabu and Gemechu Keneni

Holetta Agricultural Research Center, P.O. Box 2003, Addis Ababa, Ethiopia

ABSRACT

Field pea (*Pisum sativum* L.) is the third most important pulse crop in Ethiopia, after faba bean and chickpea, in terms of both area and total annual production. It is a source of food, feed and cash to the producers, and also plays a significant role in soil fertility restoration through biological nitrogen fixation. The productivity of field pea in Ethiopia is far below the potential, as reflected in the wide gaps in grain yields between smallholder farmers' and researchers' fields. This is due to several production constraints including the biological limitations of the crop, and biotic and abiotic stresses under farmers' conditions. Genetic improvement of the crop is more preferable to reverse the situation and increase yield than the continual manipulation of the growing environment. Biotic stresses like diseases and insect-pests of field pea have received much attention through breeding efforts since the early 1960s, while abiotic stresses like unfavorable soil environment and frost received little attention. As a result, a number of improved varieties have been released to farmers. In this paper, breeding efforts made since 1993 have been presented in terms of both scientific information and physical outputs. Secondary information, results from the analyses of primary records of some basic studies and multi-location variety trials were used as a basis for this review. Discussed in the paper also include the extent and pattern of geographical distribution of genetic diversity in the Ethiopian landraces, level of genetic variation for yield and the important yield determinants in the available germplasm. Relative values of secondary traits as selection criteria for high-yielding varieties, classification of selection environments, participation of farmers in varietal selection, extent of genotype by environment interaction and field pea varieties identified for better and consistent performance under different ecologies and cropping systems. Finally, breeding approaches for the development of appropriate varieties for different domains, challenges and opportunities are discussed.

INTRODUCTION

Though the origin of field pea (*Pisum sativum* L.) is controversial, Ethiopia is undoubtedly a center of diversity of field pea (Vavilov, 1950; Frankel, 1973; Harlan, 1973; Engels et al., 1991). According to FAO (1998) centers of origin/diversity of field pea are East Africa and West Asia with secondary centers in South Asia and South and East Mediterranean sub-regions. The species *P. sativum* is dominant in Ethiopia even though wild and primitive forms are also known to exist in the high elevations of the country (Hagedorn, 1984; Amare and Adamu, 1994).

According to CSA (2002), field pea covers about 160,000 ha of the total arable land with a total production of 113,690 tons. This constitutes about 15% of the total area covered by pulses and 11% of the total annual production of pulses in the country. Field pea grows in several regions of the country; in altitude range of 1800-3000 m asl and annual rainfall of 700-1000 mm. The crop plays an important role in the economic lives of the farming communities in the highlands of Ethiopia. It serves as a source of food and feed with a valuable and cheap source of protein. It plays a significant role in soil fertility restoration as a suitable rotation crop that fixes atmospheric nitrogen. It is also a good source of cash to farmers and foreign currency to the country.

Despite its importance, however, the productivity of the crop is only 0.8 t/ha, which fluctuates and is far below the potential as compared to the research plot yields of 2.5–3.5 t/ha. The production has been constrained by several yield limiting factors. Among them, the important ones are the inherent low yielding potential of the indigenous cultivars (Asfaw et al., 1994), diseases like Ascochyta blight (*Mycosphaerella pinodes*) and powdery mildew (*Erysiphe polygoni*) (Dereje and Tesfaye, 1994), insect-pests like pea aphid (*Acyrthosiphon pisum*), African ballworm (*Helicoverpa armigera*) in the field and bruchids (*Callosobruchus chinensis*) in the storage (Kemal and Tibebu, 1994), poor soil fertility, unimproved cultural practices such as poor seed bed preparation and lack of fertilizer use (Amare and Adamu, 1994).

A comprehensive breeding program in field pea in Ethiopia started in 1960s with the main objective of improving productivity through generation of productive cultivars tolerant/resistant to different production constraints and suitable under different agro-ecologies of the country. As a result, a number of improved varieties were developed and released to farmers before 1993 (Asfaw et al., 1994). Similar efforts continued after 1993, and varieties have been recommended for cultivation in different environmental domains. However, results of research efforts since 1993 have not been systematically summarized and documented despite the absolute importance of such information for further improvement of the crop. The theme of this paper is, therefore, to review breeding efforts made since 1993 to alleviate problems associated with field pea production in Ethiopia, and to summarize the outputs of these efforts in terms of varieties developed and scientific information generated which could be of use for further crop improvement.

GENETIC STUDIES

Geographic Diversity in Landraces

Landraces are the genetic wealth that a crop acquires over many years of its existence (Chahal and Gosal, 2002). They have considerable breeding values as they contain valuable adaptive genes to different circumstances (Ceccarelli, 1994; Bunder et al., 1996; Chahal and Gosal, 2002). A large number of field pea landraces have been collected from the most important production areas in Ethiopia (Dawit et al., 1994). Such landraces are reported to have tremendous genetic diversity (Harlan, 1969; Hagedorn, 1984). A recent systematic study of the extent and pattern of genetic diversity in Ethiopian field pea landraces revealed the existence of high genetic diversity (Gemechu et al, 2003). High to medium crop genetic diversity in collections from Shoa, Gojam, Gondar, Wollo and Tigrai, and low to trace genetic diversity in collections from Arsi, Gamogofa, Wellega, Illubabor, Kefa and Beghemidir have been reported (Melake, 1975; Melaku, 1988). Gemechu et al. (2003) reported that collections from Arsi showed greater diversity than those from other parts of the country (Table 1), although no precise explanation for this has been given. Higher genetic diversity in collections from Arsi as compared to those from Wello and Gojam has also been reported in barley (Demissie and Bjφrnstad 1997). This indicates that there is high genetic diversity in the Ethiopian field pea landraces even though it is not uniformly distributed across the regions indicating that accessions from different regions might be closely related regardless of their geographic area, and accessions from one region might have different genetic backgrounds. Generally, there was no definite correspondence between geographic origin and genetic diversity. Tesfaye (1999) found similar results with 64 accessions collected from nine major field pea-growing areas of Ethiopia. Reports elsewhere (Dobhal and Ram, 1985; Gupta et al., 1992) showed the absence of parallelism between genetic diversity and geographic diversity. Therefore, future collection and conservation missions and breeding programs should focus on effective and efficient exploitation of not only inter-regional but also on intra-regional diversity in field pea.

Genetic Variation and Heritability

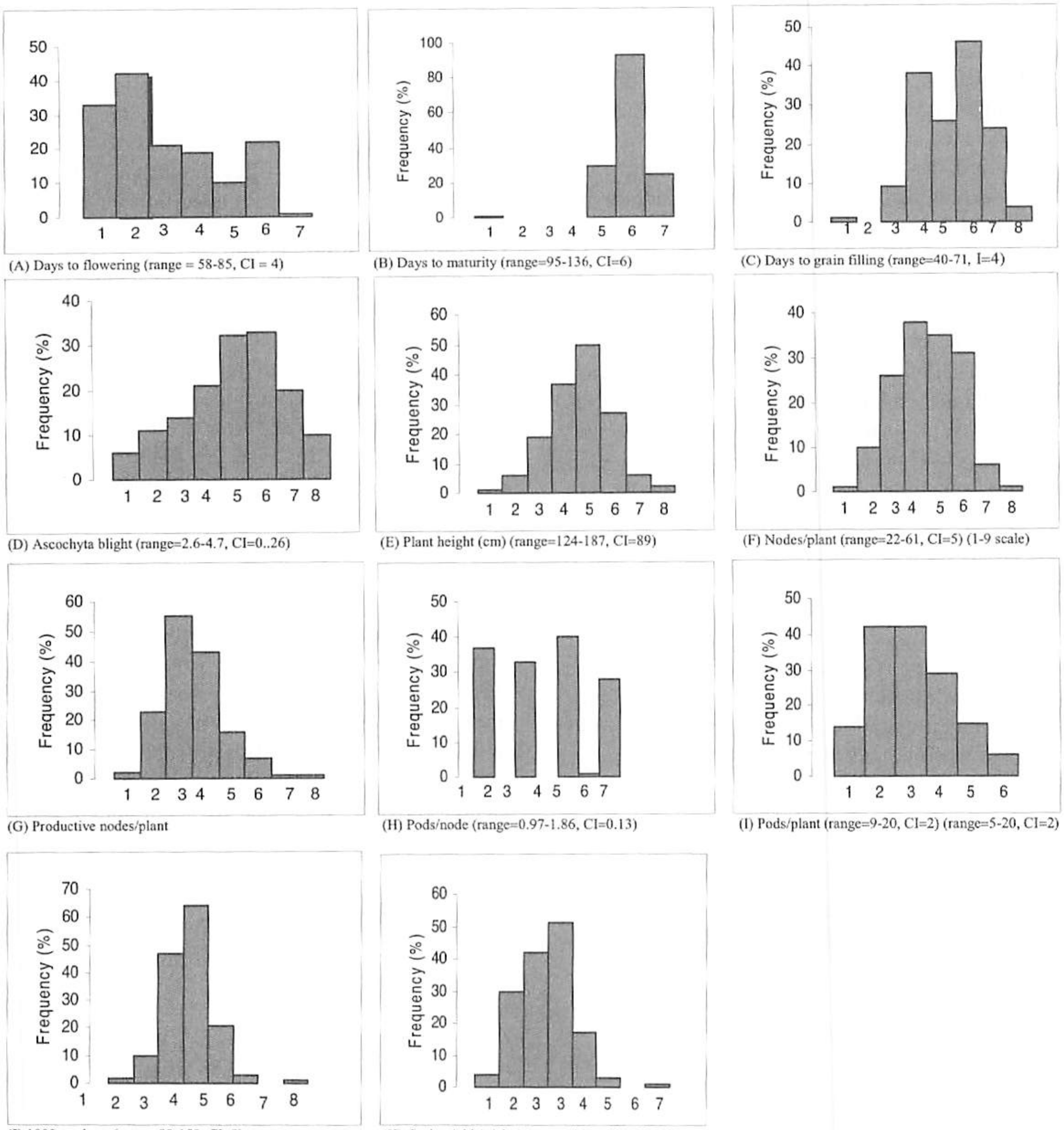
Studies of genetic variation in field pea revealed the existence of genetic variations for different traits (Tesfaye, 1999; Tezera, 2000); highest for biological and grain yields, number of seeds and harvest index per plant, number of primary branches, and 100-seed weight; intermediate for number of pods per plant and plant height, while the lowest for phonological traits. They also reported high heritability values for phenological traits (75-98%), followed by biological yield per plant (82%), number of seeds per plant and seeds per pod (77%), and harvest index per plant (75%). Genetic advance as percent of mean of grain yield, primary branches, number of seeds, biological yield, harvest index per plant were moderate (30-57%) (Tesfaye, 1999; Tezera, 2000). The frequency distributions of 11 traits in 148 field pea landraces collected from different geographical regions have shown the presence of wide range of variation for most of the traits (Fig. 1).

Tesfaye (1999) demonstrated that the greatest accuracy in estimating variability components and heritability of traits when observations were taken on a single plant basis instead of whole plot. Both genetic coefficients of variation and heritability estimates were high for seed and biological yields per plant, number of seeds per plant and primary branches as compared to that of whole plot data. Similarly, Tezera (2000) demonstrated the importance of excluding data of environments with high CV and non-significant difference for genotypes while estimating variability components and heritability of traits using data of multi-location trials. When effects of high CV were not excluded genotypic and G x E interaction variances were very much underestimated, whereas error variance is overestimated resulting in unreliable estimation of genetic variability parameters and heritability values. In general, the disparity between data based on single plant and whole plot might have occurred due to variations introduced while taking samples, and the high CV is an indication of poor management of the experiment. Such problems have practical implications on the results obtained. Therefore, care must be taken in managing the experiments, taking data and data analyses not to draw unrealistic conclusions.

Table 1. Clustering pattern over five clusters of field pea accessions from different origins.

Origin	Number of accessions	No. of accessions in each cluster (C)				
		C_1	C_2	C_3	C_4	C_5
North Wello	19	13	4	2	--	--
South Wello	7	3	4	--	--	--
North Gonder	31	17	11	3	--	--
North Shewa	36	24	10	2	--	--
Arsi	55	36	13	4	1	1

Source: Gemechu et al. (2003).



(A) Days to flowering (range = 58-85, CI = 4)
(B) Days to maturity (range=95-136, CI=6)
(C) Days to grain filling (range=40-71, I=4)
(D) Ascochyta blight (range=2.6-4.7, CI=0..26)
(E) Plant height (cm) (range=124-187, CI=89)
(F) Nodes/plant (range=22-61, CI=5) (1-9 scale)
(G) Productive nodes/plant
(H) Pods/node (range=0.97-1.86, CI=0.13)
(I) Pods/plant (range=9-20, CI=2) (range=5-20, CI=2)
(J) 1000 seed wt. (range=88-159, CI=9)
(K) Grain yield (g/plot) (range=191- 638, CI=56)

Fig. 1. Frequency distributions for 11 traits in 148 field pea landraces collected from different geographical regions. Sequential numbers represented classes; ranges with class intervals (CI) are given under each graph.

Association among Traits

Yield is a highly polygenic trait strongly influenced by environmental effects. Grain yield in field pea is assumed to be the product of critical yield determinants, the improvement of which may result in indirect improvement of grain yield. However, the genetic expression of different traits and the extent and pattern of their cause-effect relationship with grain yield can vary with the changes in genotype and the environment. Some traits may become more important than others with changes in environment (Banziger et al., 1997). Despite lower heritability and genetic variance of grain yield, heritability and genetic variation of some secondary traits may remain high, and at the same time the traits may maintain good level of positive correlation with grain yield (Bolanos and Edmeades 1996; Banziger et al., 1997).

The analysis of data from a series of variety trials conducted from 1994 to 2000 using relatively large number of genotypes to determine the relative importance of yield determinants as selection criteria for improving grain yield in field pea showed that yield had strong positive correlation with number of seeds per pod and 1000-seed weight. This indicates that 1000-seed weight is less affected by environmental factors, and the phenotype could reflect the genotype. Partap et al. (1992) and Tezera (2000) also reported the heritability of this trait to be high (96%-98%) and, therefore, simultaneous selection for grain yield and 1000-seed weight could be more efficient than direct selection for grain yield *per se*. Number of pods per plant and seeds per pod showed very low heritability and genetic variance, and hence selection through these traits to improve grain yield may not be effective.

Studies from Ethiopia (Tesfaye, 1999; Tezera 2000) and elsewhere (Singh, 1990; Rathore, 1993a,b) showed the existence of positive association between grain yield and a number of other components, namely, biological yield per plant, harvest index per plant, number of primary branches, pod length, number of pod per plant, 1000-seed weight and number of seeds per pod indicating that selection for any one of them permits improvement in grain yield. However, such positive interrelationship could be affected by environmental changes both in magnitude and direction for certain traits. For example, analysis of data from a trial conducted at nine locations showed that grain yield tended to have positive correlation with plant height in a long growing season as compared to a short growing season at Holetta and Bekoji. However, 1000-seed weight showed no such change within locations showing consistently strong positive correlation with grain yield than the other traits (Table 2 and Fig. 2).

Path coefficient analysis revealed number of seeds per plant, harvest index, plant height and biological yield exerted positive direct effects on grain yield (Devendra et al., 1995; Golaszewski and Pusio, 1996; Tesfaye, 1999) while number of days to grain filling exerted maximum negative effect on grain yield although it had positive indirect effect through number of pods per plant and 1000-seed weight.

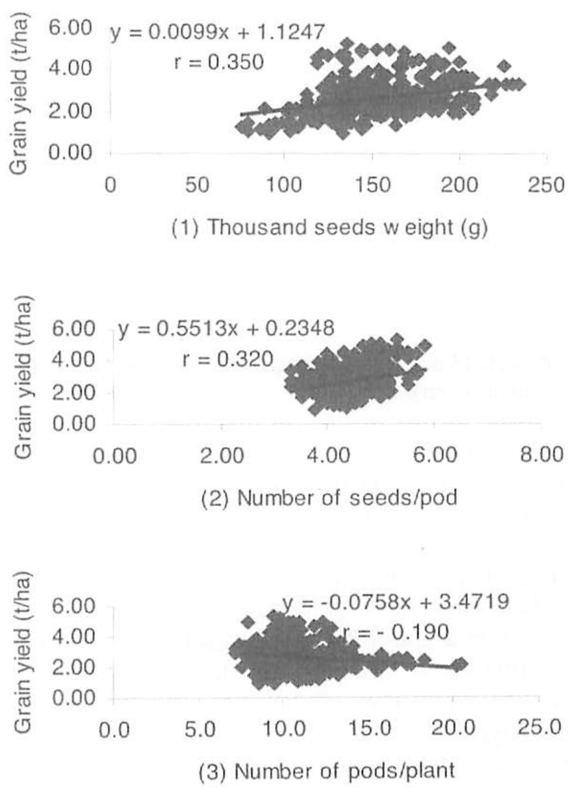


Fig. 2. Interrelationship between grain yield and some yield components – (1) number of pods per plant, (2) seeds per pod and (3) 1000-seed weight.

VARIETAL DEVELOPMENT

Objectives

The general objective of field pea breeding program is to develop and produce improved varieties that are stable and high yielding, resistant to major diseases, and of good seed size and color. It is also equally desirable to have cultivars that can be recommended for wider or specific adaptation.

Germplasm Enhancement

Genetic variation is a prerequisite for any improvement in a crop and it is the first step unless variation preexists (Sharma, 1994). From the creation of genetic variation, the next step is identification and isolation of plants having the desired combinations of characters and growing their progeny after selections. The efficiency of this activity determines the success of the breeding program. Pedigree and bulk methods are employed at the selection stages. The newly selected lines or populations are tested for grain yield and other traits to compare with the recently released varieties and the local checks. In the screening nurseries, the selected genotypes are evaluated for good pod setting, early flowering and maturity, Ascochyta blight tolerance/resistance, and for quality traits such as seed size and color (large-seeded, cream or white seeds). In addition to screening for yield and yield components, Holetta Agricultural Research Center (HARC) was used as a hot spot for screening for Acochyta blight, Denbi for Ascochyta blight and pea aphid, while Kulumsa for powdery mildew. Contributors to the field pea genetic variation are germplasm collections, introductions of exotic materials, and materials resulting from hybridization (Table 3).

Collections

Landrace collections are usually obtained either from IBCR (formerly called Plant Genetic Resource Center of Ethiopia, PGRC/E) or target collections by breeders in collaboration with IBCR. Out of 475 landrace accessions evaluated since 1994, 148 were from the target collections and the remaining were from IBCR collections. The former were recent collections from different parts of the country (Gonder, Gojam, Shoa and Arsi). Landrace collections, in general, are reservoir of genetic variablility and are sources of many valuable genes, especially those for adaptation (Chahal and Gosal, 2002). They are used either for release after selection for high yield and wide or specific adaptation or crossed with exotic materials. From the landrace collections, one variety, Holetta, has been released after selection for its superiority in grain yield and other agronomic traits.

Introductions

A total of 207 germplasm accessions were introduced from different sources between 1994 and 2002. Of these, 143 were obtained from ICARDA through Pea International Adaptation Trials; nine from Burundi; and 155 from Australia. The acquired materials were first evaluated in isolated quarantine plots at HRC, then the adapted germplasm were used for direct selection for yield, disease resistance, seed size, color, plant height, early flowering and maturity. Often, they were used for hybridization to transfer their desirable genes into the adapted materials. The introductions had remarkable qualities such as large seed size and white/cream seed color, which are preferred by users. There are many promising large-seeded materials with 1000-seed weight of more than 200 g and good level of grain yield (2.0–4.0 t/ha). From them, three varieties, viz., Tegegnech, Hasabe and Markos, were released for their superiority for grain yield and/or seed size. Tegegnech is an introduction from Burundi (pedigree of 061K-2P-2/9/2); Hassabe and Markos are introductions from ICARDA, pedigree of Ji No 116 and DMR- 4, respectively.

Hybridization

In the absence of desired variability from the existing materials, hybridization is the best method to create variability. In most cases, the exotic materials, with desirable characters, but not well-adapted, is crossed with the local adapted materials, which lack some useful characters. Hence, crosses are made between genotypes that differ for the traits of interest, and in segregating populations favorable phenotypes that have incorporated the desired characters are selected and evaluated. Crossing of field pea can easily be done manually by trained personnel. At Holetta many crosses are made every year and the segregating generations are tested at Holetta, representing high altitude area, and at Denbi and Kulumsa, representing mid-altitude areas. The level of success from crossing (ratio of effective pod to the number of crossed flowers) under field conditions ranges between 40–60% (53 % on an average), which is much better than that of faba bean (14-24%). From 1994 to 2002, three varieties (Adi, Milky and Wolmera), which were obtained through hybridization and selections, were released. Adi is a cross between a locally released variety, G22763–2C, and an introduction from USA, 305PS210813-3; Milky is a cross between two ICARDA materials, NEP 634 and 180-1; and Wolmera is a cross between a locally released variety, FpExDz, and an introduction from USA, 305PS210822-1. Relative contributions of local collection, introduction and hybridization, as sources of field pea germplasm in Ethiopia, between 1994 and 2000 are shown in Table 3.

VARIETY EVALUATION

In the advanced stage of variety evaluation, the test materials are planted and evaluated in multi-locations (usually three to five locations) to select consistently high yielding varieties that have wide or specific adaptation in the mid- and high-attitude areas of the country. These varieties are also evaluated for protein content, soaking ability, cooking time and taste in the national variety trial stage, before release. The varieties are evaluated at least at three locations each for one season in preliminary yield trials (PYT), in two replications, for one season (in three replication) in pre-national yield trials (PNYT), and for three seasons (four replications) in national yield trials (NYT). If the new variety is superior to the checks, it is planted in the final stage of variety verification trial (VVT), and evaluated by the national variety release committee for release.

A total of 1,985 germplasm obtained by collections, introduction and hybridization were evaluated in different stages of breeding from 1994 to 2002. The bulk of the germplasm were evaluated for mid-and high altitude-areas on red soils with no water-logging problem. In waterlogged Vertisols, a total of 380 germplasm from the national collections were screened at Ginchi station from 1996 to 1999 to identify materials suitable for these soils. The results indicated that field pea was much more susceptible to water logging when compared to faba bean. If drainage is improved using raised beds such as broad bed and furrow, the yield of field pea could be higher because these soils are inherently more fertile. This calls for a simultaneous improvement of drainage as well as varieties. Multi-location yield trials are mainly conducted at Denbi, Kulumsa, Asassa, Adet, Sodo Zuria and Mekele, representing the mid-altitude areas, and Holetta, Bekoji, Sinana, Dabat and Shambu, representing the high-altutude areas.

Table 2. Genetic correlation coefficients of six traits with grain yield at nine test locations.

	Traits correlated with grain yield					
Location	1000-seed weight (g)	Number of seeds/pod	Plant height (cm)	Days to flower	Days to mature	Days to grain filling
Denbi	0.27	-0.37	-0.01	-0.35	-0.28	0.16
Arsi Negele	0.55**	0.00	0.22	-0.26	-0.16	0.31
Kulumsa	0.52**	0.53**	-0.44*	-0.35	-0.57**	0.10
Asassa	0.36	0.21	0.30	-0.03	-0.07	-0.30
Sagure	0.56**	0.15	-0.51**	-0.26	-0.35	-0.14
Arsi-Robe	0.58**	0.35	-0.22	-0.30	-0.41	-0.58**
Holetta	0.32	0.12	0.29	0.32	0.46**	-0.01
Bekoji	0.10	0.63**	0.66**	-0.12	0.40	0.55**
Meraro	0.13	0.39	0.07	0.19	-0.28	0.06

* and ** Significant at 0.05 and 0.01 level, respectively. Source: Modified from Tezera (2000).

Table 3. Relative contribution of local collection, introduction and hybridization to the field pea germplasm in Ethiopia (1994 to 2002).

Source of germplasm	Year	Number in nurseries	Number in variety trials[1] PVT	PNVT	NVT	VVT	Total
Collection	1994	-	56	21	2	2	81
	1995	-	24	18	15	2	59
	1996	119	22	23	17	-	181
	1997	-	16	17	16	1	50
	1998	-	-	10	11	1	22
	1999	-	-	10	11	1	22
	2000	320	1	-	10	1	332
	2001	36	2	-	3	-	41
	2002	-	-	1	-	-	1
Subtotal		475	121	100	85	8	789
Introduction	1994	23	-	9	-	3	35
	1995	23	11	6	1	-	41
	1996	23	8	9	4	-	44
	1997	24	12	10	5	-	51
	1998	24	25	12	8	-	69
	1999	24	22	12	8	-	66
	2000	42	25	8	8	1	84
	2001	86	26	8	5	-	125
	2002	27	14	9	5	-	55
Subtotal		296	143	83	44	4	570
Hybridization	1994	-	-	6	12	1	19
	1995	-	14	2	10	3	29
	1996	50	15	3	6	4	78
	1997	48	16	7	3	4	78
	1998	56	44	12	5	4	121
	1999	40	44	12	5	2	103
	2000	-	11	14	3	-	28
	2001	-	16	16	10	-	42
	2002	100	19	3	6	-	128
Subtotal		294	179	75	60	18	626
Total		1,065	443	258	189	30	1,985

[1]PVT, PNVT, NVT and VVT is preliminary, pre-national and national variety trial and variety verification trial, respectively.

Analysis of Experiments

Analyses of data for individual location and across locations indicated that the test locations tend to differ for their discriminating ability. Some locations consistently show high CV (>20%) with non-significant differences among the genotypes, while others show lower CV with mostly significant differences among genotypes. Obviously, high CV characterizes locations that have low yield performances. It is generally believed that CV is usually high under marginal environments as compared to the potential ones.

It is not uncommon to see non-significant differences between the test genotypes for number of pods per plant and seed per pod either due to low genetic variability among the tested genotypes for these traits or because of the high CV%. On the contrary, 1000-seed weight and grain yield showed significant genotypic and G x E interaction effects but the former were characterized by very low CV (usually below 10%), while the later by high CV%. Coefficient of variation normally indicates the degree of precision with which the treatments are compared and is a good index of the reliability of the experiment. It expresses the experimental error as percentage of the mean and, thus, the higher the CV the lower will be the reliability of the experiment. As observed from the experiments, the CV varies greatly with the traits measured and the environment under which the experiment is conducted. The interrelationship between CV and mean grain yield performances at each location showed negative correlation, i.e., high CV values were related to low grain yield values and *vice versa* (Table 4 and Fig. 3). In addition, locations with high CV for grain yield showed non-significant differences for genotypes (data not shown).

Table 4. Mean performance, range and CV for grain yield (t/ha) at the test locations for 14 variety trials conducted from 1994 to 2000 (combined over years and locations).

Location	Range	Mean ± SE	CV%
Mid-attitude			
Adet	0.47 – 1.78	1.23 ± 0.535	42
Denbi	0.29 - 2.25	1.36 ± 0.378	27
Kulumsa	1.21 – 2.97	1.96 ± 0.657	25
Asassa	2.67 – 4.81	3.69 ± 0.675	15
High-altitude			
Shambu	1.00 – 2.68	1.82 ± 0.675	29
Holetta	0.92 – 2.98	1.85 ± 0.548	26
Dabat	1.38 – 1.70	1.54 ± 0.582	25
Bekoji	1.83 – 6.59	3.90 ± 0.816	19
Sinana	2.90 – 6.49	4.79 ± 0.635	10

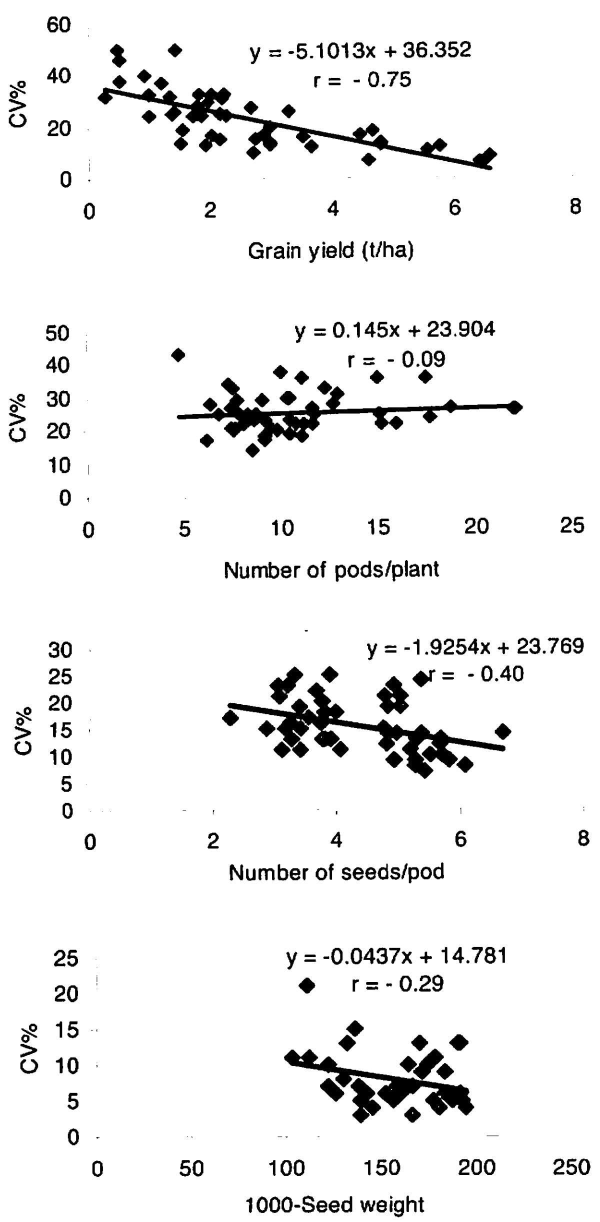


Fig. 3. Interrelationship between CV% and mean grain yield, number of pod per plant, seeds per pod and 1000-seed weight performances.

Genotype by Environment (G x E) Interaction

The G x E interaction is of major significance to the plant breeders in the process of evaluation of improved varieties. Very often, breeders encounter situations where the relative ranking of varieties could vary from location-to-location and/or between seasons resulting in the differential genotypic expression across environments, and thus forcing plant breeders to examine genotypic adaptation and measuring G x E interaction carefully to determine an optimum breeding strategy for releasing genotypes, with adequate adaptation to target environments (Romagosa and Fox, 1993). Several authors have reported the presence of G x E interaction in field pea with both crossover and non-crossover G x E interactions for different traits including grain yield (Gupta et al., 1992; Chaudhary et al., 1994; Rathore and Gupta, 1994; Dumoulin et al., 1996; Tezera 2000). Nleya et al. (2000) also reported a significant effect of G x E interaction for protein content and cooking quality in field pea. The crossover and non-cross-over interactions are important in decision-making relating to crop improvement strategies in that the presence of cross over type of interaction justifies the need for breeding for specific adaptation (Chahal and Gosal, 2002).

Using the joint regression of Eberhart and Russell (1996), Tezera (2000) reported the presence of linear (predictable) and non-linear (non-predictable) G x E interaction. He found linear type of G x E interaction for biomass, 1000-seed weight and days to flowering and maturity. This shows differences in the genotypes in their responses to changing environments. Non-linear types of G x E interactions were found for grain yield, 1000-seed weight, number of seeds/pod, plant height, days to flowering and maturity, grain filling, Ascochyta blight and powdery mildew. Both linear and non-linear types were observed for 1000-seed weight, days to flowering and maturity, but only linear for biomass and non-linear for grain yield.

Performance Stability of Traits

Fluctuation in yield is a common phenomenon in pulses production in general and in field pea in particular (Kelley et al., 2000). Genotypes that perform best in one environment and/or season might not be the same in other environments and/or seasons, and most of the time, change is a common phenomenon in varieties when grown at multi-locations (Singh, 1990; Sharma, 1994; Chahal and Gosal, 2002). This happens due to differences in environments for soil factors (type, fertility status, and pH), moisture regime and temperature, and the differential response of the varieties to such environments resulting in G x E interaction.

Studies conducted in Ethiopia on stability of trait performance in field pea showed that there are genotypes that are stable for one or multiple traits (Tezera, 2000). Even the released varieties showed differences in their responsiveness, stability and mean yield performances across different environments. Three released varieties, FpExDz, G22763-2C and Holetta showed general adaptability with stable performance but were low yielding (below average); other released varieties, Mohanderfer and Tegegnech, showed general adaptability, stable performance and were high yielding (above average); whereas other released variety, Markos, showed adaptability to responsive/favorable environments with high yield in such environments. Two promising genotypes, Century and EH90-021-3 having general adaptability, were stable with top yield performances. In addition, the released varieties, Markos, Tegegnech and Mohanderfer and two promising genotypes EH90-037-1 and EH90-021-3 have large seed size but are unstable. Genotypes, EH90-021-3, Century, MG100446 and EH90-002-1-1 and a released variety Mohanderfer have large seed size with stable performance across environments. Genotype EH90-037-1 and a released variety Markos were unstable for 1000-seed weight. Tegegnech was the most stable for number of seeds per pod, while G22763-2C for days to flowering and maturity. Thus, in general, there was no uniformity among the tested materials for responsiveness and stability parameters. Emphasis should be given to genotypes like EH90-021-3 and Century, which have superior performances and stability for more than one trait. For example, grain yield and the two other important traits, 1000-seed weight and biomass in this case.

Tezera (2000) also reported a strong correlation among stability parameters (mean, bi and S^2di) using range indices (Langer et al., 1979) for responsiveness of grain yield and range indices of yield (R1 and R2). R1 and R2 are the differences between the minimum and maximum yield of a genotype in a series of environments and R2 is the difference between yield of a genotype in the lowest and best production environments, respectively. R1 and R2 of grain yield were positively correlated with responsiveness of grain yield, indicating that range indices of genotypes could be used as an easy indicator of responsiveness of genotypes across locations. In general, it is suggested that in the early stages of breeding program the use of simple methods like range indices of Langer et al. (1979) would be more appropriate in that it is related to the productivity of genotypes as crude measure of production response in different environments. On the other hand, the correlation between stability parameters for different traits showed weak associations in most of the cases, indicating that they were independent and it was possible to breed genotypes for high yield along with the desired degree of responsiveness and stability. Rathore et al. (1993a,b) and Gupta et al. (1974) also found similar results. Another interesting association is the positive relationships of mean grain yield with mean of biomass; responsiveness of grain yield with mean and responsiveness of biomass and mean of plant height; and mean of yield with mean of 1000-seed weight. These relationships indicate that by incorporating high biomass, plant height and large seed size, it could be possible to breed genotypes responsive for grain yield.

Regarding diseases like Ascochyta blight and powdery mildew, there was high variability between locations than between genotypes. There were a few genotypes that seemed to have moderate tolerance to these diseases but this needed a thorough investigation.

Classification of Testing Environments

The pattern of response of environments to genotypes can be analyzed based on genotypic and environmental means and this made it possible to group environments for their similarity based on their responses to different genotypes evaluated in each environment (Chahal and Gosal, 2002). Multivariate approaches such as "clustering" are commonly used to cluster environments into groups having similar ranking of all the genotypes with similar magnitude of G x E interaction, which has important implication on deciding the environments for screening and evaluation of genotypes. Using cluster analysis the whole structure of the groups is represented by a branch of a tree in a dendrogram that depicts composition of a group and dissimilarity among groups. The environments in each cluster are expected to have a similar contribution to G x E interaction as compared to the environments in the different groups of the cluster. Clustering of testing environments having similar characteristics in genotypic response and other factor is helpful in reducing the G x E interaction effects to a practical minimum for simple and effective breeding activities (Ghaderi et al., 1980; Yau et al., 1991). A number of analytical approaches are available to decide the structure and number of clusters depicting relationship with each other (Romagosa and Fox, 1993).

A study was conducted in Ethiopia to group the testing environments based on their response to the tested genotypes. Each year and location was used as a unique environment, for example, Holetta 1994 and Holetta 1995 were considered as two different environments. In this way, a total of 26 mid-altitude and 22 high-altitude environments were clustered using mean yield performance of field pea genotypes tested in NVTs from 1994 to 1996.

The 22 high-altitude environments were classified into four larger categories in which the first cluster consisted of three poor environments, the second 10 poor environments that were better yielding than the first cluster, the third four good yielding environments, and the fourth five high yielding environments (Fig. 4). Different seasons of Holetta, Debre Tabor and Shambu were categorized as poor to intermediate, and those of Bejoji and Sinana, intermediate to high yielding environments for field pea.

The 26 mid-altitude environments *were also* classified into four major clusters in which the first cluster consisted 13 poor yielding environments, second two best yielding environments, the third three relatively better environments that were better than the environments in the first cluster, and the fourth eight good yielder next to the environments in the second cluster (Fig. 5). Different seasons of Adet and Sodo Zuria were categorized as poor yielding; those of Denbi and Mekele from poor to intermediate; of Kulumsa from poor to high; and those of Asassa from intermediate to high yielding environments. Different seasons of Kulumsa and Asassa were highly variable than of the other locations. Tezera (2000) also classified some testing environments according to similarity of their interaction with a set of genotypes using environmental indices and categorized Asassa and Meraro as favorable, Sagure and Holetta as average, and Denbi, Bekoji, Arsi-Robe, Kulumsa and

Arsi Negele as unfavorable environments for grain yield

In general, the locations showed remarkable seasonal variations and there were no definite patterns of grouping of similar locations and /or seasons in one cluster. Instead, the environments were clustered based on their performances. The variations in location and/or seasons could result from differences in factors such as amount and distribution of rainfall, the prevailing temperatures during the crop-growing period and soil factors. The seasonal variability indicates that it is equally or even more important than geographical position. Talbot (referred by Chahal and Gosal, 2003) expressed his experience that year and years by genotype interaction effects were usually larger than the location effects and their interactions as a result of which less number of locations and more number of years would be desirable to assess the yield potential of varieties. The wide or specific adaptation of a variety should, therefore, be confirmed both in multi-environments and seasons in the process of varietal development.

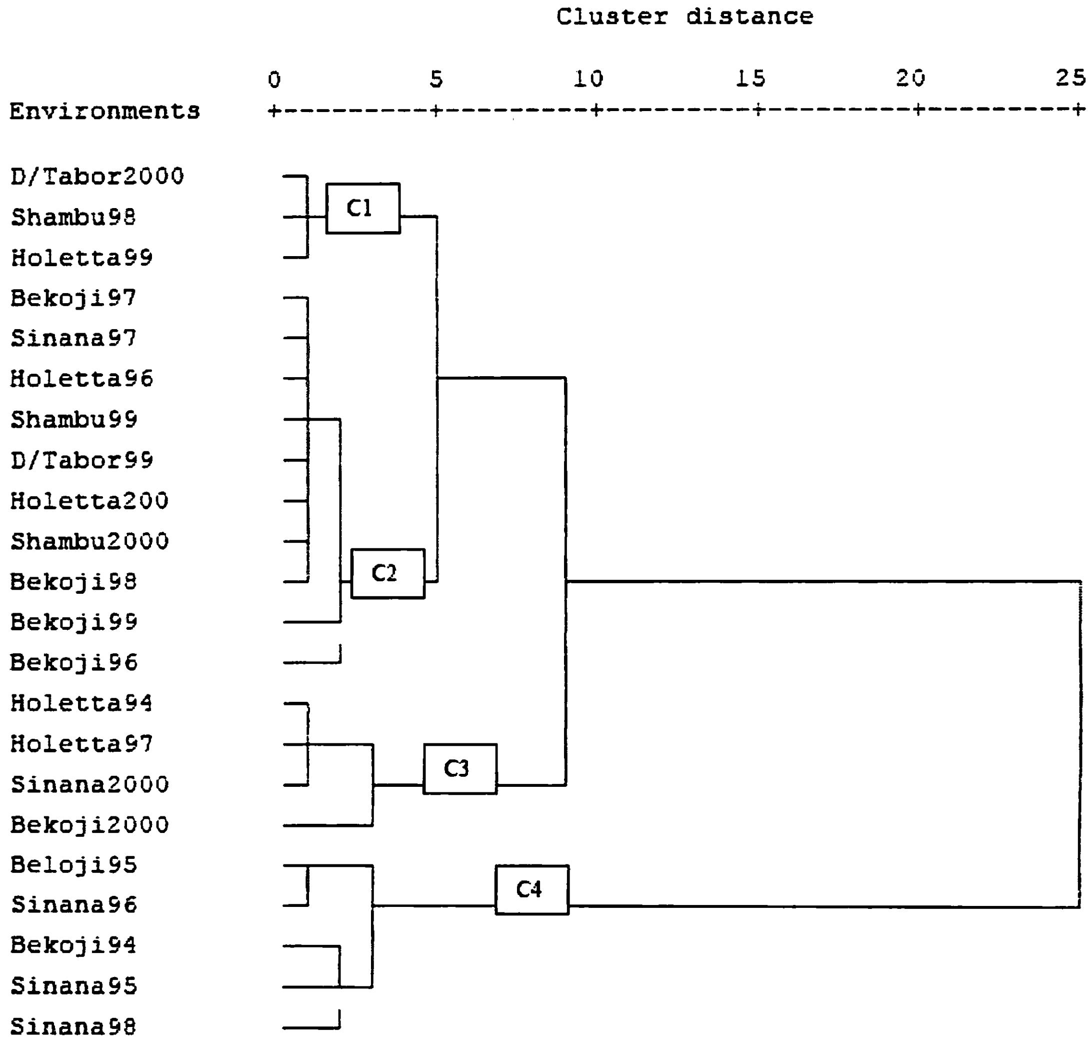


Fig. 4. Dendrogram of 22 high-altitude testing environments based on mean grain yield performance of field pea genotypes.

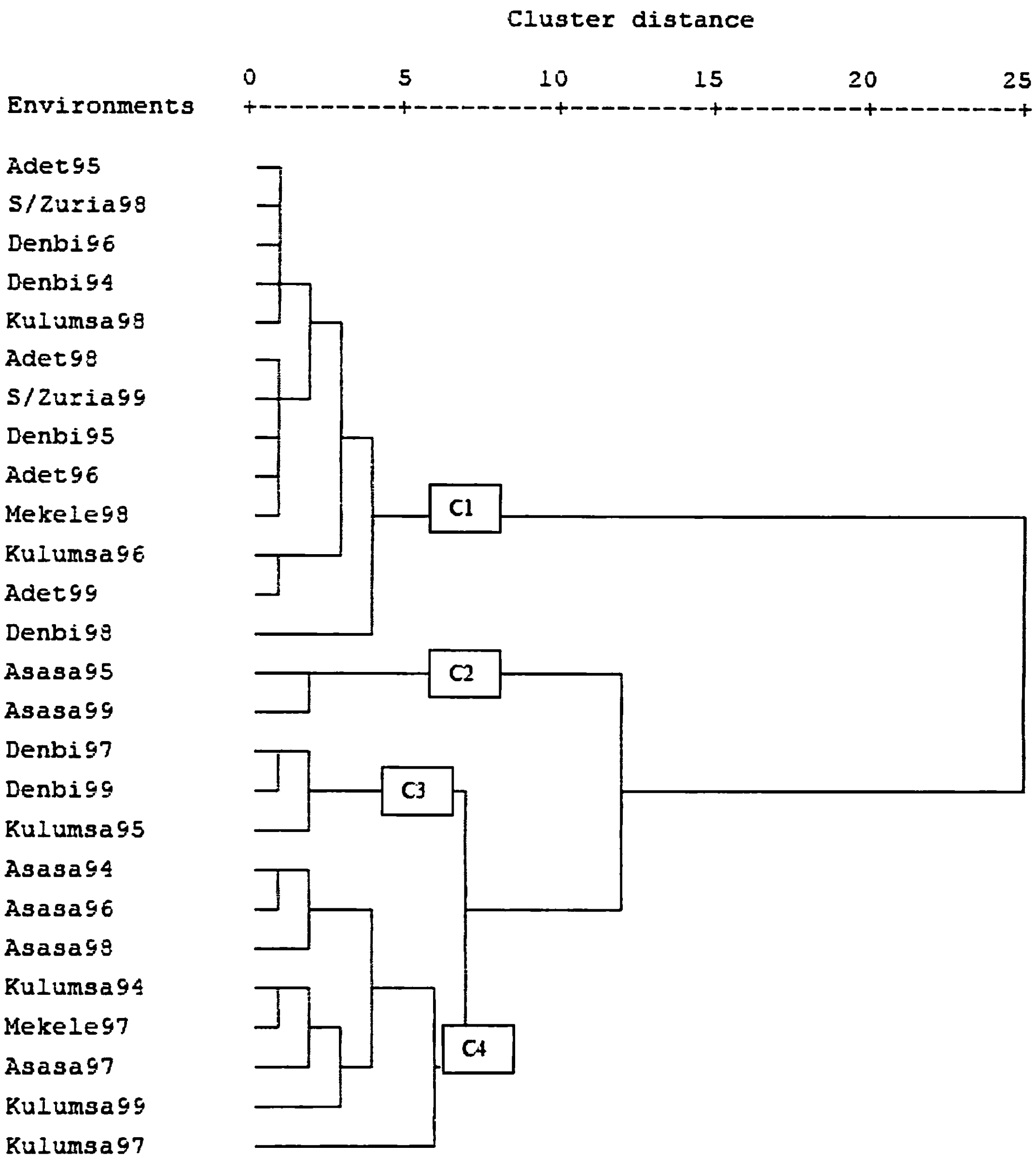


Fig. 5. Dendrogram of 26 mid-altitude testing environments based on mean grain yield performance of field pea genotypes.

Important Achievements

Through consorted efforts, seven improved field pea varieties (five for high- and two for mid-altitude areas) have been released during the last decade. The yield potential and relative advantages of these varieties over the standard checks are presented in Table 5.

Table 5. Field pea varieties released for mid- and high-altitude areas since 1994.

RV	Pedigree	YR	DTM	TSW (g)	Seed size	Seed color	Seed shape	Grain yield (t/ha) RV	S.Ch	% Ad[2]
For high-altitudes (2330-3000 m asl)										
Tegegnech	061K-2P-2/9/2	1994	135	215	Large	Cream[1]	Round	4.01	3.56	12
Adi	G22763-2C x 305PS210813-2	1995	130	209	Large	White	Round	4.40	3.30	33
Milky	NEP 634 x 180-1	1995	130	157	Medium	White	Round	4.00	3.30	21
Holetta	Holetta local - 90	1996	135	143	Small	LB	Wrinkled	3.8	3.3	15
Wolmera	FPExDz x 305PS210822-1	2000	140	174	Medium	White	Round	4.84	4.55	6
For mid-altitudes (1800-2300 m asl)										
Hasabe	JI No116	1995	117	132	Small	LB	Wrinkled	2.88	2.25	28
Markos	DMR - 4	1995	122	188	Large	Cream*	Round	3.06	2.91	5

[1]Has black hilum; LG and LB = light green and light brown; RV= released variety; YR= year released; DTM= number of days to mature; TSW= 1000-seed weight; S.Ch =standard check; [2]%Ad =percent advantage over the standard check.

The yield potential of the released varieties is high (2.9-4.8 t/ha) as compared to the low national average yield (0.8 to 1.0 t/ha). This shows that the potential of improving the low national average if the varieties along with agronomic and crop protection packages are used widely by small-scale farmers in the major field pea growing areas of the country. The white and cream color varieties are good for *kik* making and preferred for market. Hence they could fetch higher prices in the local and export markets. The gray color variety is preferred in the local market for *shiro* making.

Participation of Farmers in Variety Evaluation

Even though a number of improved field pea varieties have been released, it is not possible to conclude that they have been widely adopted and used by small-scale farmers to improve field pea productivity at farm levels (Gemechu et al., 2002). Similar to other food legumes, the current conventional breeding approach in Ethiopia is based on the development of varieties under high management level on experiment stations, whereas breeding for the target environment is being emphasized by several other workers (Ceccarelli, 1994; Banziger et al., 1998; Gemechu and Adugna, 2001) to minimize the yield gaps of selection and target environments. To this end, a variety evaluation was conducted at Wolmera Goro and Ilala Gojo districts for two years (1999 and 2000) with farmers' full involvement, where it was learnt that farmers (male and female) and researchers have their own unique and common selection criteria. Male and female farmers also showed differences in that female farmers were more interested in the culinary traits such as seed color and size that is important for *kik* (de-hulled split) making and they also believed that seed color and size are major price determining factors, whereas the male farmers were more interested in higher yields. Farmers preferred different varieties for different purposes. For instance, they classified varieties of field pea into *shiro* and *kik* types based on the morphological nature of the seed, particularly ease of splitting. Varieties that could easily be split are said to be *kik* types, while those that do not be split easily are *shiro* types. The participation of the farmers in process of variety evaluation is, therefore, essential in that selection criteria overlooked by researchers might be addressed. This is expected to fasten the dissemination of the released varieties, as farmers are the end-users.

CHALLENGES, OPPORTUNITIES AND FUTURE DIRECTIONS

Challenges

There is an ever- increasing demand and radically dwindling supply of field pea in Ethiopia, a case similar to other food legumes. In addition to the ever-increasing population, the low and unstable yield is a major challenge to a steady and constant supply of pulses at low and stable prices. Pulses in general are highly susceptible to changes in environmental factors as compared to other crops (Kelley et al., 2000). Soils in the majority of field pea growing areas are highly degraded with very low pH, and on top of that, farmers traditionally allocate the poorest plot of land to this crop as they can not afford to use high inputs with improved technologies that are responsive to better management because of their socio-economic problems and their production mostly for subsistence than for marketable surplus. Therefore, the annual national production shows no or little change from year to year.

There are no identified sources of resistance to the major biotic constraints like Ascochyta blight and pea aphid, which contribute to low and instable yields in most parts of the country. The country has highly diversified agro-ecologies, and at present 18 major and 49 sub-agro ecologies are identified nationally, among which field pea grows in about six of the major and in more than 20 of the sub agro-ecologies. The big challenge is whether to develop a variety for each agro-ecology, which is very expensive, or to develop a widely adaptable variety, which is virtually impossible. The absence of governmental and/or private processing and marketing organization is also a limiting factor. Also, there is lack of improved seed production and distribution system in the country as well.

Opportunities

Field pea is of multi-dimensional importance in the livelihood of the Ethiopian farming community. It is a major and cheap source of protein in the daily diet of the people. Its ability to fix nitrogen enables it to grow on low N soils and to produce seeds high in protein. It is well known by farmers for the roles it plays in the farming system in breaking cereal monoculture in the high lands of the country. It also fetches relatively higher price and it is a source of income for the producers. The export promotion strategy of the government for "high value crops" which includes field pea is a good opportunity for field pea to compete in international market and the producers will be beneficiary if they produce surplus high quality product for market. Field pea is the most important export commodity in international markets (Lovett and Gent, 2000) and its demand very much exceeds its supply, and many countries import it. The recently established extension system in the country that helps to extend the improved technologies is another opportunity for the producers. The availability of improved high yielding varieties and the wealth of genetic variation in the Ethiopian germplasm in addition to the introductions are good opportunities for increased field pea production.

Future Directions

Improvement in field pea in the future should focus on yield fluctuation, which is a function of production system, use of input and price. Increasing area and productivity or both could increase production. Therefore, the following need a special focus in the future:

Breeding for quality. Quality in protein content determines the suitability of pulse crops for various users. Culinary qualities such as seed size, color, shape, texture, uniformity, purity and cooking time and splitting characteristic are the major price determining factors. Although crude protein content in the released field pea varieties is known, their essential amino acid composition is not known. Crude protein by its own may not mean anything unless it is possibly associated with the level of essential amino acids like methionine and tryptophane. There is a felt need to fill the gap in this aspect while breeding field pea varieties for better productivity.

Breeding for resistance to diseases and insect pests: Resistant varieties offer the cheapest and the most convenient method of disease and insect pest management as resistant varieties not only increase production but also help in stabilizing it. In this regard, the varieties released so far have some level of disease tolerance but no resistance materials are obtained for major pests like Ascochyta blight and pea aphid. The development of field pea varieties resistant to these pests will be a landmark to boost the field pea productivity, and hence needs to be focused. As starting a breeding program for resistance from the beginning may take longer period of time, the conversion of the otherwise well-adapted released varieties into their resistant versions should be followed as a short- and medium-term strategy.

REFERENCES

Amare Ghizaw, and Adamu Molla. 1994. Faba bean and field pea agronomy research. p. 199-227. *In* Asfaw Tilaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

Asfaw Telaye, Beyene Demtsu, and Tesfaye Getachew. 1994. Genetics and breeding of field pea. p. 122-137. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA: Aleppo, Syria.

Banziger, M., G. O. Edmeades, D. Beck, and M. Bellon. 1998. Breeding for drought and low N tolerance in maize. Paper Presented at the Regional Workshop for Breeders and Agronomists of ASARECA Member States, held in Arusha, Tanzania, September 1-14, 1998.

Banziger, M., F.J. Betran, and H.R. Lafitte. 1997. Efficiency of high-nitrogen selection environments for improving maize for low-nitrogen target environments. *Crop Science* 37: 1103-1109.

Bunder, J., A. Loeber, J.E.W. Broers, and B. Havertkort. 1996. An integrated approach to biotechnology development. p. 201-227. *In* J. Bunders et al. (Eds.) *Biotechnology; Building on Farmers' Knowledge*. Macmillan, London and Basingstoke.

Bolanos, J., and G.O. Edmeades. 1996. The importance of the anthesis-silking interval in breeding for drought tolerance in tropical maize. *Field Crops Res.* 48: 65-80.

Ceccarelli, S. 1994. Specific adaptation and breeding for marginal conditions. *Euphytica* 77: 205-219.

Chahal, G.S., and S.S. Gosal. 2002. Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches. Narosa Publishing House, New Delhi.

Chaudhary, H.K., V.P. Gupta, and J. Kumar. 1994. Stability of seed in pea. *Crop Improvement* 21: 84-86.

CSA. 2002. Report on the preliminary results of area, production and yield of temporary crops (*Meher* season, private peasant holdings). Part I. Ethiopian Agricultural Sample Enumeration. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Dawit Tadesse, Asfaw Tilaye, and Geletu Bejiga. 1994. Genetic resources in Ethiopia. p. 79-96. *In* Asfaw Tilaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria.

Demissie, A., and A. Bjφrnstad. 1997. Geographical, altitude and agro-ecological differentiation of isozyme and hordein genotypes of landrace barleys from Ethiopia: Implications to germplasm conservation. *Genetic Resources and Crop Evolution* 44: 43-55.

Dereje Gorfu, and Tesfaye Beshir. 1994. Field pea diseases in Ethiopia, p.--317-327. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Aleppo, Syria.

Devendra, K., B.P.S. Malik, S.K. Sharma. and D. Kumar. 1995. Path coefficient analysis in peas (*Pisum sativum* L.). *Annals of Biol.* 11: 69-72.

Dobhal V.K., and H. Ram. 1985. Genotypic divergence in pea. *Indian J. Agri. Sci.* 55: 67-71.

Dumoulin, V.B., J.B. Denis, I.L. Henaut, and G. Eteve. 1996. Interpreting yield instability in pea using Genotypic x Environmental covariates. *Crop Sci.* 36: 115-120.

Eberhart, S.A., and W.A. Russell. 1966. Stability parameters for comparing varieties. *Crop Sci.* 6: 36-40.

Engles, J.M.M., J.G. Hawkes, and Melaku Werede (Eds.). 1991. Plant Genetic Resources of Ethiopia. Cambridge University Press.

FAO. 1998. The State of World Plant Genetic Resources for Food and Agriculture. FAO, Rome.

Frankel, O.H. (Eds.). 1973. Survey of genetic resources in their center of diversity. First Report. FAO/IBP, Rome.

Gemechu Keneni, and Adugna Wakjira. 2001. Genetic uniformity of crop cultivars: Challenges and opportunities. A Paper Presented at the 10th Annual

Conference of the Crop Science Society of Ethiopia. 19-21 June 2001, EARO, Addis Abeba.
Gemechu Keneni, Mussa Jarso, Belay Asmamaw, and Maaza Kersie. 2002. On-farm evaluation of faba bean and field pea varieties around Holetta. p. 176-187. *In* Gemechu Keneni et al. (Eds) *Towards Farmers' Participatory Research: Attempts and Achievements in the Central Highlands of Ethiopia*. Proc. Client-Oriented Research Evaluation Workshop, 16-18 October 2001, Holetta Agricultural Research Center, Holetta, Ethiopia.
Gemechu Keneni, Mussa Jarso, Tezera Wolabu, and Getnet Dino. 2005. Extent and pattern of genetic diversity of morpho-agronomic traits in Ethiopian highland pulse landraces I: Field pea (*Pisum sativum* L.). *Genetic Resources and Crop Evolution* 52: 539-549.
Ghaderi, A., E.H. Everson, and C.E. Cress. 1980. Classification of environments and genotypes in wheat. *Crop Sci.* 20: 707-710.
Golaszewski, J., and I.M. Pusio 1996. Path analysis in estimation of interdependence of some seed yield components of edible field pea. *Biuletyn Instytutu Hodowili-I Aklimatyzacji-Roslin* 200: 317-322.
Gupta, V.P., S.R. Rathore, and P. Plaha. 1992. Divergence analysis of some powdery mildew resistant lines of pea. *Crop Improvement* 19: 18-22.
Gupta, V.P., S. Ramanujam, and A.K. Kaul. 1974. Stability analysis in respect of protein, sulfur and protein value index of seed and its implication in adaptation of chickpea (*Cicer arietinum* L.). *Genetic* 6: 247-261.
Hagedorn, D.J. 1984. Compendium of Pea Diseases. University of Wisconsin, Madison.
Harlan, J.R. 1969. Ethiopia: A center of diversity. *Econ. Bot.* 23: 309-314.
Harlan, J.R. 1973. Genetic resources of some field crops in Africa.p. 45-64. *In* O.H. Frankel (Ed.) *Survey of Crop Genetic Resources in their Center of Diversity*. First Report. FAO/IBP, Rome.
Kelley, T.G., P. Parthasarathy Rao, and H. Grisko-Kelley. 2000. The pulse economy in the mid-1990s: A review of global and regional development. p.1-29. *In* R. Knight (Ed.) *Linking Research and Marketing Opportunities for Pulses in the 21st Century*. Proc. Third International Food Legumes Research Conference. Kluwer Academic Publishers, Dondrecht.
Kemal Ali, and Tibebu Habtewold. 1994. Research on insect pests of cool season food legumes. p. 367-395. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Aleppo, Syria.
Langer, I., K.J. Frey, and T. Bailey. 1979. Association among productivity, production response and stability indexes in oat varieties. *Euphytica* 28: 17-24.
Lovett, J.V., and G.P. Gent. 2000. Market demand and research opportunities: Addressing the supply/demand gap for pulses. p.221-233. *In* R. Knight(Ed.) *Linking Research and Marketing Opportunities for Pulses in the 21st Century*. Proc. Third International Food Legumes Research Conference. Kluwer Academic Publishers, Dondrecht. Melake
Hail. 1975. Crop germplasm diversity and resources in Ethiopia. Genetic Resources for Today and Tomorrow. *International Biological Program* 2: 309-314.
Melaku Werede. 1988. Diversity and genetic resource base. *Ethiopian Journal of Science* 10: 39-52.
Nleya, T., A. Vandenberg, G. Araganosa, T. Warkentin, F.J. Muehlbauer, and A.E.Slinkard. 2000. Produce quality of food legumes: Genotype (G), Environment (E) and G x E considerations. p. 173-182 *In* R. Knight (Ed.) *Linking Research and Marketing Opportunities for Pulses in the 21st Century*. Proc. Third International Food Legumes Research Conference. Kluwer Academic Publishers. Dondrecht.
Partap, P.S., G.L. Bhatia, and S.K Arora. 1992. Studies on genetic variability and heritability for yield and component characters in pea (*Pisum sativum* L.) *Crop Res.* 5(3): 505-511.
Rathore, P.K., V.P. Gupta, and P. Plaha. 1993a. Nature of variation and interrelationships among seed yield and some physiological traits in pea. *Crop Improvement* 20: 51-54.
Rathore, P.K., V.P. Gupta, and P. Plaha. 1993b. Association of stability parameters in pea. *Crop Improvement* 20: 201-206.
Rathore, P.K., and V.P. Gupta. 1994. Crossover and non-crossover interactions and regression analysis for seed yield and its components in pea. *Crop Improvement* 21: 14-18.
Romagosa, I., P.N. Fox. 1993. Genotype x environment interaction and adaptation. p. 373-390. *In* M.D. Hayward (Eds.) *Plant Breeding: Principles and Prospects*. Chapman and Hall, London.
Sharma J. R. 1994. Principles and Practices of Plant Breeding. Tata McGraw-Hill, New Delhi. 599 pp.
Singh, B.D. 1990. *Plant Beeding: Principles and Methods*. Kalyani Publishers, New Delhi, Ludhiana, India.
Tesfaye Getachew. 1999. Genetic variability and association of characters in some Ethiopian field pea (*Pisum sativum* L.) germplasm. M. Sc. Thesis. Alemaya University of Agriculture.
Tezera Wolabu. 2000. Genotype x Environment interaction in field pea (*Pisum sativum* L.) for yield and other traits across central and southern Ethiopia. M. Sc. Thesis. Alemaya University of Agriculture.
Vavilov, N.I. 1950. The origin, variation, immunity and breeding of cultivated plants. *Chronica Botanica* 13: 1-366.
Yau. S.K., G. Ortiz-Ferrara, and J.P. Srivastava. 1991. Classification of diverse bread wheat-growing environments based on differential yield responses. *Crop Sci.* 31: 571-576.

Breeding Lentil for Wider Adaptation

Asnake Fikre[1] and Geletu Bejiga[2]

[1]*Debre Zeit Agr. Res. Center, P.O.box 32, Debre Zeit, Ethiopia,* [2]*Green Focus Ethiopia, P.O.Box 802. Addis Ababa, Ethiopia.*

ABSTRACT

Lentil (*Lens culnaris* Medik.) is one of the most important pulse crops in Ethiopia. It is widely consumed in different forms as an integral part of the daily diet of the people. It has a great potential for improvement to meet the growing demand of the domestic and export markets. Reviewing a decade's activities of the program is of paramount importance in analyzing the process so far, availing summarized information and to have a clear future direction. Efforts have been made to improve its productivity by utilizing the Ethiopian germplasm collection and exotic materials introduced from different sources. As a result, several varieties, Adaa, Gudo, Chekol and Alemaya have been released since 1994. Good sources of resistance/tolerance to rust, fusarium wilt and root rot, water-logging, frost and drought were identified. Correlation studies revealed that harvest index, grain yield per plot, biological yield, plant height, number of secondary branches and pods per plant had positive associations with grain yield per plant. However, the path coefficient analysis indicated that biological yield and harvest index are the major direct contributors of grain yield. In general, breeding approaches based on the major stresses and agro-ecological zones have helped to successfully develop varieties suitable for different situations.

INTRODUCTION

Lentil (*Lens culinaris* Medik. subsp. *culinaris*) is among the principal food legumes widely grown in diverse agroecological zones ranging from hot submoist lowlands to cool humid mid-highlands of central highlands, southeastern, western, northern and northeastern parts in Ethiopia. Lentil is grown in six major agroecological zones (Table 1) of Ethiopia (NRMRD, 1998) that accounts for about 45% of arable land (Figure 1). The agroecological zoning was based on thermal zones and length of growing periods (LGP). These diverse agroecologies have specific features and constraints (Table 1) to be addressed by research.

The production area is characterized by rainfall range of 650-1500 mm and altitudes of 1700-3500 m asl, with temperature domain between 5 and 25c^0 (Geletu, 1992 unpublished). It grows from light loam to black cotton soils (Vertisols) and tolerates moderate alkalinity (Westphal, 1974). Currently, the crop covers an area of about 90,000 ha with an annual production of 55,000 tones; the average national productivity being about 0.6 t/ha (CSA 2000). Ethiopia ranks first in Africa and 10th in the world in lentil production (FAO, 2001).

Lentil is cultivated mostly for domestic consumption (*wot, nifro, sambusa, shorba*), which is an important source of protein accounting for 22.6% in the human diet (Agren and Gipson, 1968). Moreover, the demand and request for both whole and split red cotyledon lentil is very high, particularly in Lebanon (EEPA, 2003a), India (EEPA, 2002a, b, c and EEPA, 2003b), Sri Lanka (EEPA, 2003c) and Bangladesh (EEPA, 2002a). Because of significant economic role and social conditions its production has recently been expanding in both stressed and non-stressed environments.

Table 1. Potentials and constraints of lentil production in agroecological zones (AEZ) of Ethiopia.

Agroecological zone	Potential	Constraints
SM1: Hot to warm sub moist lowlands	Rainfed and irrigated agriculture Increase productivity	Erratic and low rainfall Shallow soil, stony, rocky Erosion, deforestation Rust
SM2: Tepid to cool sub moist mid- highlands	Crop livestock, forestry, wildlife production Mechanized farming	Moisture stress Shallow soil, workability, wind erosion Termite, aphids, rust, wilt/root rots, mildew, storage insects
M2: Tepid to cool mid-highlands	Rainfed agriculture Livestock, forestry, wild life production	Low rainfall, stony rock Termite , drainage Steep slopes, land shortage, soil erosion Rugged topography Aphides, rust, mildew, blight, storage insects
SH2: Tepid to cool sub-humid mid-highlands	Crop, livestock, forestry	Deforestation, erosion Moisture stress Steep slopes, termites, shallow stony soil, low fertility Aphids, termite, rust, mildew, wilt/ root rots
SH3: Cold to very cold sub-humid, sub-afro alpine to afro-alpine	Forest and mild life production	Low temperature, steep slopes, shallow stony soil, poor infrastructure Aphids
H2: Tepid to cool humid mid-highlands	Crop livestock and forestry production	Steep slopes, shallow soil, stony, low soil fertility, land scarcity, fuel wood shortages, deforestation Aphids

Source: Natural Resource Management and Regulatory Department (NRMRD) (1998)

The Ethiopian lentil belongs to the microsperma race, known as *G. aethiopicae*. It has 1-2 blue or violet flowers on each peduncle, calyx teeth much shorter than corolla, leaves with 3-7 pairs of elongated leaflets, and fruit with a typical elongated apex (Barulina 1930, Muehlbauer et al., 1985). The seeds are usually smaller (1-3 g/100 seeds), dark brown with black spots and red cotyledons. The Ethiopian Lentil Improvement Project (ELIP) has made use of genetic information studied elsewhere as literature access has been facilitated by the International Center for Agricultural Research in the Dry Areas (ICARDA) and other sources. So far, research efforts and achievements on lentil were reviewed in 1994, and therefore in this paper, research achievements and advances in breeding/genetics of lentil during a decade since 1994 are presented.

GENETIC STUDIES

So far, only a few genetic studies have been undertaken on lentil in Ethiopia. Tigist (2003) studied the associations and extent of effects on yield of 12 characters in 34 exotic lines and two checks at Sinana Agricultural Research Center, and at Lower Dinsho in Bale highlands, southeastern Ethiopia.

Correlation and Path Analyses

Correlations between different traits at both locations were very close, which could be attributed to less environmental differences between the locations under study. There were positive and significant correlations for harvest index and grain yield per plant to grain yield per plot (Tigist, 2003). Similar study at Akaki and Debre Zeit by Seifu (1988) indicated that number of pods per plant had significant association with grain yield of lentil. Both at Sinana and Lower Dinsho, biological and grain yield per plot were positively associated, and hence, could simultaneously be selected for improvement. The path coefficient analysis based on both genotypic and phenotypic correlations at Sinana (Tigist 2003) showed that harvest index and biological yield had positive direct effect on grain yield per plot and were the important traits for selection for grain yield. While Seifu (1988) reported that number of pods per plant and 100-seed weight were major direct contributors to grain yield.

GERMPLASM ENHANCEMENT

The major source of germplasm for ELIP is ICARDA (Table 2). Seven out of eight released lentil varieties in Ethiopia are from these introduced germplasm accessions. This is mainly due to their high yielding ability, larger seed size, resistance to rust, fusarium wilt and root rot diseases. On an average, about 170 lentil accessions and breeding materials were introduced to Ethiopia every year for breeding purposes. Of these, 31% were selected for advanced yield trials, and six varieties (one for a particular region and others for the national use across all major agroecologies) have been released from these materials during the last decade. This indicates a typical pin-cone shaped graph between genotype accessions as inputs at the base and finished technologies as output on the tip. The breeding program also runs crossing activity using different elite sources of lentils to introduce useful traits to otherwise adaptive genotypes. Accordingly, it is one of the sources of variability in developing adaptive genotypes with reasonable yield across diverse agroecologies. Through such an effort, varieties with more than 1.8 t/ha grain yield (three-fold of the national average) and better rust resistance were identified from the vigorous breeding materials developed involving one Ethiopian parent (Table 3).

An elite line developed from cross between two lines, Precoz and PGRC-7/92-DZ/2, was among the best performing varieties across locations and was proposed for release by Sinana Agricultural Research Center in 2002. At Arsi Robe, the cross Precoz x PGRC-7/92-DZ/3 indicated the yield potential of lentil in the Ethiopian highlands that could be exploited by using high yielding varieties with improved agronomic management. The yields obtained at Chefe Donsa from NEL-358 x PGRC-211126/92-DZ/2, Precoz x PGRC-211126/92-DZ/2, Precoz x EL-142/92-DZ/9, PGRC-211126 x EL-142/92-DZ/2, Precoz x EL-142/92-DZ/2 and Precoz x PGRC-7/92-DZ/2 have confirmed that the productivity potential of lentil in Ethiopian highlands has not yet been fully exploited (Table 3).

Table 2. Number of exotic and local diverse nurseries utilized in lentil breeding program of Ethiopia (1994-2003).

Years	No of test entries	Source of lines and number of selection of ICARDA introduction										Germ-plasm local	Total selection
		LIEN-E	LIFWN	LISN-L	LIRN	LICTN	LISN-S	LISN-E	LISN-SL	LISN-DT	Yield trial		
1994	300	-	28(19)	36(8)	19(11)	15(0)	-	-	-	-	24(4)	-	42
1995	172	-	32(5)	26(7)	-	-	39(16)	36(7)	-	-	24(3)	-	39
1996	153	-	-	30(4)	-	16(5)	-	-	34(14)	27(8)	46(9)	-	40
1997	152	-	-	23(3)	-	-	48(4)	-	25(3)	32(0)	24(8)	-	18
1998	186	-	40(19)	24(15)	-	-	48(23)	-	22(4)	28(13)	24(4)	-	78
1999	310	-	40(19)	24(15)	-	-	48(23)	-	24(18)	28(13)	-	146(88)	176
2000	84	35(15)	-	-	30(14)	-	-	-	-	19(7)	-	-	36
2001	not int.	-	-	-	-	-	-	-	-	-	-	-	-
2002	62	35(5)	-	-	-	-	-	-	-	27(2)	-	-	7
2003	110	45	-	-	40	-	-	-	-	25	-	-	
Total	1529	-	140(62)	163(52)	49(25)	31(5)	183(66)	36(7)	105(39)	134(43)	142(28)	146(88)	1419(436)

( ) selected; LIEN-E: Lentil International Elite Nursery -Early; LIFWN: Lentil International Fusarium-Wilt Nursery; LISN: Lentil International Screening Nursery (L:Large-seeded; S:Small-seeded; E:Early; SL:Southern latitude; DT:Drought); LIRN: Lentil International Rust Nursery; LICTN: Lentil International Cold Tolerance Nursery. Source: DZARC (Department of Pulse Breeding Research).

Table 3. Across location yield performance (1998-2002) of elite lines developed by DZARC National Lentil Improvement Program

No	Variety	Location and yield (kg/ha)												Mean
		Enewary	Bichena	Akaki	Chefe Donsa	Debre Zeit	Arsi Robe	Asassa	Mekele	Alem Tena	Minjar	Sinana	Dabat	
1	Precoz x PGRC-7/92-DZ/3	456	1431	1488	538	756	4000	1750	-	-	-	-	-	1488
2	NEL-358 x PGRC-14/92-DZ/1	831	419	1169	1288	700	2213	1656	-	-	-	-	-	1182
3	NEL-358 x PGRC-211126/92-DZ/2	1375	575	2949	3119	2000	1663	-	-	-	-	2251	1369	1913
4	Precoz x PGRC-211126/92-DZ/2	1035	731	1657	2985	1438	985	-	-	-	-	-	-	1300
5	PGRC-211126 x EL-142-/92-DZ/2	1731	-	2712	1913	1911	-	2103	468	1169	1769	-	719	1505
6	Precoz x EL-142/92-DZ/9	906	538	1551	2572	1079	1085	-	-	-	-	-	-	1289
7	74TA-441 x Pant-L-639	1744	-	938	2288	1129	-	1850	425	1004	513	-	-	1236
8	PGRC-211126 x EL-142/92-DZ/2	-	-	-	2813	1650	-	1700	450	1500	-	-	-	1623
9	ILL-6037x ILL-8007-4	-	-	1813	-	750	-	1144	-	438	706	-	-	950
10	Precoz x EL-142/92-DZ/2	1578	269	1466	3110	1472	1410	-	-	-	-	-	-	1551
11	Precoz x PGRC-7/92-DZ/2	1544	-	2479	3100	1319	1425	-	-	-	-	2589	1463	1919
12	Alemaya (standard check)	1731		2906	3119	2838	1719	2563		900	2000	1844	2131	2175
13	Local check	1544		2100	2094	2125	1994	1819		869	1456	1869	2156	1802
	Mean	1315	660	1935	2411	1474	1832	1823	447	980	1289	2138	1567	1533

Source: Department of Pulse Breeding Research, DZARC.

VARIETAL DEVELOPMENT

Based on the ecological limitations the national breeding strategy is geared to develop varieties that perform well across diverse environments. In the process of varietal development for wider adaptation varieties best suitable to limited nitches are also identified for the specific agroecological zones.

The key success in Ethiopian lentil improvement project started with the release of EL-142, R-186 and NEL-358 varieties in the early 1980s. The ELIP has developed two major categories of lentils: early- and late-maturity groups, targeted for long and short rainy period environments. Thus, two varieties, 'Chekol' and 'EL-142' were released for short LGP to fit to the short rainy season environments like the lowland of the Rift Valley, while three varieties 'Adaa', 'Gudo' and 'Chalew' were developed suitable for long LGP environment, (sub-moist to moist) in the mid- to highland ranges. On the other hand, the variety 'Alemaya', a recent release, has been found to have high quantitative and qualitative traits that help it to fit into diverse environments. Therefore, it was stated as a 'self adjusting' variety by Geletu and Yadeta (1998) with maturity range between 81 to 136 days to bridge the gaps among low-, mid- and highland environments (SM1 to H2), which vary in altitude, rainfall, temperature, light intensity, relative humidity and edaphic conditions. This rust-resistant and wilt and root rot-tolerant variety outyielded 'Chekol' by 33 % and 'Adaa' by 73% in their respective adaptation environments (Geletu and Yadeta, 1998). Currently, the variety is becoming popular and replacing almost all the varieties ever released in the country.

Evaluation and Selection

Both biotic (rust, wilt and root rots) and abiotic (drought, frost and water-logging) stresses are important constraints to lentil production in Ethiopia. Genotypes with multiple stress resistance, high adaptability to diverse agroecological zones, high yields, and better grain size and color as desired by producers and consumers are priorities of the breeding program. Therefore, breeding for major stresses have been undertaken, and major achievements are briefly discussed below.

Rust: Studies conducted in Ethiopia (Geletu et al., 1998; Geletu and Yadeta, 1999) have shown that the resistances for rust is available in the local as well as exotic accessions, and has been introgressed in good agronomic background and some lines have been released. For instance, 28% of collected accessions evaluated showed moderate to high resistance to rust (Geletu and Yadeta, 1999). This gives an opportunity for exploiting the resistance sources for developing rust resistance combined with wider adaptability, high yield and good grain quality.

Fusarium Wilt: Geletu et al., (2001) reported that lines such as Adaa, HC-972, FLIP 84-43L, 81515 and 78596013 were resistant to *Fusarium oxysporum*, while F-130 and SPS ILL-669 were found moderately resistant in Debre Zeit sick plot. Work to incorporate those genes into the promising varieties is in progress at Debre Zeit. The Nile Valley and Red Sea Regional Network on Management of Wilt and Root *Rots may* also contribute a lot in further identification of the sources of resistance to fusaruim wilt as more lines will be evaluated in Ethiopia, Sudan and Egypt, and resistant lines would be available to all the three participating national programs.

***Drought*:** Generally, the small-seeded Ethiopian lentils have high tolerance to drought, mainly because of their early escaping mechanisms. They have evolved through such stresses and hence perform better with this sort of stress adaptation (DZARC, 1999). Genotypes for drought resistance were identified from ICARDA germplasm accessions introduced as international drought or early-maturing nurseries. The early-maturing groups of lentils are those which mature with in 75 days. They are adapted mainly for arid and semi-arid areas with the LGP less than 60 days and warm to hot environments with temperature of over 21°C. Varieties El-142, Chekol and Alemaya fall in this category.

In the major lentil production areas of Ethiopia, planting of lentil is done usually late in the rainy season. This exposes the crop to terminal moisture stress during flowering and podding stages, and result in low economic yield due to either flower abortion and/or impeded synthesis and assimilates translocation to filling grain. If very late-maturing lines are planted in the late season they will not even flower due to desiccated dry winds against their slow development. This is why most of Ethiopian lentils are of early- to medium-maturity groups. Moreover, it has been confirmed that early planting in July to beginning of August can improve yields provided excess soil moisture is properly managed.

Water-logging: Water-logging is a serious problem on heavy Vertisols and can cause 100% crop failure if water stands in a field of lentil crop for more than two days. However, if proper soil drainage management is combined with water-logging-tolerant/resistant varieties of lentil, yield can be significantly increased in Vertisol production areas irrespective of early planting. Geletu and Yadeta (1995) indicated that there were about 39% of the genotypes, which survived in complete water-logging conditions for 20 days. Their findings indicated the possibility of breeding varieties for growing on Vertisols in the full rainy season where high moisture stress would no more be a limitation for maximizing lentil yields.

Frost: Frost is also among the major lentil production constraints occurring infrequently in different years and could cause complete crop failure. Geletu and Wondafrash (1999) found 11% of evaluated lentil genotypes as resistance/tolerant (< 5 score on a rating scale of 1- 9) to frost at Sheno (about 10 days below 0^0C). However, none of the genotypes was found free from rust damage or highly resistant with the exception of ILL-2626, which showed resistance reaction but was late-maturing. In another study, 128 genotypes were evaluated at Sheno in 1999, and 20% of these showed tolerant reaction (SARC, 2001).

The efforts made in this area of research need to be strengthened in developing appropriate screening techniques rather than only depending on natural unpredictable frost conditions.

Yield: High grain yielding genotype selection is the ultimate goal of the lentil breeding program. Strategically, the research program follows an identification and selection of genotypes from germplasm and breeding lines so long as they are high yielding with good seed quality and stable over diverse environments. In spite of yield variations among genotypes, in most cases, it seems that those genotypes, which are highly productive in relatively low stress environments, are also better productive under non-stress environments. Yield of early-maturity sets of lentil were observed to increase as they were taken from less-stressed to non-stressed environments. However, there may be dramatic yield loss the other way round when late-maturity sets are taken to the moisture stress environments like to the Rift Valley. The yield increase in good environment could be due to the improvement of yield components like biomass, seed size, more branching and podding, where available moisture and lower temperature allows syntheses and assimilate accumulation for relatively longer time as well. In general, the late sets have better yield potential than the early sets when grown in their respective environments probably because they have maximum resource accumulation chance in the longer physiological growth period. On the other hand, significant genotypic variability was manifested for almost all yield and yield-related components in both the groups in the combined analysis over years and locations (Table 4). Similarly, significant genotype by location interactions were observed for all set of parameters in the late-maturity group (Table 5) indicating a need to develop specific lentil genotypes for the specific locations. The same could be drawn in the early-set group as interaction was significant for yield. It is also noticed that all parameters do not follow similar response scale in varying environments.

SALIENT ACHIEVEMENTS

During the last decade, six improved varieties were released for farmers, who realized two- to three-fold advantage in both biological and grain yield from improved varieties over the local lentil cultivars (Table 5). Varieties 'Adaa' and 'Alemaya' have especially played a successful economic role when produced by replacing the rust susceptible farmers' cultivars in large areas of production. It is through adoption of the improved varieties and better agronomic practices that the average national yield has increased from 593 kg/ha in 1998 to 613 kg/ha in 2001 (ICARDA, 2001). For example, the farmers who adopted the improved varieties at Chefe Donsa district got 2.5-3 t/ha (ICARDA, 2001) and generated USD 700-1000 net incomes compared to 0.5-0.6 t/ha produced with the local cultivars.

Participatory evaluation of released varieties of lentil by Farmers Research Group (FRG) since 1998 proved a four- to seven-fold yield advantage with the improved varieties over the local cultivars (Table 6). This has brought a drastic attitudinal change in the subsistence farmers in utilization of the improved lentil cultivars. Moreover, establishment of lentil processing mills at farmers' village provided an opportunity for specialized production of the crop and utilization of the by-product '*haulm*' as feed for animal fattening and employment. This signified the economic role of lentil in improving livelihood at both the community and family level. A net benefit of about 200% has been achieved according to a socioeconomic study of improved lentil varieties compared to the local cultivars in 2001 (Anonymous, 2002). However, still the high management variation along with significant yield gaps existing between researcher-managed and farmer-managed farms on the same variety deserves due attention for narrowing it down.

FUTURE DIRECTIONS

The ELIP should continue on the on-going activities and should pay more attention to the following in the breeding program:

1. Identification of sources of resistance for wilt/root rots
2. Development of adaptive genotypes for semi-arid to arid environments, and for mechanical harvesting
3. Screening for water-logging and frost tolerance for developing varieties for Vertisols and frost-prone areas
4. Coordinating effort to develop and induce the exportable yellow (white) lentil cultivars in the production system that is underutilized
5. Develop lentil varieties for irrigated areas which is underexploited
6. Strengthening hybridization work to back up the genetic sources in the national research program
7. Multidisciplinary linkage strengthening to maximize utilization and contribution of lentil in Ethiopia.

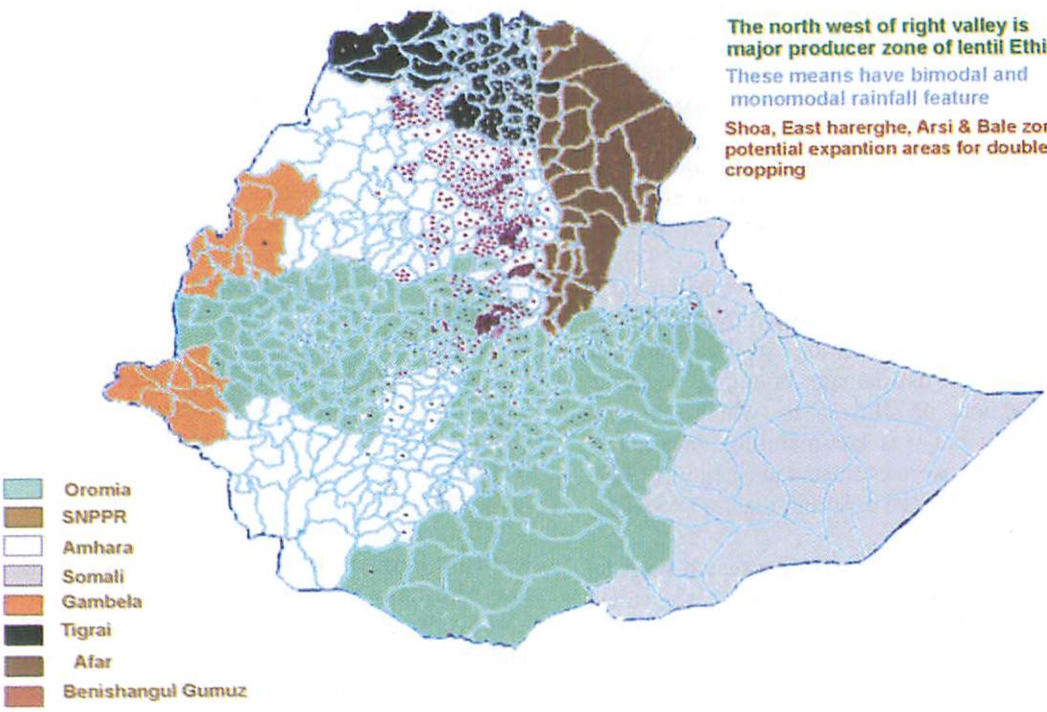


Fig. 1. Distribution of lentil production area in Ethiopia by region and districts, a dot represents 100 ha unit (developed from survey of MOA, 2002). Source: Geletu and Wondafrash (1999).

Table 4. Mean square values of yield and some agronomic characters in lentil based on early-set comprising 17 lines, and late- set comprising 20 genotypes in the national yield trial combined over seven locations and two years (2001-2002).

Source of variation	DF	DM	PTHT/ (cm)	100-SW (g)	Biomass (kg/ha)	Grain Yield kg/ha
Early-set group						
Year (Y)	2184**	281NS	1627**	0.003 NS	9290493 NS	9053643**
Location (L)	3550**	8579**	3024**	2.696**	890529771**	27763828**
YL	840**	2565**	1910**	3.119**	146677808**	21024682**
R(LY)	9**	305 NS	56*	0.216 NS	5083475**	169843 NS
Genotype (G)	377**	444 NS	123**	3.163**	41695858**	489888**
YG	25**	154 NS	22 NS	0.357 NS	5520691**	494880**
LG	20**	168 NS	19 NS	0.608 NS	15595917**	299143*
YLG	16**	174 NS	17 NS	0.483 NS	7005560**	231995*
Error	4	143	9	0.313	2484080	66341
CV %	3.72	12.64	9.76	15.28	33.85	23.21
Late-set group						
Year (Y)	0.289 NS	1142**	1190**	3.193**	52298261**	205418 NS
Location (L)	7498**	24825**	5818**	10.600**	460515687**	62525937**
YL	1349**	2761**	2475**	7.008**	335208166**	30030261**
R (LY)	119**	65 NS	36**	0.212 NS	6277320**	204775 NS
Genotype (G)	4098**	9633**	354**	24.670**	1100252**	6774422**
YG	175**	170**	22**	0.849**	12152509**	1748802**
LG	49**	164**	31**	0.550**	4938001**	721298**
YLG	43**	59**	14*	0.287**	8046850**	1108027**
Error	23	24	11	0.191	2418172	190220
CV (%)	7.56	4.12	10.68	11.92	37.6	32.05

*, ** Significant at 5% and 1% level, respectively, DF= Days to flowering; DM= Days to maturity; PTHT= Plant height, 100SW=100-seed weight. Source: DZARC (2002).

Table 5. Some agronomic and other characteristic features of released varieties of lentil (1994-2002).

Variety	YR	DM	SR	HSW (g)	Grain yield (kg/ha) FF	RF	(%) Change	Seed color	Sowing Date	Rust RX	Adaptation Zone Altitude (m asl)	Rainfall (mm)
FLIP 84-78L(Gudo)	1995	86-151	80-120	4.4-6.1	14-18	18-25	129-139	Reddish Brown	Early-mid July	R	1850-2450	500-1900
FLIP 86-41L (Adaa)	1995	86-157	80-110	3.3-4.2	16-24	19-26	119-108	Grey	Early-mid July	RR	1850-2450	500-1100
FLIP 89-63L (Alemaya)	1997	81-136	65-80	2.7-3.3	18-24	20-30	111-125	Yellow reddish	Early-mid July	RR	1650-2600	450-1200
*FLIP 96-49L(Alem Tena)	2003	81-115	80-100	2.9-3.9	14-18	17-23	121-128	Grey	Early-mid July	R	1600-2400	400-600
*FLIP 96-46L (Teshale)	2003	97-129	80-100	3.1-4.1	16-26	18-31	113-119	Grey	Mid July	R	1800-2400	400-800

* Provisional release. Source: DZARC annual research reports, and department of pulse breeding. YR: year of release, DM: days of maturity, SR: seed rate, HSW: Hundred seed wt, FF: farmers field, RF: Research Field, RX: Reaction

Table 6. Participatory performance of lentil varieties against local cultivars.

Varieties	Values	Districts: Adaa (Grain yield, kg/ha)	Alem Gena (Grain yield, kg/ha)	Chefe Donsa (Grain yield, kg/ha)	Chefe Donsa (Biological yield, kg/ha)	Rust reaction
Adaa	Maximum	2024	1520	2142	8000	Resistant
	Minimum	400	360	1458	5800	
	Mean	1207	925	1735	2800	
Alemaya	Maximum	-	3333	3571	11250	Resistant
	Minimum	-	333	2110	7750	
	Mean	-	1587	2896	8823	
Local	Maximum	400	00	1046	4750	Susceptible
	Minimum	00	00	22	1250	
	Mean	144	00	525	2850	

Source: Anonymous (2002)

REFERENCES

Agren, G., and R. Gipson. 1968. Food composition table for use in Ethiopia. ENI, Addis Ababa, Ethiopia.

Anonymous 2002. Cool Season Food and Forage Legume (CSFFL) Report 2002. Debre Zeit Agricultural Research Center (DZARC), Ethiopia.

Barulina, H.1930. Lentils of the USSR and other countries (in Russian). Bulletin of Applied Genetics and Plant Breeding, Leningrad.

CSA. 2000. Area and crop production report. Central Statistics Authority (CSA), Addis Ababa, Ethiopia.

DZARC. 1999. Annual Research Report. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit,, Ethiopia.

DZARC. 2002. Annual Research Report. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Etthiopia.

EEPA. 2002a. Pulses for India. Trade Point Newsletter. Oct. 2002. Vol 5 (18): 4.

EEPA. 2002b. Pulses (bean, peas and lentils) for India. Dec. 2002.Vol 5 (20): 3.

EEPA. 2002c. Pulses for India. Trade Point Newsletter. Vol 5 (21): 2.

EEPA. 2003a.Red lentils for Lebanon. Trade Point Newsletter Jan 2003. Vol 6(2): 2.

EEPA. 2003b.Chickpea, red split lentils, green mung beans and white kidney beans for India Jan 2003.Vol. 6 (2): 3.

EEPA. 2003c. Split lentils for Sri Lanka. June 2003.Vol 6 (7): 3.

FAO. 2001.Statstical Bulletin 1: 17-38. Food and Agriculture Organization (FAO),Rome, Italy.

Geletu Bejiga.1992. Lentil production in Ethiopia. EARO, Debre Zeit, Ethiopia (Unpublished).

Geletu Bejiga, and Yadeta Anbessa. 1995. Water logging tolerance in lentil. LENS Newsletter 22: 8-10.

Geletu Bejiga and Yadeta Anbessa. 1998. 'Alemaya': Self-adjusting lentil variety to different environments in Ethiopia. NVRSRP Newsletter No.1: 1-4.

Geletu Bejiga, and Yadeta Anbessa. 1999. Development of rust-resistant lentil cultivars in Ethiopia. Lens Newsletter Vol.26: 33-34.

Geletu Bejiga and Wondafrash Mulugeta.1999. Evaluation of lentil genotypes for resistance to frost in Ethiopia. NVRSRP Newsletter No. 2: 19-21.

Geletu Bejiga, Nigusse Tadesse, and Willie Erskine.1998. We fixed rust! Next, wilt and root rots. ICARDA CARVAN No.9: 12, 14.

Geletu Bejiga, N.Abov-Zeid, W.Suliman, Seid Ahmed, and A. Hassanein. 2001. Managing wilt and root rots of food legumes in the Nile Valley countries. ICARDA Caravan No. 15: 39-40.

ICARDA. 2001. Annual Report. Aleppo, Syria.

Muehlbauer, F.J., J.I. Cubero, and R.J. Summerfield. 1985. Lentil (*Lens culinaris Medik.*). p. 266-311. *In* R.J.Summerfield and E.H.Roberrts (Eds.) Grain Legumes Crops. Collins, London, UK.

MOA. 2002. Preliminary results of area, production and yield of temporary crops (*meher* Season, private peasant holders). Part I and II. Ministry of Agriculture. Addis Ababa, Ethiopia.

NRMRD. 1998. Natural Resource Management and Regulatory Department Working Document. Addis Ababa, Ethiopia.

SARC.2001.Annual Research Report. Sheno Agricultural Research Center (SARC), Sheno, Ethiopia.

Seifu Tsegaye. 1988. Correlation and path coefficient analysis in lentil (*Lens culinaris* Medik.) and their implication for selection. M. Sc. Thesis, Alemaya Agric .University, Ethiopia.

Tigist Dejene. 2003. Genetic variability and associations among yield and yield related characters in exotic lentil (*Lens culinaris* Medik.) lines. M. Sc. Thesis.

Westphal, E. 1974. Pulses in Ethiopia, their taxonomy and agricultural significance. Agric. Res. Rep., Wageningen, the Netherlands.

Development of Improved Haricot Bean Germplasm for the Mid- and Low-Altitude Sub-humid Agro-ecologies of Ethiopia

Teshale Assefa[1], Habtu Assefa[1] and Paul Kimani[2]

[1]*Melkassa Agricultural Research Center, PO Box 436, Nazareth, Ethiopia,* [2]*Nairobi University, PO Box 29053, Nairobi, Kenya*

ABSTRACT

Haricot bean (*Phaseolus vulgaris* L.) is one of the most important grain legumes grown in the lowlands of Ethiopia, particularly in the Rift Valley. In these areas farmers grow white bean for export. Haricot bean is also a principal food crop particularly in southern and eastern parts of Ethiopia. The crop is rich in protein, is a source of minerals especially iron and zinc in the diet, and has an advantage of improving soil fertility. Besides, it has a short maturity period of about three months. It is therefore, available for family consumption during the period when other crops are immature. The potential for haricot bean is high in the mid- and low-altitude areas of Ethiopia. However its yield has remained low because of different constraints. Research in haricot bean was initiated to evaluate different classes of haricot bean targeting for yield improvement and other acceptable quality traits for small-scale farmers. Different genotypes in each growth habit (determinate bush, indeterminate bush and indeterminate prostrate) were evaluated at different locations in replicated trials under rainfed conditions in Ethiopia. The results obtained over years and across locations indicated that the improved and those in the pipeline with their improved management practices gave higher yields compared to the local varieties. The average yield increment of the improved and pipeline materials over the local varieties were more than 30%, 35% and 40% for small white-, different colored- and large-seeded beans, respectively. This reveals that the improved and pipeline materials have higher yielding capacity, disease- and insect-pest resistance, good market and cooking characteristics compared with the local varieties. These improved bean lines would improve productivity and incomes of smallholder farmers, if disseminated and accepted by the farmers. With this background, this paper reviews development of haricot bean germplasm for wide adaptability since the mid 1990s.

INTRODUCTION

Haricot bean (*Phaseolus vulgaris* L.) is one of the most important grain legumes grown in the lowlands of Ethiopia, particularly in the Rift Valley, where farmers grow white bean for export. Haricot bean is also a principal food crop particularly in southern and eastern parts of Ethiopia. The crop is rich in protein; it is a source of minerals especially iron and zinc in the diet, and has an advantage of improving soil fertility. Besides, it has a short maturity period of about three months. It is therefore, available for family consumption during the period when other crops are immature (Amare Abebe, 1989).One million people in eastern, central, southern and western Ethiopia depend on lowland pulses, especially haricot bean. It is not exactly clear when beans were introduced in Ethiopia, but some estimate suggests the existence of kidney beans in northern part of the country around 1560. Research on haricot bean in the country began in the late 1960s. However, a nationally-coordinated research in Ethiopia began in the early 1970s with Melkassa Agricultural Research Center (MIARC) taking the lead to improve its productivity. At early stages, it was found clear that there was lack of haricot bean in the lowlands. Large numbers of haricot bean germplasm were introduced and evaluated for adaptation and productivity. In the early 1980s priorities were set. The mid- and low-altitude sub-humid agro-ecologies are the areas that receive fairly reliable rainfall. These areas mainly lie between altitudes of 1400-2000 m asl. They are the most important bean producing environments in Ethiopia. The production of haricot bean ranged from 34,430 metric tons in 1995 to 166,909 metric tons in 2001, and the export earnings ranged from US$ 9,591456 in 1990 to US$ 13,281116 in 2002 (Export Promotion Agency, personal communication). Even though the potential for bean production is high in the mid- and low-altitude sub-humid agro-ecologies of Ethiopia, bean yield levels have remained stagnant. This is mainly due to unavailability of the improved bean technologies. To alleviate the problem, efforts have been made to develop improved bean technologies by the National Bean Research Program (NBRP). Thus, this paper briefly discusses progress made in the development of improved bean germplasm for the mid- and low-altitude sub-humid agro-ecologies during the last decade.

MAJOR AREAS OF PRODUCTION

Haricot bean has a wide range of adaptation and grow well between 1400 and 2000 m asl (Table 1). The minimum and maximum mean temperature requirements are 10°C and 32°C, respectively, with a distributed rainfall of 350 to 500 mm (70 to 100 days), and the relative humidity should not exceed 75%.

Central Zone

The central zone (mainly in the Rift Valley and Lake Region) ranks first in hectarage (48%) and production (55%) of haricot bean in Ethiopia. This zone is particularly important for the white pea bean type beans that are destined for export market. Generally, small, rounded, white pea beans of bush growth habit for sole cropping are preferred for export. Specifically, varieties that have prostrate growth habit, tolerance to drought, earliness, resistance to biotic and abiotic stresses with high and stable yield potential, and good canning quality are preferred. For food beans, low cooking time, good qualities for *shiro* and *kik* are desirable qualities.

Southern Zone

The southern zone that consists of Sidamo and Gamo Gofa accounts for about 25 % of area under haricot bean. They are grown as a sole and inter-crop. The major emphasis of research in this zone is on red and speckled types grown for food. High yield potential, earliness, appropriate plant density, acceptable cooking time, red kidney or small rounded whites are preferred seed types. Resistance to pests and diseases (especially bean fly and rust), poor nitrogen fixation, and declining soil fertility are some of the research areas that require due attention.

Eastern Zone

The eastern zone constitutes mainly of the Hararge highlands, where haricot bean is the dominant crop grown mainly for food. Haricot bean is grown as a sole-or inter-crop with sorghum, maize or *chat*. Several mixtures of cultivars are grown here for various purposes. As in the southern zone, farmers here produce haricot bean twice a year. Generally, colored food beans and small whites are grown. Bushy growth habit is preferred to facilitate leaf stripping of inter-cropped sorghum. High yield potential, early-maturity, tolerance to drought and low phosphorus, improved nitrogen fixation and compatibility to the inter-cropping system are important areas of research.

Western Zone

This includes Wellega, Kaffa and Illubabor areas, which account for 17.6% of land area occupied by haricot Bean. Bushy habit is needed for sole-cropping and climbing types for inter-cropping with maize and in garden cropping. High yield potential, early-maturity for climbers, medium- to late-maturity for bush types, improved resistance to diseases especially to angular leaf spot, floury leaf spot and ascochyta blight, and large seed size are preferred.

Northwestern Zone

This includes Pawe and Chagnie areas, which account for 5% of land area occupied by haricot bean. Bushy habit resistant to web blight, and climbers resistant to angular leaf spot with high yield potential are needed.

Northern Zone

This includes Sirinka, Kobbo, Mekele and Adet areas that account for less than 5% area under haricot bean.

VARIETAL DEVELOPMENT

Germplasm Enhancement

During 1970s local collections were made mainly from market samples and haricot bean traders (Ohlander, 1980). These collections were tested with other introduced accessions starting from 1972 at Nazareth and other locations. Initially, the amount and diversity of locally collected germplasm were limited but after 1980s the number and diversity of germplasm was increased through introductions from exotic sources including recent climbing bean introductions. Since 1995, introduction of germplasm was greatly increased both in number and diversity including climbing and snap beans, and reached a total of 3258 accessions (Fig. 1). These germplasms were introduced from International Center for Tropical Africa (CIAT), and East and Central Africa Bean Research Network (ECABREN). From these introduced materials, 1923 lines are now being maintained. Screening for adaptation and other characteristics of the maintained lines, the hybridized material generated by NBRP and introduced lines is done each year.

Table 1. Classification of haricot bean and production zones (AEZ)

Production zone	Region	Production system	Production constraints	Specific purpose
East	Jijiga	Irrigation		
North	Kobbo	Mono-crop, *meher*	Moisture stress, common bacterial blight,	Cash + Food
Central	Mieso		bruchids,	
East .	Babile			
Central	Ziway	Mono-crop, *meher*	Weeds, low N&P, moisture stress, bruchids,	Cash
Central	East Shoa		CBB, rust and anthracnose, lack of food	
North	Tigrai		varieties, bean stem maggot, flower beetles	
East	Western	Inter-cropping in	Diseases, weeds, shattering, bruchids, erosion,	Food + Cash
East	Hararge	sorghum/maize/chat, *meher* and *belg*	varieties compatible with inter-cropping system	+ Feed
South	Wolketie	Mono-crop, inter-crop, *meher*	Bean stem maggot, weeds, low plant density,	Mostly
South	North Omo		low soil fertility, rust, bruchids, land scarcity,	food
South	South Omo		varieties	
West	Bako	Bush+climber, inter-cropping,	Wild animals, angular leaf spot, floury leaf spot,	Food
West	Jima	*meher*	anthracnose, bruchids, draft power, staking, termites	
North west	Pawe	Bush and climber, *meher*, mono-crop	Web blight, angular leaf spot, Ascochyta, bruchids, varieties	Mostly food
West	Abobo Assosa	*meher*, inter-crop, mono-crop	Insect-pests, varieties	Mostly food as dry bean or the leaf as vegetable
South	Konso	Inter-cropping	varieties compatible with inter-cropping, low N	Mostly food

Source: EARO (2002).

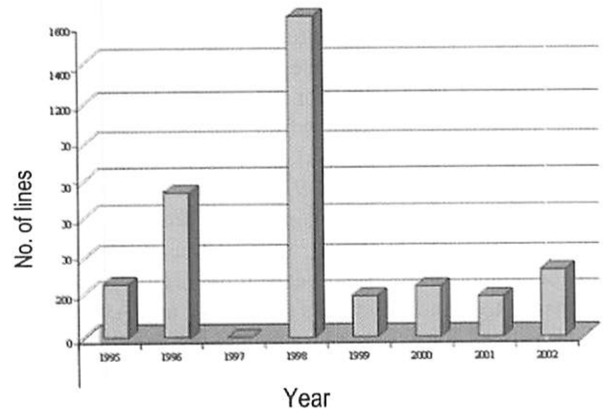


Fig. 1. Number of bean lines introduced annually from 1995 to 2002.

Evaluation and Selection

In view of the importance of haricot bean for both export and local consumption, the varietal selection program was refined from 1983 by aiming at the development of improved varieties for both demands. Based on seed size, color and bushy growth habit, three series of variety evaluations were formulated.

1. White pea bean series: small-seeded, usually pea bean shape, white seed coat and with good canning quality
2. Different colored, medium-seeded bean series: varieties for local consumption; yield, consumer preferences and cooking time as important criteria
3. Large-seeded bean series: criteria for different classes, but with larger seed size

The following steps are followed in variety evaluation:

1. Observation nursery
2. Regional yield trial (RYT)
3. Pre-national yield trial (PNYT)
4. National yield trial (NYT)
5. Farm verification trial (FVT)
6. Variety release

New introductions are mostly grown in observation nurseries at 1-5 locations. Under this post-entry quarantine nursery, the materials are assessed for diseases and general performance. The RYT is a trial organized for a specific zone for a specific reason. Up to 25 varieties including standard check varieties are compared in the PNYT. Each variety is grown in six-row, 4-m plots at six or more locations. An RCBD with three replications is used. At each location, the recommended cultural practices for the area are followed with respect to sowing date, fertilizer application and weed control. All pertinent field data are recorded and yield data are statistically analyzed. The superior varieties (yielding >10-20% over the checks) are selected for evaluation in the NYT, which is conducted similar to the PNYT, with more test locations. The trial is repeated for two years, and based on the results, outstanding two to three varieties are evaluated through the FVT in non-replicated 100m^2 plots on station and on farmer's fields in the localities where the new varieties are to be released. The FVT is conducted under the supervision of the National Variety Releasing Committee (NVRC).

Based on the information from the farm verification trial together with documents provided by the breeder, the NVRC makes the appropriate recommendation. The variety is considered for release in an area or region if it is superior to the existing variety in yield or if it is superior in quality, or some other special characteristics. Following the approval by the NVRC, the new variety is assigned a name. Seed multiplication is begun by the Ethiopian Seed Enterprise.

National Yield Trials (1995 to 1996)

The objective of these trials was to identify high yielding varieties with wide adaptations. The main emphasis throughout was on white-seeded varieties for the export market, whereas the colored and the large-seeded varieties were for the local needs. The trials were also used to test new areas where little haricot bean had been grown in the past. Mean yields in 10 white pea beans across seven locations exceeded 1813 kg/ha (Table 2). Lines BAT-1248, PAC-29, PAN-182, PAN-173 and PAN-142 were the top yielders, outyielding the standard check by 19 to 34%. Besides, the varieties were also resistant to rust and anthracnose, and moderately tolerant to common bacterial blight.

Of the 11 colored and medium-sized varieties tested at seven locations, five (GX-1175-3, A-439, TY 3396-1, A-265, A-445) were top yielders, exceeding the check (Roba-1) by 35 to 44 % (Table 2). All these varieties are colored and hence useful for local consumption. They were also resistant for diseases like rust and anthracnose, and moderately tolerant for common bacterial blight. The results for large-seeded beans at seven locations indicated that four varieties (G-2816, MX- 2500-19, A-262, GLPX-92) outyielded the standard check (Brown Speckled at 1653 kg/ha) by 38 to 56% (Table 2).

By putting data from previous years and 1995 to 1996 together, several varieties were proposed by NBRP for release. Of these, GX-1175-3, renamed as Zebra, and A-262, a large-seeded variety renamed as Atendaba, were released by the NVRC for mid- and low-altitude agro-ecologies of the country. During this period, besides yield and other characteristics, cooking time and earliness were also taken as the main criteria in variety selection.

National Variety Trials (1997 to 1998)

Germplasm introductions were increased to some extent during this period with additional flow of promising varieties in the selection scheme. Early results from introductions with an approach for germplasm advancement led to the release of four varieties during this period. These materials are the most performing ones when compared with others. Among the white pea beans, PAN-173, BAT-1248, PAN-182, REZ-19 and PAN-154 showed good yield performance, exceeding the checks (Awash-1 and Mex-142) by 11 to 19 % (Table 3). The top yielders among different colored beans were TY-3396-12, CTC-1, MAM- 41 and TY-3396-1, and all of them outyielded Roba-1 as check (2297 kg/ha) by about 7 to 21%). These varieties were resistant to common bacterial blight and angular leaf spot. In the large-seeded group, MX-2500-19, A-197, G-2816 and ICA-15541 were the highest yielders, surpassing Brown Speckled (a check and the lowest yielder at 1602 kg/ha) by 50 to 54%. Besides yield and cooking time, soakability of the variety was considered as one of the criteria in varietal selection for different colored and large-seeded beans.

Generally, the goal of a variety development program is to release better yielding varieties for adoption by farmers. In these two years, four varieties were accepted by NVRC for release for farmers' use. These included: one from white pea bean (PAN-182, renamed as Awash Melka); two from the colored group (G-2816 and GLPX-92 and renamed as Gofta and Ayenew, respectively); and one from the large-seeded group (ICA-15541, renamed as Geberasha). The accepted white pea bean is a high yielder as compared to standard checks (Mex-142 and Awash-1), which is used for export purpose and has good canning quality. In other three varieties from large-seed group soak ability and cooking time were also taken as main criteria for selection and release.

Table 2. Mean yields (kg/ha) of white pea beans, different colored bean and large-seeded bean by site, 1995-1996

No.	Variety name	Bako	Sirinka	Jimma	Alemaya	Melkassa	Awassa	Ziway	Mean
(a)White pea bean									
1.	PAN-142	1361	1641	2610	3003	1891	3145	1974	2232
2.	PAN-154	1202	1434	2524	2744	1821	3106	1665	2014
3.	BAT-1248	1729	1712	2660	3256	2070	2793	2394	2516
4.	PAN-182	1690	2151	2576	3029	2086	3151	1860	2363
5.	PAN-164	1617	1411	2884	2419	2187	2914	1644	2154
6.	PAN-173	1684	1673	2951	3297	1820	3055	2009	2356
7.	G-18330	1292	1348	2870	2918	2092	2988	1902	2201
8.	PAC-29	1553	1743	2978	3066	2437	3145	1887	2401
9.	PAC-19	1353	1313	1589	1969	2207	2410	1853	1813
10.	MEX-142	1121	1523	1569	2322	1947	2206	1713	1872
(b) Different color bean									
1.	BZ 1289-9	1295	2124	2534	3434	2610	3408	1741	2449
2.	TY-3396-1	2061	2312	2703	4223	2403	2751	2012	2638
3.	A-445	1389	2603	2509	4088	2463	2976	2199	2604
4.	A-265	1272	2557	2381	4572	2314	3054	2124	2611
5.	TY-3396-7	1476	2187	2625	3656	2188	2913	1943	2426
6.	TY-3396-6	1593	2311	2656	3588	2339	2904	1914	2472
7.	XAN-104	1362	3104	2554	3479	1912	2950	1688	2436
8.	BAT-336	1142	1317	2586	2294	1980	2725	1428	1925
9.	A-439	1267	2324	2814	3920	3530	2628	2239	2675
10.	GX-1175-3	1513	2525	2946	4348	2683	3013	2315	2763
11.	ROBA-1	1272	2157	2178	1646	2017	2650	1535	1922
(c) Large-seeded bean									
1.	A-197	466	1705	2265	2982	2412	2962	2327	2160
2.	PVA-1076	935	2778	1315	2713	2416	2414	2143	2102
3.	LRK-1	1053	1714	1473	2636	1630	2490	1805	1972
4.	G-2816	1114	2546	1948	4432	2891	2922	2187	2577
5.	MX-2500-19	1323	2143	1795	3978	3235	2542	2176	2456
6.	PVA-1145	973	1580	1257	2656	2222	2660	2146	1928
7.	AND-636	968	1898	1438	2767	2625	2511	2167	2054
8.	AND-661	1029	1886	1507	3141	2726	2668	1919	2125
9.	GLPX-92	1196	2195	1903	3157	2829	2478	2187	2278
10.	A-262	1139	2341	1734	4517	2393	2474	2361	2423
11.	PVA-774	1167	1337	1360	2821	2179	2770	2227	1980
12.	BROWN SPECKLED	1081	1344	1057	2106	2420	1912	1649	1653
Altitude (m)		1650	1850	1750	2125	1550	1650	1650	
Mean annual rainfall (mm)		1172	1008	1576	699	768	1045	775	
Temperature (°C)	Max	27.9	26.1	26.3	22.8	28.6	26.9	27.4	
	Min	12.1	13.3	11.5	10.2	13.8	12.2	12.1	

Source: IAR (1997).

Table 3. Mean yields of white pea, different colored and large-seeded beans by site, 1997-1998.

No	Variety name	Location							Mean
		Bako	Sirinka	Jimma	Alemaya	Melkassa	Awassa	Ziway	
(a)White pea bean									
1.	PAN-173	1342	2372	2480	2522	1734	2786	1681	2131
2.	PAN-182	1580	1805	2501	2402	1532	3125	1347	2041
3.	PAN-154	1056	1732	2379	2327	1637	2417	1654	1886
4.	BAT-1248	1288	1939	2535	2683	1803	2940	1543	2104
5.	PAN-142	1257	1816	2353	2308	1991	2150	1780	1950
6.	PAN-164	1099	1835	2388	1931	1867	2766	1615	1928
7.	MX-142	927	1462	2343	2026	1102	1168	1028	1436
8.	EMP-212	1262	1173	2963	1428	1528	2706	1877	1848
9.	REZ-19	1421	1689	2382	2641	1835	2823	1317	2015
10.	MCM-3511	1045	1556	2149	1979	1825	2083	1262	1699
11.	EMP-247	1026	1871	2213	1878	2012	2406	1285	1813
12.	REN-19	1100	1581	2402	2393	1765	2440	1658	1905
13.	AWASH-1	929	1988	2477	2007	1681	2347	1295	1817
(b) Different colored bean									
1.	TY-3396-12	1792	2529	2874	3829	3064	3370	1994	2779
2.	TY-3396-1	1963	1932	2462	3707	2287	3047	1810	2458
3.	A-439	1896	2228	2313	3213	2646	2668	1926	2413
4.	A-445	1954	2091	1948	2995	2582	2588	1688	2264
5.	CTC-1	2214	2822	2461	3741	3534	2149	1550	2639
6.	TRA-3	1833	2366	3056	2311	2059	3119	1750	2356
7.	MAM-41	2112	3057	2789	2462	3125	1546	2590	2526
8.	EMP-220	2070	2280	2514	2763	2378	2773	1798	2368
9.	EMP-236	1878	2250	2738	2694	2786	2770	1912	2433
10.	DICTA-65 ROWN	1298	2425	2450	2874	2758	2372	2204	2340
11.	EMT-5	2100	1578	2393	2729	1866	1963	1714	2049
12.	ROBA-1	1891	1990	2265	2414	2559	2660	2301	2297
(c) Large-seeded bean									
1.	A-197	1325	2212	2656	290-4	2503	2797	2534	2419
2.	PVA-1145	1442	1241	2492	2378	2063	2896	1902	2058
3.	PVA-1076	1382	1715	2295	2449	2109	3127	1868	2135
4.	ENT-6	1702	1190	2460	2230	2023	2686	1692	1997
5.	RAB-484	1682	1756	2358	2261	2158	2523	2493	2176
6.	AFR-907	2040	1927	2522	2848	2494	2500	2114	2349
7.	AFR-585	1385	1605	2414	2682	2311	2544	1983	2132
8.	BRK-66	1640	3934	2252	2318	2054	2764	1641	2372
9.	PVA-774	1667	1502	2378	2238	2020	2888	2675	2195
10.	BROWN SPECKLED	1341	1435	1537	2075	1575	1826	1425	1602
11.	GLPX-92	1338	2647	2848	2015	1985	1677	1090	1943
12.	G-2816	1252	2692	2707	2678	2814	2669	2096	2415
13.	MX-2500-19	1914	2509	2798	2704	2260	3115	1934	2462
14.	ICA-15541	2150	2132	2508	2524	2396	2744	2350	2401
Altitude(m)		1650	1850	1750	2125	1550	1650	1650	
Mean annual rainfall (mm		1172	1008	1576	698.9	768	1045	774.6	
Temperature (0C)Max		27.9	26.1	26.3	22.8	28.6	26.9	27.4	
Min		12.1	13.3	11.5	10.2	13.8	12.2	12.1	

Source: IAR (1997, 1998).

National Variety Trials (1999 to 2001)

Mean seed yields of 16 white pea beans across 13 locations are shown in Table 4. During this period, EMP-233, SEQ-35, G-17426 and ACC No 1207 were the top yielders, outyielding the standard checks (Awash-1 and Mex-142) by 30 to 41%. Of the 15 colored, medium-seeded varieties tested at 13 locations, variety G-6 outyielded GX-1175-3 (advanced check), and varieties TY-3391-1 and CTC-1 yielded as good as the advanced check (GX-1175-3). These three varieties yielded better than the standard check (Roba-1) by 7 to 22% (Table 5). Results for large-seeded beans at 13 locations indicated that three varieties, CIFFAAC-87110, G-11010, MMS-25 and CALIMA, gave better mean yield than the standard checks (Brown speckled and Goberasha) by 25 to 47 % (Table 6).

During this period, the NBRP paid attention to medium, red-seeded beans compared to other colored groups based on the preference of the small-scale farmers for consumption. During the three years of intensive selection, EMP-376, DOR-554, DICTA-105 and EMP-385 were the top yielders over the standard check (Red Wolaita) by 46 to 52% (Table 7). Two medium- and red-seeded bean varieties (DOR-554 and DICTA-105) were proposed to VRC during 2002; both were accepted by the Committee.

In the past 10 years, 12 varieties have been released by NBRP for cultivation by farmers (Table 8). A comparison of the failures and successes of strategies followed by the Program, during the three periods of its life, demonstrates the importance of using a large and diverse germplasm base for selection. The Program is now on a course to recommend a series of new improved varieties of all the three Ethiopian bean classes over the next few years.

Table 4. Mean grain yields (kg/ha) of white pea beans by site, 1999-2001.

No.	Variety name	Location													Mean
		Bako	Sirinka	Jimma	Alemaya	Melkassa	Awass	Ziway	ArsiNegele	Assassa	Pawe	Adet	Ambo	Finote Selam	
1.	NZBR-2-5	1498	1773	2580	1781	1828	1402	1712	2083	1402	1186	2250	2685	2503	1939
2.	EMP-212	1168	1384	2534	1902	1814	1323	1650	1573	1323	922	2012	1759	2799	1784
3.	EMP-233	1539	1657	2813	2535	2091	1589	1689	2205	1589	1183	2358	3727	3136	2222
4.	STTT-165-72	1503	2274	2646	2164	1516	1250	1607	2601	1250	855	2015	2258	2809	2000
5.	ACC NO 1207	1373	1701	1843	1945	1974	1257	1773	2192	1257	940	1361	1010	2490	2056
6.	SEQ-35	788	1552	1942	2489	1779	949	4447	1812	949	790	981	832	2124	2075
7.	UTT-27-24	807	751	4045	2325	1920	1201	1280	2057	1201	1049	937	1283	2456	1560
8.	STTT-565-95	846	2083	1140	2178	1580	1036	1896	2667	1036	1049	1114	1054	2803	1615
9.	NZBR-2-8	1873	1726	2526	2162	1848	1102	1631	2001	1102	1214	2356	2347	2601	1929
10.	CENTALIA	581	1214	1454	1784	1613	1160	1282	1526	1460	954	209	783	1805	1219
11.	UTT-24-131	685	2317	1769	2256	1933	1507	1590	2250	1507	990	543	1860	2124	1680
12.	HAROFLEET	1603	1544	783	1856	1459	1475	1275	1381	1475	730	125	793	1154	1162
13.	G-17426	1303	1687	2176	2242	1679	1418	1539	2960	1418	739	1504	1642	2522	2073
14.	PAN-182	2293	2219	2747	2062	2012	1370	1273	2154	1370	1152	1562	2114	2857	2020
15.	AWASH-1	855	1206	2296	2410	1467	1268	1661	2380	1268	1104	1441	1553	2369	1694
16.	MEX-142	685	2145	2007	2753	1614	1521	1465	1675	1521	666	833	2849	1205	1578
Altitude (m)		1650	1850	1750	2125	1550	1650	1650	1960	1550	1100	2060	2225	1710	
Mean annual Rainfall (mm)		1172	1008	1576	698.9	768	1045	774.6	781.6	731.0	1831.8	917.2	1523.6	980	
Temperature: Max		27.9	26.1	26.3	22.8	28.6	26.9	27.4	25.2	24.2	32.4	25.4	25.6	25.2	
Min		12.1	13.3	11.5	10.2	13.8	12.2	12.1	12.4	5.6	15.0	7.8	11.2	11.6	

Source: EARO (2001).

Table 5. Mean grain yields (kg/ha) of different colored beans by site, 1999-2001.

No.	Variety name	Location											Mean
		Bako	Sirinka	Jimma	Alemaya	Melkassa	Awassa	Ziway	Assassa	Pawe	Adet	Ambo	Finote Selam	
1.	EMP-236	1682	2988	3673	2528	2605	2747	1996	2173	1170	3117	2988	2718	2535
2.	EMP-220	1749	3060	1958	2456	2695	2792	1786	2523	1165	2752	3029	2402	2364
3.	CTC-1	1973	2953	2996	2999	3425	2215	2002	2348	1263	1887	3109	3099	2606
4.	TRA-3	1637	2832	2581	2260	2433	2387	1699	2041	1008	2761	3095	2687	2284
5.	MAM-41	1884	2953	2899	3289	2241	1743	1943	1870	1028	2647	3059	2304	2322
6.	EAP-4	1253	2681	2136	2365	2681	2920	1724	1949	790	1976	2332	2112	2076
7.	FEB-147	1582	2391	2917	2426	2638	2560	1499	1972	1009	3101	2663	3017	2315
8.	G-6	1383	1981	3998	1997	2321	2362	1550	1616	1003	2818	2378	2612	2885
9.	RAB-404	1449	1968	3082	2461	2294	2766	1746	1945	987	2663	2177	2489	2204
10.	SXWW-2-3	1552	2166	2806	2414	2423	1954	1682	2257	948	2686	2693	2389	2164
11.	SXWW-1-3	1772	2490	2980	2582	2375	1635	1792	2219	724	2437	2822	2198	2173
12.	TY-3396-1	1728	3091	2808	2459	3105	2624	2075	2734	1292	3203	3136	2520	2656
13.	A-445	1680	2752	2943	2311	2640	2133	1915	2389	980	2675	2606	2596	2379
14.	ROBA-1	1642	2356	3452	2536	2172	2736	1613	1762	1303	3873	2263	2849	2359
15.	GX-1175-3	2778	2924	2875	3843	3645	2897	2424	2161	1018	3134	2932	2353	2757
Altitude (m)		1650	1850	1750	2125	1550	1650	1650	1550	1120	2060	2225	1710	
Mean annual Rainfall (mm)		1172	1008	1576	698.9	768	1045	774.6	731.0	1576	917.2	1523.6	980	
Temperature: Max		27.9	26.1	26.3	22.8	28.6	26.9	27.4	24.2	32.3	25.4	25.6	25.2	
Min		12.1	13.3	11.5	10.2	13.8	12.2	12.1	5.6	16.1	7.8	11.2	11.6	

Table 6. Mean grain yields (kg/ha) of large-seeded beans by site, 1999-2001.

No	Variety name	Location												Mean
		Bako	Sirinka	Jimma	Alemaya	Melkassa	Awassa	Ziway	Assassa	Pawe	Adet	Ambo	Addis Zemen	
1.	AFR-579	1234	762	2238	1913	1654	1908	1285	1952	832	1441	1877	349	1454
2.	AFR-585	1222	1160	2103	2261	1975	2100	1375	1993	1914	1093	1684	356	1603
3.	AFR-907	1291	978	1904	1675	1861	2370	1115	2220	1218	982	2314	476	1534
4.	RB-484	1056	693	1718	1846	1851	1702	1242	1996	850	1515	2789	321	1465
5.	PVA-774	1255	479	2063	1611	1584	1946	1053	1570	907	639	2111	253	1289
6.	PVA-1145	1413	720	1812	1811	1620	2196	1092	1424	777	752	1531	175	1277
7.	AFR-550	1253	1049	1819	2283	1713	2171	1063	1858	1242	1415	1662	331	1488
8.	CALIMA	2298	573	2278	2219	1427	1850	1155	2016	1051	1178	1443	247	1747
9.	CIFAAC 87110	1461	1397	1893	2089	1902	6909	1434	1938	1323	1356	2481	492	2056
10.	G-13609	1313	1430	1666	2531	1697	1956	1208	1135	1069	1073	2296	868	1520
11.	MMS-25	1042	1816	2490	2908	1655	2545	1561	2629	1146	1968	1478	301	1795
12.	G-7	1297	1146	1815	1757	1566	2286	1349	2201	1236	1450	2560	336	1608
13.	G-11010	1377	1360	2291	2545	1656	2611	1038	2591	993	1417	2737	254	1906
14.	GOBERASHA	1447	840	1671	2233	1844	2243	1240	1679	934	1027	1355	345	1405
15.	A-197	1471	892	2227	2477	1810	2252	1658	2043	983	1439	1256	283	1566
16.	BROWN SPECKLED	1477	851	1254	2074	1423	1492	1282	1920	1024	1148	1274	506	1394
Altitude(m)		1650	1850	1750	2125	1550	1650	1650	1550	1120	2060	2225	1780	
Mean annual rainfall (mm)		1172	1008	1576	698.9	768	1045	774.6	731.0	1576	917.2	1523.6	970	
Temperature Max		27.9	26.1	26.3	22.8	28.6	26.9	27.4	24.2	32.3	25.4	25.6	25.2	
Min		12.1	13.3	11.5	10.2	13.8	12.2	12.1	5.6	16.1	7.8	11.2	10.2	

Table 7. Mean grain yields (kg/ha) of medium, red-seeded beans by site, 1999-2001.

No.	Variety name	Location												Mean
		Bako	Sirinka	Jimma	Alemaya	Melkassa	Awassa	Ziway	Assassa	Pawe	Adet	Ambo	Areka	
1.	DICTA-105	1156	2037	3092	1777	2210	3099	2483	1087	1509	2092	1222	1656	2010
2.	VAC-67	1113	1851	2200	1683	1961	2017	2579	591	1457	2794	2551	778	1798
3.	EMP-376	1773	2058	2469	1770	2346	2995	2950	1001	2098	3020	1603	1082	2097
4.	DOR-554	1871	1897	2587	1750	2076	2548	2578	937	2261	2498	2112	1397	2043
5.	EMP-445	1544	1341	2699	2108	1898	2645	3127	858	1322	2871	1764	1088	1939
6.	DOR-705	1034	1134	2585	1993	2285	2436	3838	857	1479	2369	2275	845	1927
7.	DOR-582	1203	1094	2451	1601	1861	1798	3301	817	1802	3000	1758	865	1796
8.	EMP-385	1214	2002	2196	1981	2583	2058	3234	684	1765	3622	1754	982	2006
9.	DOR-711	1036	1913	2224	1917	2143	1732	3057	784	1667	3423	2468	924	1901
10.	XAN-317	985	1590	2719	2147	1972	2010	2622	749	1896	3853	1612	1467	1968
11.	DOR-517	970	1309	2347	1242	1903	2236	3256	839	1547	3295	1335	1147	1785
12.	XAN-312	1472	1298	2537	1544	2080	2201	2685	837	1839	3386	2205	940	1919
13.	DOR-567	1087	1055	2458	1556	2059	2215	2752	709	1806	3384	2163	879	1843
14.	DOR-523	816	1419	2376	1548	2120	2104	2644	977	1908	3444	870	742	1747
15.	DOR-764	1380	1796	2469	2222	2049	2651	3318	515	1948	3725	1327	656	2005
16.	RED WOLAITA	847	749	1318	1623	1545	1263	2339	717	829	2873	1780	696	1377

Table 8. List of the released haricot bean varieties since 1990.

Bean Type	Variety	Year of Release	Important Features
Export Beans	Awash - 1	1990	Good canning quality, high yield
	Awash-melka	1999	Good canning quality, anthracnose resistance
Food Beans	Roba	1990	High yield, good for shiro and kik
	Atendaba	1996	High yield
	Gofta	1996	High yield
	Ayenew	1996	High yield
	Beshbesh	1998	BSM resistance, high yield
	Melkie	1998	BSM resistance, high yield
	Zebra	1999	High yield, adaptation to CRV
	Goba Rasha	1999	High yield, adaptation to humid tropics
	Tabor	1999	High yield, adaptation to southern Ethiopia
	Dicta-105	2003	High yield, wide adaptation
	Dor-554	2003	High yield, wide adaptation

Source: EARO (2000)

Genotype x Environment Interaction

Ethiopia is a country of great environmental variations (EMA, 1988). which leads to significant genotype and environment interaction will also be great (Fehr, 1992). Setegn and Habtu (2002) reported genotype by environment interaction and stability of seed yield in navy bean genotypes after evaluating 16 navy beans genotypes at four locations in the mid- and low-altitude sub-humid agro-ecologies of Ethiopia. The major haricot bean growing environments can be classified into four based on their RF, T°, relative humidity, soil type and other environmental factors. The environments are generally grouped into central lowlands (central Rift Valley), western area (Jima, Bako and Pawe), eastern (Alemaya, Hirna and Asebeteferi), and southern (Awassa and Areka). Thus, specific breeding programs were recommended for the different bean agro-ecologies of Ethiopia. However, stability of performance of bean genotypes within a particular agro-ecology should be considered in the selection of bean varieties.

FUTURE DIRECTIONS

With favorable environments available for common bean production in the mid- and low- altitude sub-humid agro-ecologies and great genetic variability in beans, further increment in yield is expected. To surpass current yield levels, identification of different varieties for different agro-ecologies of Ethiopia is very important. The EARO in collaboration with East and Central Africa Bean Research Network (ECABREN) and CIAT is developing different crossing materials at Melkassa, Awassa and Alemaya. Efforts have also been made to improve previously released varieties (like Mexican- 142 and Roba-1) by introgression of selected bean germplasm into them. However, further introgression of germplasm into commercial varieties (which are susceptible to different diseases and pests) using different breeding methods for the mid- and low-altitude sub- humid agro-ecologies are deemed very important. Evaluation of ECABREN and CIAT germplasm for local adaptation and utilization in the national breeding program is the other alternative for bean breeders working in these agro-ecologies. Germplasm improvement for tolerance to different biotic and abiotic stresses in the mid- and low-altitude sub-humid regions is also an important challenge for bean breeders in the future. Breeding for tolerance to rust, anthracnose, common bacterial blight and bean stem maggot is also important for attaining higher bean yields. Currently, the national bean research project at Melkassa allocates 80-90 % of resources and time for the development of white pea beans and different colored beans, and 5-10 % for the development of large-seeded bean, and this effort will continue to be one of the activities of bean breeders because white pea bean and different colored bean varieties will serve the desired interests of poor farmers for cash and food. The NBRP has also a plan to work on the market-type beans (particularly on white and red beans). Development of improved varieties with different maturity periods for different cropping systems will also remain a priority.

REFERENCES

Amare Abebe. 1989. Haricot bean (Phaseolus vulgaris L.) varieties performance and recommended methods of production. p. 229-252 In Proc. 19th National Crop Improvement Conference, 22-26 April 1987. Addis Ababa, Ethiopia

EARO. 2000. Lowland pulses research strategy. Ethiopian Agricultural Research Organization (EARO), Addis Ababa. Ethiopia.

EARO. 2001. Melkassa Agricultural Research Center Progress Report for the Period 1999/2001. Ethiopian Agricultural Research Organization (EARO), Melkassa.

EMA. 1988. National Atlas of Ethiopia. Ethiopian Mapping Authority (EMA), Addis Ababa, Ethiopia.

Fehr, W.R. 1992. Principles of Cultivar Development: Theory and Technique. Iowa State University, USA.

IAR. 1997. Melkassa Agricultural Research Center Progress Report for the Period 1995/96. Institute of Agricultural Research (IAR), Melkassa.

IAR. 1998. Melkassa Agricultural Research Center Progress Report for the Period 1997/98. Institute of Agricultural Research (IAR), Melkassa.

Ohlander, T. R. 1980. Research on haricot bean (Phaseolus vulgaris L.) production in Ethiopia, 1972-1976. Swedish University of Agricultural Science, Department of Plant Husbandry. Uppsala, Sweden.

Setegn Gebeyehu, and Habtu Assefa. 2002. Genotype x environment interaction and stability analysis of seed yield in navy bean. African Crop Sci J. 11: 1-7.

Soybean Genetic Improvement in Ethiopia

Asrat Asfaw[1], Abush Tesfaye[2], Sintayehu Alamire[3] and Mulugeta Atnaf[4]

[1] Awassa Research Center, P.O.Box 6, Awassa, Ethiopia; [2] Jimma Research Center, P. O. Box 192, Jimma, Ethiopia; [3] Jimma College of Agriculture, P.O. Box 307, Jimma, Ethiopia; [4]Pawe Agricultural Research Center, P. O. Box 25, Metekle, Ethiopia

ABSTRACT

Soybean, known in many parts of the world as a complete food plant, is of recent introduction to Ethiopia. The genetic improvement work on the crop started in 1950s with variety trials constructed from introductions. Plant introduction has been playing a significant role in soybean variety development in the country. The introduced materials from different sources (INTSOY, IITA, AVRDC, Uganda, FAO, Germany, etc.) have been screened for adaptation, yield, resistance to pests and desirable agronomic characters at different locations. Six best adapted and good yielding varieties with varying length of maturity have been recommended or released for cultivation by farmers. At present, some new varieties have reached the final stage of yield testing, and several new promising lines have been identified. Since introductions are being used as the only source of new genes for yield improvement, 300 introductions are maintained at Awassa Agricultural Research Center for future use in breeding program. The main objective of soybean breeding program in the country is development of disease-resistant varieties that produce high yield. Since the late 1990s, soybean production has been started by large-scale farmers. The development of varieties resistant to lodging and suitable for combine harvesting are the focus areas of soybean breeding. The paper reviews recent advances in soybean breeding in the country.

INTRODUCTION

Soybean (*Glycine max* L. Merrill) belongs to family Leguminosae, subfamily Papilionoideae, tribe Phaseolae, and genus Glycine. It is an important legume crop of the world. It is reported to be domesticated in Asia, probably in northeastern China about 2500 B.C. (Poehlman and Sleeper, 1995). Since then, it has spread to different countries in the world and become an established component of world agriculture. Among grain legumes, soybean has the highest protein and oil content. The soybean seed, on an average, contains 40% protein and 20% oil (Norman *et* al., 1995; INTSOY, 1975; Poehlman and Sleeper, 1995). Its protein has a good balance of the essential amino acids approximating the standards established by FAO (FAO, 1994). Its uses are numerous as a human food and animal feed. Being a legume crop it also plays significant role in soil improvement in the cropping system by fixing atmospheric nitrogen via symbiotic bacteria. Due to its versatile uses, soybean is known in many parts of the world as a complete food plant, golden bean, miracle bean, crop of the planet, the cow of China, the meat of the fields, the protein hope of the future, and God's sent golden bean (Hittle, 1975).

Soybean breeding in Ethiopia was started in 1950s on evaluation of introduced varieties with main emphasis of replacing the soybean flour import with locally produced soybean flour and introducing the crop into the existing crop production system and in the diet of the poor farmers (Hammer and Haraldson, 1975). Soybean breeding in Ethiopia is characterized by plant introductions, which are being used as the only source of new genes. The introductions were evaluated to identify varieties well adapted to the country, and at the same time to identify potential areas for producing the crop (Amare, 1987). During the four decades of breeding effort in the country, varieties suitable for different areas of production in the country were identified. The present paper deals with the progress after the major review of Amare (1987).

HISTORICAL BACKGROUND OF SOYBEAN BREEDING IN ETHIOPIA

Breeding work on the crop was started in 1950s and was characterized by plant introduction. The introductions were evaluated to select suitable varieties adaptable to different environmental conditions of Ethiopia, and at the same time to identify potential areas for soybean production in the country. According to Hammar and Haraldson (1975) and Amare (1987) the first variety trial was conducted at Jimma College of Agriculture in 1956. Then the variety trials were conducted at Debre Zeit Agricultural Research Center (DZARC) from 1958-1963. The breeding work was discontinued for some time. Thereafter, trials on some introduced varieties from America and Germany were conducted at CADU (Chilalo Agricultural Development Unit) from 1967-1970. In 1971, CADU and ENI (Ethiopian Nutrition Institute) launched a joint introduction program with major objective of replacing imported soybean flour, and inclusion of the crop to the existing farming system and diet of the peasant farmers. The program attempted variety trial with 112 introduced entries from Uganda and 63 entries from FAO in 1971. The joint program also evaluated the materials introduced from West Africa, Indonesia, USA and Japan at different locations in 1972. A nationally coordinated soybean research was started in 1974 by the then IAR (Institute of Agricultural Research). Before and after the decentralization of agricultural research in 1990s, Awassa Agricultural Research Center (AwARC) of the present SRARI (Southern Regional Agricultural Research Institute) has been coordinating the soybean genetic improvement work nationally. Plant introduction and to some extent selection from introductions were the breeding methods used.

BREEDING OBJECTIVES

Soybean breeding in the country focuses mainly on seed yield, disease resistance, resistance to shattering and crop maturity for different areas of production. Since late 1990s when the large-scale farmers started producing soybean, more emphasis in breeding soybean has been put on the development of varieties resistant to lodging and suitable for combine harvesting.

BREEDING PROCEDURES

Development of varieties superior to the existing ones in yielding ability, disease and insect resistance and other characteristics is an ultimate goal of any breeding program (Singh, 1983). In the development of soybean varieties for commercial production, various stages of trials are followed in the country, some of which are: Nursery -I, Nursery -II, Pre-National Varity Trial (PNVT), National Variety Trial (NVT) and Variety Verification Trial (VVT) (Fig. 1).

Nursery-I

The working germplasm pool constructed from introductions, selections from introductions and international trials are tested for one year at one location. The objective of this trial is to make sure that the new entries are superior in performance from already existing best variety. In this nursery, more attention is given to the reaction of the new entries to the diseases and insect pests, and some agronomic traits such as days to maturity, and resistance to shattering and lodging. Most of the time this nursery is non-replicated, where test entries are planted in one or paired rows spaced 75 cm apart in augmented design. Since the materials at this stage are from different maturity groups emphasis is given to classify the new entries to different maturity groups for the next stage of testing. The maturity classification of test entries is further refined at Nursery-II.

Nursery -II

This nursery is conducted at one location for one year and is often referred to as the PVT. In Nursery-I, the entries are subjected to high selection pressure for different constraints such as diseases (bacterial blight, bacterial pustule, and virus resistance/tolerance), resistance to shattering and lodging and good seed quality (free from seed staining). Only those entries expressing superior performance are selected for Nursery-II to make sure that the new entries are superior to the existing ones before putting them under the PNVT multi-location trial and at the same time to reduce the numbers to manageable size. In this nursery, the plot size is 4, 4-m rows with inter-row spacing of 40 cm for early and 60 cm for medium- and long-maturity duration genotypes (the same spacing is used in all variety trials). Plant to plant spacing is 5 cm. It is a replicated nursery and most often a simple lattice design is used. At this stage, more emphasis is given to grain yield and repeatability of positive traits assessed in Nursery-I.

Pre-National Variety Trial

This trial is an initial multi-location trial conducted at two to three locations for one year. The plot size is similar to that of Nursery-II but is replicated three times in a randomized block or lattice design. The objective of this trial is to evaluate the repeatability and performance of the new entries across locations.

National Variety Trial (NVT)

The entries that are outstanding in seed yields, resistance/tolerance to major diseases and some agronomic traits such as lodging and shattering resistance in PNVT of the previous year are promoted to the NVT. It is conducted at least at five locations for 2 to 3 years. The plot size is six, 4-m rows. The design used is randomized block with three to four replications depending on the seed availability. The objective of this trial is to assess the stability of the performance of the entries at different environments, and to select stable and high yielding entries for VVT.

Variety Verification Trial (VVT)

Variety verification trial is conducted both at on-station and on-farm for one year. One or two new high yielding and stable entries with other desirable agronomic and disease-resistant traits identified from NVT are tested on a 10 x 10 m single plot along with best checks. At this stage, the breeder proposes the release of an entry as a variety to National Variety Release Committee (NVRC). The committee evaluates and makes recommendation for its release. Once released, the seed multiplication and dissemination of the variety will be followed up by the Ethiopian Seed Enterprise (ESE).

In general, nearly 6 to 7 years are required to identify a soybean variety for release. This variety evaluation procedure is a generalized scheme and could be shortened. When a new breeding cycle is started with a manageable size of finished variations with known desirable traits, some of the early stage testing steps may be jumped

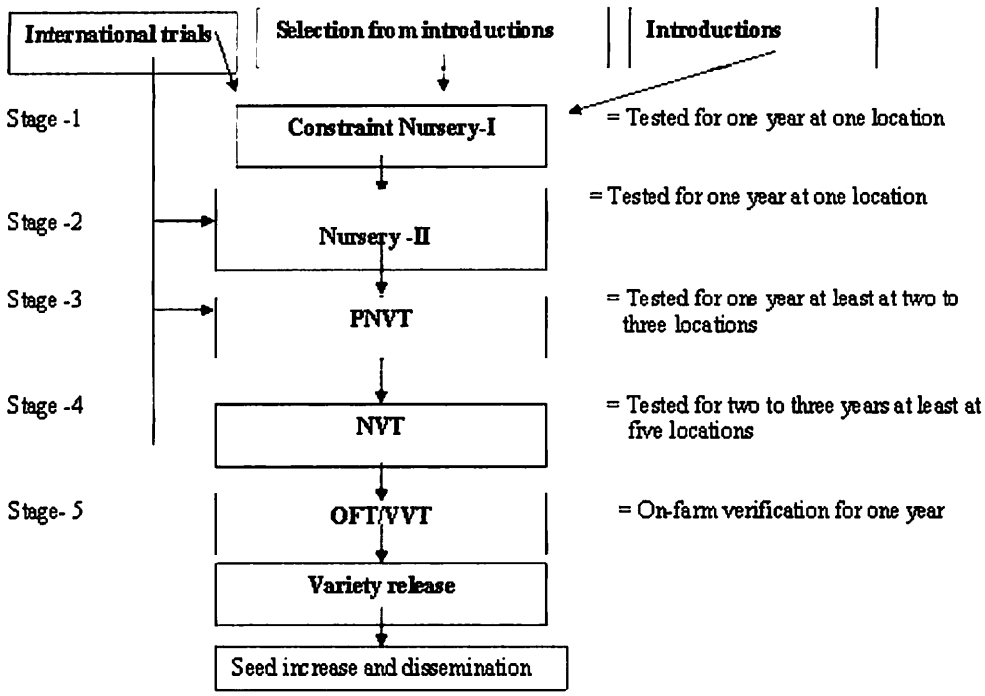


Fig1. Soybean variety evaluation procedure.

PROGRESS IN SOYBEAN GENETIC IMPROVEMENT

Identification of Suitable Varieties and Areas of Production

During the last 45 years, a large number of soybean introductions with varying maturity duration were evaluated for adaptation, yield potential and desirable agronomic characters at several locations ranging from 300 to 2200 m asl in the country. As a result, varieties suitable for production in the country were recommended or released for general cultivation (Table 1).

Since the crop is new to the country, identification of areas suitable for production was of primary concern in the process of variety development. The crop can grow at different altitudes ranging from 300 to 2200m asl. Soybean is said to be a medium-altitude crop well adapted to areas located in altitudes ranging from 1300 to 1800m asl and receiving annual rainfall of 900 to 1300 mm (Hammer and Haraldson, 1975; Amare, 1987). The crop also does well in some areas as low as 500 m asl and as high as 1900 m asl that receive a well distributed average rainfall of 550 to 700 mm throughout the growing period.

The varieties recommended or released are of varying length of maturity and their suitability to different agroecologies depend on the length of growing period of the given agro-ecology. The soybeans in Ethiopia are classified in to three maturity groups based on the number of days they require to reach physiological maturity (Amare, 1987). Williams, Crawford, Clark 63K and Awassa-95 are early maturing varieties reaching physiological maturity in 90 to 120 days. The early-maturing varieties are suitable for short rainfall areas, and may also suit for double cropping in long rainfall areas. Davis and Cocker-240 are medium-maturing varieties (requiring 121 to 150 days to reach physiological maturity) and suitable for production in areas with intermediate and long rainfall areas. Belessa-95 and TGX-13-3-2644 are late-maturing varieties (requiring more than 150 days to reach physiological maturity) and suitable for production in areas with long growing season. Categorizing varieties based on maturity periods may not be reliable because of high genotype by environment interaction for maturity (Table 8). Some varieties classified as medium and late in higher altitude areas like Awassa (1700m asl) may fall in early-maturing category when grown at low-altitude areas like Abobo (520 m asl). This could be due to temperature differences at different locations, which is reflected in the physiological development of the crop. The recommended or released soybean varieties are described in Tables 1 and 2.

Multi-location Yield Trials and Grain Yield

When yield trial first started at Jimma College of Agriculture in 1956, it was discouraging as the best yield of 1100 kg/ha was obtained from cultivar Acadian (Hammer and Haraldson, 1975). In 1980, the overall mean yield of 1920 kg/ha was obtained from variety trials conducted at different locations in the country. The top three yielding varieties in the 1980 yield trial were TGX-13-3-2644, TGM 260-2-2-2493 and Jupiter. In 1984, a mean yield of 1722 kg/ha was obtained from a yield trial conducted at six locations with Clark-63k, F-76-8827 and Gail as the three top yielders. The existing files of variety trials reveal that varieties of all maturity duration were tested together up to 1984. When mean of the 1984 yield trial was compared with that of the first variety trial in 1956, there was 71.7% yield advance, which is about 2.6% yield gain every year.

From 1985 onwards, the variety trials were constructed in three groups: early-, medium- and late-maturity classes. The soybean multi-location yield trials from 1985 to 2002 are summarized in Tables 3, 4, 5 and 6. In 1985, among the varieties tested in early-maturity class, Crawford, Wright and Williams were top yielding varieties with a mean yield of 1167.3 kg/ha. In 2000 and 2001 the mean yield of three top yielding early varieties were 1749.9 and 2098.9kg/ha, respectively. When it was compared with the 1985 mean of top three yielding varieties, there was 64.9% per cent yield gain. In medium- and late-maturity class (Tables 5 and 6), yield gain was observed in the first 5-year trials but no yield gain was observed in recent years. This could reveal that either low yielding potential genotypes were evaluated or the erratic rainfall was experienced in the country which hindered the genotypes to express their full yield potential. However, in variety testing procedure, entries are promoted from one stage to next stage yield testing whenever they are superior to the standard check(s) in yield or other desirable traits. Thus, the latter justification could be true. A drought in early 2000 might have caused wet seasons *shorter than* the optimum growth period for medium- and late-maturing soybean genotypes. Yield reduction in soybean happens if soil moisture is depleted before seeds reach physiological maturity (Hinson, 1974).

Comparisons of the yielding potentials of three maturity classes in different years of trials revealed no wide yield gap among them (Fig. 2 and 3). However, early- and medium-maturity classes, on an average, expressed relatively better yielding potential. This could be due to the growing periods at many of the variety testing locations favoring early- and medium-maturity sets, and disfavoring late-maturity set even though the varieties in this set were higher yielding in areas, where the growing seasons accommodated them. From the mean yield of the last 15-year trials, the breeding program learnt that focus should be given for the development of early- and medium-maturing varieties than the late-maturing ones, in general, as the present weather was not favoring late-maturing varieties in majority of the test locations. The program has also looked for late-maturing variety development for areas receiving longer rainfall, especially in the western part of the country.

Table 1. Characteristics of some soybean varieties recommended or released for cultivation in Ethiopia.

	Variety									
Characteristics	Williams	Crawford	Clark 63K	Awassa-95	Cocker 240	Davis	Jalale	Cheri	Belesa-95	TGX-13-3-2644
Maturity group	Early	Early	Early	Early	Medium	Medium	Medium	Medium	Late	Late
Days to maturity	90-120	90-120	90 -120	90-120	121 - 150	121-150	120 - 133	135	> 150	> 150
Growth habit*	D	D	D	D	D	D	-	-	ID	ID
General adaptability	Short rain fall areas	Short rain fall areas	Short rainfall areas	Short rainfall areas	Intermediate and long rainfall areas	Intermediate and long rainfall areas	Intermediate and long rainfall areas	Intermediate and long rainfall areas	Long rainfall areas	Long rainfall areas
Seed rate (kg/ha)	60	60	60	60	60	60	60	60	60	60
Spacing (cm)	40 x 5	40 x 5	40 x 5	40 x 5	60 x5	60 x 5	60 x 5	60 x 5	60 x 5	60 x 5
Grain yield (kg/ha)	15 - 20	15- 20	15 - 20	17 - 26	15 - 25	15 - 25	16 - 21	24	17 - 29	20 - 25

* D = Determinate, ID = Indeterminate

Table 2. The likely areas of adaptation of soybean varieties.

Location	Best performing varieties
Gojebe (1250 masl)	Cocker-240
Jimma (1750 masl and surrounding	Cocker-240, Davis, Clark-63K, TGX-3-3-2644, Awassa-95, Belessa-95
Gambella (520 masl)	Awassa-95, Belessa-95
Metu	Davis , Clark -63K
Awassa (1700 masl)	Williams, Clark -63K, Crawford, Cocker -240, Davis, Awassa-95
Arsi Negelle (1960 masl)	Cocker -240,Clark-63K,Williams,Crawford
Belle Wolayta (1400 masl)	Clark-63K,Williams
Arbaminch (1400 masl)	Cocker -240,Williams
Bako (1650 masl)	Cocker -240,Davis,Williams,TGX-13-3-2644, Bellessa-95
Anger Gutin (1400 masl)	Davis, Cocker-240, Clark-63K, Williams
Deddessa (1300 masl)	Davis, Williams, Cocker-240, Clark-63k
Pawe (1200 masl)	Belessa-95, TGX-13-3-2644, Awassa-95, Crawford
Lower Birr Shelleko (1530 masl)[a]	Clark-63K, Davis, Cocker-240, TGX-13-3-2644
Melka Worer (750 masl)[b]	Cocker-240, Clark-63K, Williams
Zeway/Alage	Early maturing varieties
Wolediya (1900 masl), Bure (2150 masl) and Harbu (1500 masl)	Clark -63K, Williams, Davis,

[a] Potential area for soybean production where more than 5 tons/ha were recorded in yield trials. [b] With supplementary irrigation.

Table 3. Mean yield (kg/ha) of top performing varieties in national variety trial from 1980 to 1984.

Year	No. of locations	Mean yield	Mean yield of top three varieties	List of top yielders
1980	9	1920	-	TGX-13-3-2644, TGM 260-2-2-2493, Jupiter
1982	6	1720	2328	V1, Davis, TGX 47-5C
1983	5	1463	1868	V1, Awassa Sel. 81, Alamo
1984	6	1722	1889	Clark-63K, F-76-8827, Gail

Table 4. Mean yield (kg/ha) of top performing early maturing soybean varieties in national variety trial from 1985 to 2001.

Year	No. of Locations	Over location mean yield	Mean yield of top three varieties	List of three top yielders
1985	7	913	1167	Crawford, Wright, Williams
1986	7	1398	1686	Bossier, Crawford, Columbus
1987	6	1810	2053	Bossier, Crawford, AGS-66
1988	1	1316	1709	Doucrop, OC-793, Kwankyo
1989	4	1539	1858	Doucrop, OC-793, Kwankyo
1990	1	2594	3038	Sable, Wright, OC-793
1991	2	2055	2577	Crawford, Wright, Sable
1994	1	834	1003	Williams, G-2261, Crawford
1996	1	948	1059	Kwankyo, SH-824025, Sable
1997	1	833	892	Sable, OC-793, Crawford
1998	1	1181	1253	Sable, G-2261, SH-824025
1999	1	1335	1532	Sable, OC-793, Crawford
2000	3	1774	2099	G-2261, Crawford, Duocrop
2001	3	1525	1750	Duocrop, Sable, OC-793

Table 5. Mean yield (kg/ha) of top performing medium-maturity duration soybean varieties in national variety trials from 1985 to 2002.

Year	No. of locations	Over location mean yield	Mean yield of top three	List of top three yielders
1985	8	1090	1596	TGX-573-1040, UFV1, G-9945
1986	8	1982	2409	V1, UFV1, UFV1 (BP-2)
1987	8	2363	2620	Tunia, Forest, V1
1989	7	2035	2299	UFB1, Tunia, SH 1274
1990	2	1969	2173	Cocker-240, DB-1601, SH-1274
1991	2	2020	2228	Davis, NM3, UFV1
1994	1	1430	1749	PR-160-6, Wright, PR-137-7
1996	1	618	684	NM3, PR-160-6, UFV1
1997	1	945	1127	PR-160-6, V1, Cocker-240
1998	1	1235	1380	V1, PR-160-6, Davis
1999	1	1117	1242	SH-1274, NM3, Tunia
2000	2	1523	1676	PR-160-6, V1, Tunia
2001	3	1155	1308	PR-160-6, G-9945, Tunia
2002	4	1086	1200	TGX-1892-10F, Cocker-240, TGX-1895-4F

Table 6. Mean yield (kg/ha) of top performing late maturing soybean varieties in national variety trial from 1985 to 2002.

Year	No. of locations	Mean yield	Mean yield of top three varieties	List of top three yielders
1985	8	1190	1313	Sj-2, TGX-13-3-2644, TGM 260-22-249
1986	6	1338	1630	ICAL-125, TGX-13-3-2644, 4_2-S_2
1987	6	1951	2137	TGX-13-3-2644, Imp. Pelican, ISRA-44 A/73
1989	6	1935	2099	4_2-S_2 , TGX-13-3-2644, ISRA 44A/73
1990	2	1472	1597	Imp. Pelican, 4_2-S_2 AGS-8
1991	1	1427	1667	Imp. Pelican, PK-7386, 4_2-S_2
1994	1	525	776	PR-149-6, TGX-13-3-2644, Jankbackong
1996	1	844	1059	PR-149-6, TGX-13-3-2644, IPB-81-Ep
1997	1	1094	1193	PR-149-6, IPB-142-81-EP_7
1998	1	1073	1182	Imp. Pelican, TGX-47-5C, TGX-13-3-2644
1999	1	1106	1273	PR-138-8, PR-149-6, TGX-47-5C
2000	4	1571	1726	PR-149-6, IPB-142-81-EP_7, PR-138-8
2001	5	1812	1999	PR-149-6, Jankbackong, IPB-81-EP7
2002	4	1055	1181	TGX-1993-7F, TGX-1838-5E, TGX 1891-3F

Fig. 2. Mean grain yield of three maturity class varieties in different years.

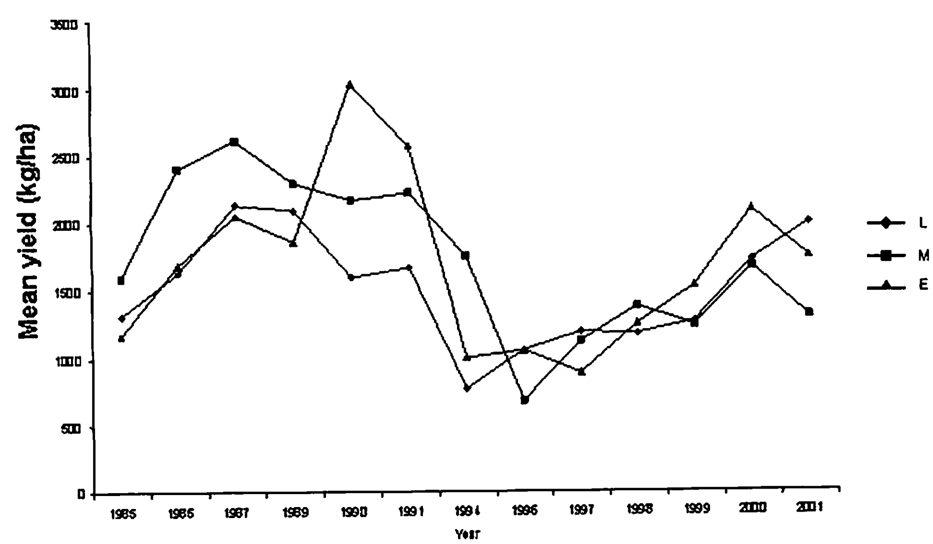


Fig. 3. Mean grain yield of three top yielding varieties of different maturity groups in different years.

Yield in Relation to Reproductive and Vegetative Growth

Results of yield and plant growth characteristics of varieties in different maturity groups tested from 1999 to 2001 at different locations are presented in Tables 7 and 8. The varieties flowered and matured relatively earlier in low-altitude areas like Abobo (520 masl) and Pawe (1200 masl) than at high-altitude areas like Awassa (1700 m asl) (Table 7). As a result, the varieties classed in late- and medium-maturity groups in high-altitude areas like Awassa and Jimma fell in early group in low-altitude areas like Abobo. This could be due to the environmental conditions of lowland areas characterized by high temperatures that promoted reproduction and early maturation faster, thereby enabling the varieties to reach maturity in less than 120 days. The productive period (taken as the time elapsed between flowering to maturity) is almost same in all the maturity groups except a 30-day difference observed between early variety G-2261 and late variety IPB-142-81-EP_7. In high-altitude locations like Awassa and Jimma, late-maturing varieties were taller than early ones although height differences were observed even within the same maturity class (Table 7). In plant height, growth habit matters more than the maturity duration, it is indeterminate growth habit that favors tallness. But, all the late varieties under the test conditions were of indeterminate growth habit hence taller than early- and medium-maturing varieties.

It was also revealed that late-maturing varieties in areas with long rainfall like Bako, Jimma and *Pawe* gave relatively higher yield (Table 7). This could be due to prolonged pod-filling period in late-maturing

Table 7. Growth characteristics of soybean varieties under different maturity groups, 1999-2001.

Trait	location	Variety/ Maturity group											
		PR-149-6	PR-138-8	IPB-142-81-EP7	TGX-13-3-2644	PR-160-6	Tunia	Cocker-240	Davis	G-2261	Sable	Williams	Crawford
		Late	Late	Late	Late	Medium	Medium	Medium	Medium	Early	Early	Early	Early
Days to flowering	Awassa	72	70	75	66	57	62	57	60	64	60	53	59
	Jima	83	84	84	83	-	-	-	-	42	43	42	41
	Bako	75	74	75	71	54	57	54	55	54	54	55	53
	Pawe	54	55	54	54	47	45	45	44	49	46	38	39
	Abobo	45	46	44	44	32	33	30	30	-	-	-	-
	Mean	66	66	66	64	48	49	47	47	52	51	47	48
Days to maturity	Awassa	156	148	168	141	128	131	121	122	120	126	109	120
	Jima	140	136	141	135	-	-	-	-	110	120	100	113
	Bako	141	142	146	134	115	119	115	115	94	98	88	93
	Pawe	113	106	113	118	97	99	94	97	90	91	93	93
	Abobo	101	102	107	98	95	92	74	79	-		-	-
	Mean	130	127	135	125	109	110	101	103	104	109	98	105
Flowering to maturity (Days)	Awassa	84	78	93	75	73	68	63	62	57	67	56	61
	Jima	57	52	57	52	-	-	-	-	68	77	58	72
	Bako	66	67	71	64	61	62	61	60	40	44	33	40
	Pawe	59	51	59	65	50	54	49	53	41	45	55	54
	Abobo	53	56	64	54	63	59	44	49	-	-	-	-
	Mean	64	61	69	62	62	61	54	56	52	58	51	57
Plant height (cm)	Awassa	88.6	80.1	68.9	61.7	54.7	64.6	47.8	46.5	57.0	53.0	36.0	43.0
	Jima	71.1	70.9	70.3	69.9	-	-	-	-	35.4	41.4	23.1	29.7
	Bako	78.7	71.3	54.9	62.8	39.3	52.5	30.5	28.0	43.3	43.5	30.3	32.8
	Pawe	76.3	67.1	58.0	66	51.1	53.0	54.7	51.1	53.0	57.0	53.0	51.5
	Abobo	75.7	66.8	50.9	63.6	77.9	77.0	36.0	32.7	57.8	73.0	62.1	52.5
	Mean	78.1	71.2	60.6	64.8	55.8	61.8	42.3	39.6	49.3	53.6	40.9	41.9

varieties (Table 8). However at Abobo, early-maturing varieties gave high yield in reverse conditions. This might be because the moisture during the growing season did not support relatively long-duration varieties to fully express their potential.

Grain yield was positively correlated with days to flowering, days to maturity, days from flowering to maturity and plant height but the correlation was stronger with days to flowering and plant height (Table 9). This indicates that varieties with delayed flowering and maturity, with prolonged reproductive period and tall plant height produce more grain yield. This holds true in an environment with long growing period. Days to flowering is positively and strongly associated with days to maturity indicating that varieties with delayed bloom require more time to reach maturity. Similar results were reported by Camacho (1974).

CONCLUSIONS

Soybean can play a significant role in Ethiopian agriculture. It has great yield potential, wide range of adaptability, high nutritional value for both food and feed, and a great importance in cropping systems. Breeding work on the crop mainly concentrated on evaluation of introductions to identify suitable varieties well adapted to the country. As a result of rigorous evaluation of the introductions, more than six varieties were recommended or released for general cultivation in the country. Areas suitable to soybean production were also identified. However, the total area of soybean production under peasant holdings in the country is only 1769.47 ha, which is very low as compared to other pulse crops (CSA, 2002). The varieties recommended/released are also not popular among smallholder farmers. Hence, attention should be given to include the crop in existing cropping system and diet of peasant farmers using adaptive and mini-kit trials (trials conducted on-stations and in farmers' fields in larger plots). If the crop is included in the existing cropping system, it may serve as a cheap and rich source of quality protein for poor people who have less access to animal protein.

Since soybean is an exotic crop and of recent introduction in the country, there is not enough diversity to effectively run a sustainable genetic improvement program. There has been limited introduction in recent years, which is the only source of new genes for soybean improvement. Therefore, a hybridization program has to be initiated to generate new genetic variability.

The soybean in Ethiopia is classed in three groups: early, medium and late. The results of the three maturity classes in variety trials revealed that early- and medium-maturing varieties have potential for Ethiopia. They have potential in short and intermediate rainfall areas and are suitable for multiple-cropping systems in long rainfall areas. Thus the soybean breeding program in the country should focus on the development of early- and medium-maturing varieties, as a short-term strategy. Besides, the breeding program should also plan for development of late-maturing varieties, which have great potential in the longer rainfall areas.

Table 8. Mean grain yield (kg/ha) of soybean varieties evaluated at different locations from 1999 to 2001.

		Location					
Variety	Maturity group	Awassa (3)	Jimma(1)	Bako	Pawe	Abobo	Mean
PR-149-6	Late	1319.3	2865.8	2865.8(2)	2273.6(2)	1227.2(2)	2110.3
PR-138-8	Late	1431.1	2304.8	2073.1(2)	2021.9(2)	1250.8(2)	1816.3
IPB-142-81-EP7	Late	1106.3	2518.5	2253.4(2)	1909.9(2)	1358.4(2)	1829.3
TGX-13-3-2644	Late	1293.8	2205.8	1900.9(2)	1774.3(2)	1500.5(2)	1735.1
PR-160-6	Medium	1270.8	-	1771.1(1)	1337.7(1)	1687.4 (1)	1516.6
Tunia	medium	1222.8	-	1777.6(1)	1000.4(1)	1765(1)	1441.5
Cocker-240	Medium	1210.1	-	1134.1(1)	1209.6(1)	1593.0(1)	1286.7
Davis	Medium	1136.8	-	1251.7(1)	1409.8(1)	1592.5(1)	1347.7
G-2261	Early	1458.1	1912.5	1993.6(1)	1757.2(1)	3999.5(1)	2224.2
Sable	Early	1274.9	2064.8	2143.2(1)	1989.7(1)	2048.2(1)	1904.2
Williams	Early	1189.8	1076.5	1320.9(1)	1679.7(1)	2094.6(1)	1472.3
Crawford	Early	1433.7	1741.3	1643.1(1)	1741.6(1)	2505.5(1)	1813.0

() Years of evaluation.

Table 9. Correlation between grain yield and some vegetative and reproductive traits.

	GY	DF	DM	RP
GY	1			
DF	0.670*	1		
DM	0.534	0.945**	1	
RP	0.378	0.819**	0.961**	1
PH	0.770**	0.912**	0.854**	0.731**

GY= Grain yield, DF= Days to flowering, DM= Days to maturity, RP= Reproductive period (days from flowering to maturity) , PH= Plant height in cm.

REFERENCES

Amare Belay. 1987. Progress and future prospect in soybean research in Ethiopia p. 252-265. *In* Proc. 19th National Crop Improvement Conference, Addis Ababa, Ethiopia, 22-26 April, 1987. Institute of Agricultural Research, Ethiopia.

Camacho, Luis H. 1974. Breeding soybeans for tropical conditions p. 55-64. *In* Proc. Workshop on Soybeans for Tropical and Subtropical Conditions. University of Puerto Rico Mayaguez Campus, 4-6 February, 1974. INTSOY Publication Series Number2.

CSA. 2002. Ethiopian agricultural sample survey enumeration, 2001/2002. Report on the preliminary results of area, production and yield of temporary crops. (*Meher* season, private peasant holdings). Part I. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

FAO. 1994. Tropical soybean improvement and production. Brazilian AgriculturalResearch Enterpise, National Soybean Research Center (EMBRAPA-CNPSO), Plant Production and Protection Series, No 27.

Hammer, O., and L.G. Haraldson. 1975. Introduction of soybeans in Ethiopia p. 196-197. *In* D.K. Whigham (Ed.) Soybean Production, Protection and Utilization: Proc. Conference for Scientists of Africa, the Middle East, and South Asia. 14-17 October, 1974. Addis Ababa, Ethiopia, INTSOY Series No. 6.

Hinson, Kuell. 1974. Tropical production of soybeans, p. 38-54. *In* Proc. Workshop on Soybeans for Tropical and Subtropical Conditions. University of Puerto Rico Mayaguez Campus, 4-6 February, 1974. INTSOY Publication Series Number 2.

Hittle, C.N. 1975. Soybeans around the world, p. 5-10. *In* D.K. Whigham (Ed.) Soybean Production, Protection and Utilization Proc. Conference for Scientists of Africa, the Middle East, and South Asia. 14-17 October, 1974. Addis Ababa, Ethiopia, INTSOY Series No. 6.

INTSOY. 1975. Soybean Production, Protection and Utilization Proc. Conference for Scientists of Africa, the Middle East, and South Asia. 14-17 October 1974. Addis Ababa, Ethiopia, INTSOY series No 6.

Norman, M.J.T., C.J. Pearson, and P.G. Seark. 1995. Tropical Food Crops in their Environment. 2nd Edition

Poehlman, J.M., and D.A. Sleeper. 1995. Breeding Field Crops. 4th edition. Iowa State Press, Ames, Iowa.

Singh, B.D. 1983. Plant Breeding Principles and Methods. Kalyani Publishers, New Delhi.

Breeding Grass Pea, Fenugreek and Lupine for Wide Adaptation in Ethiopia

Asfaw Telaye[1], Wondafrash Mulugeta[2] and Lijalem Korbu[1]

[1] *Debre Zeit Agricultural Research Center, P.O.Box 32, Debre Zeit, Ethiopia,*[2] *Sheno Agricultural Research Center, P.O.Box 112, Debre Berhan, Ethiopia*

ABSTRACT

Ethiopia is considered as one of the primary centers of diversity for grass pea (*Lathyrus sativus* L.) and fenugreek (*Trigonella foenum-graccum* L.), while lupine (*Lupinus albus* L.) is an introduced crop. Grass pea and lupin have anti-nutritional factors limiting their use in human diet. Contrarily, grass pea consumption could lead to lathyrism, the crippling of human legs. The Ethiopian grass pea landraces have high β-N-oxalyl-L-α,β-diaminopropionic acid (ODAP) content in their seeds. Lupine would also lead to lupinosis unless boiled or soaked for several days in water and then roasted to remove the bitter principal. Efforts have been made to reduce the levels of toxic chemicals through genetic manipulation. Grass pea varieties with low ODAP content were developed through mutation and soma clone culture techniques and the promising ones are promoted to multi-location variety trials. Sweet lupine cultivars free of bitter principal were introduced from Australia, tested for adaptability, and the promising genotypes have been promoted to multi-location variety trials under low and high rainfall areas. A few basic studies on genetic variability and association of traits were also made on these crops. The theme of this paper is, therefore, to review past research efforts and show future directions of grass pea, fenugreek and lupin breeding in Ethiopia.

INTRODUCTION

In response to an ever-increasing global demand for food and feed resources and the need to diversify modern cropping systems, the genus lathyrus (*Lathyrus sativus* L.) is receiving increased attention from agricultural scientists. Among the several toxic amino acids reported in the genus lathyrus, β-N-oxalyl-L-α,β-diaminopropionic acid (ODAP) assumes greatest significance since it causes lathyrism both in human and animals. The presence of this toxic amino acid in the seeds of lathyrus species restricted the agricultural development of the crop in several countries.

The consumption of sufficient grass pea causes neurolathyrism. The largest numbers of patients suffering from lathyrism have been registered during times of drought and flooding when lathyrus becomes the major food crop. The disease remains an important medical problem in many developing countries in Asia and Africa (Getachew and Narayan, 1994). Landrace cultivars with high ODAP content are grown by majority of the farmers in Ethiopia.

Fenugreek (*Trigonella foenum-graecum* L.) is an important field crop in Ethiopia, Egypt, India, North Africa and Turkey (Beyene, 1965; Westphal, 1974). It is widely cultivated in different parts of Ethiopia, which is considered as one of the sources of its genetic diversity. It is very common to get fenugreek seeds in nearly every market in the country as the crop has been cultivated since ancient times for use as food, spice and medicinal crop. Fenugreek is also a good cash crop serving as a source of income to the farmers.

Lupine (*Lupinus albus* L.) production and distribution is limited to the northern and northwestern parts of the country, which mainly cover Gojam, Gonder and some parts of Tigrai (Westphal, 1974). Utilization is limited due to luponesis, caused by an alkaloid (13- hydorxy lupanine). The Ethiopian lupine is bitter in taste and needs scarification prior to its utilization.

So far, only limited research efforts have been made to develop suitable varieties of the crops along with proper crop management and protection practices. Some basic studies on genetic variability and association of traits have also been made on these crops. The theme of this paper is, therefore, to review past research efforts and show future directions of grass pea, fenugreek and lupine breeding in Ethiopia.

GENETIC STUDIES

Studies on genetic diversity among grass pea germplasm collected from Ethiopia exhibited quite a high value for seed coat color, primary branches/plant, and *ODAP* content in the seed. The heritability value of 33.6% was reported for grain yield, 54.4% for above ground harvest, and 84.14% for days to flowering (Wuletaw, 2002). Evaluation of 100 introduced selections from ICARDA and 14 breeding materials from Adet Agricultural Research Center (AdARC) at Inewari and Molale showed great variation for grain yield, pod/plant and ODAP concentration, showing that there was a wide variability and, hence, good chance for further improvement.

Protein content of grass pea seed is weakly associated with grain yield like in most of the other legumes. However, grain yield was found positively associated with biomass, days to flowering, days to maturity, harvest index, number of pods/plant, number of seeds/pod and plant height in Ethiopian grass pea germplasm (Wuletaw, 2002). However, another study at Molale and Inewari did not show consistent results among locations, seasons and populations of germplasm. Low ODAP content is an important quality trait, which has attracted more attention as a breeding priority. Unfortunately, grain yield had a negative direct effect on ODAP content and improvement in one trait could adversely affect the other. Therefore, for improving one trait through selection, a compromise for the other must be made or the breeder must set minimum standards for one trait while selecting for the other. Another option is to follow separate breeding programs for seed yield and ODAP content.

Breeding work on fenugreek in Ethiopia was started with systematic exploration and collection of germplasm around 1970s. High level of variability was observed for economic traits like grain yield (583-1900 kg/ha) in 60 accessions collected from different parts of the country, indicating a possibility to develop improved varieties through selection.

Characterization of lupine accessions at Adet showed high variability for grain yield, number of pods/plant and days to maturity. Exotic lupine genotypes introduced from Western Australia were also evaluated for different agronomic characters in 1995/96 at Adet. The first 14 introductions were categorized under the species *Lupinus albus* and the remaining as *Lupinus angustifolius* (AARC, 1996).

Association of some morphological traits revealed that number of branches/plant and plant height had positive association with grain yield at Debre Zeit and Denbi. Days to flowering and maturity and 100-seed weight had negative association with grain yield under moisture-stress condition at Alem Tena. Thus, it is expected that in moisture stressed environments with short growing season like Alem Tena, early genotypes that are able to complete their life cycle within a short duration could escape the effect of terminal moisture stress, and may perform better than late genotypes.

VARIETALY DEVELOPMENT

Development of improved varieties in grass pea is very challenging because of the ODAP content. Past breeding efforts resulted in the identification of promising varieties compared to the local checks. However, the National Variety Release Committee (NVRC) withheld the varieties thus developed due to certain legal requirements related to ODAP. Fenugreek and lupine are considered important but due attention was not given until very recently. Efforts made so far have resulted in some promising fenugreek lines (PGRC/E 053034, PGRC/E 053044 and PGRC/E 053003) for further evaluation under multi-location variety trials. Efforts to screen sweet varieties of lupine from Australian are also underway.

FUTURE DIRECTIONS

The development of cultivars with safe quality, reasonable yield and good adaptation should be focused in all three crops. In grass pea, the potential of landraces for developing cultivars with high seed yields and low ODAP content need to be determined. Therefore, collection and characterization of local landraces would need more focus in near future. Bilateral collaboration with international research institutes and universities should be strengthened to share experiences particularly with ICARDA in areas of silencing the gene mediating the induction of ODAP generation at seedling stage of the crop.

To improve the productivity of fenugreek intensive utilization of the native germplasm, basic studies in areas of flower biology and fertilization behavior need to be focused. The utilization of introduced lupine materials to counteract problems of powdery mildew and wilt/root rot, sour taste and productivity needs to be strengthened.

REFERENCES

AdARC. 1996. Progress reports for the year 1995/96. Adet Agricultural Research Center (AdARC), Ethiopia.

Beyene Chichaibelu, 1965. Studies on biological evaluation of the protein quality of tef (Eragrostis abisynica) and abish (Trigonella foenum-gracium) and the supplementary value of abish when added to tef. M. Sc. Thesis presented to the faculty of Graduate School of Cornell, New York, USA.

Getachew Addis, and R.K.J. Narayan. 1994. Quantitative variation in the amount of neuro toxin, Oxalyl diamino propanic acid, in Lathyrus sativus during ontogeny. p. 83-88. In B.M. Abegaz et al. (Eds.) The Grass Pea and Lathyrism. Proc. Second International Lathyrus/Lathyrism Conference in Ethiopia. New York, Third World Medical Research Foundation.

Westphal, E. 1974: Pulses in Ethiopia: their taxonomy and significance. Center for Agricultural Publication and Documentation, Wageningen, The Netherlands.

Wuletaw, Tadesse, and Endashaw Bekele. 2002. Variation and association analysis in grass pea (*Lathyrus sativus* L.). *Ethiopian J. Sci.* 25(2): 191-204.

Breeding Food Legumes for Increased Yield and Stress Resistance in Southern Ethiopia

Asrat Asfaw[1], Daniel Dauro[1] and Yasin Goa[2]

[1]Awassa Agricultural Research Center, P. O. Box 6, Awassa, Ethiopia, [2]Areka Agricultural Research Center, P. O. Box 79, Areka, Ethiopia

ABSTRACT

In southern Ethiopia, small farmers cultivate different food legume species as source of protein, cash, animal feed and soil fertility. Due to the lack of improved varieties and effect of abiotic and biotic stresses, the productivity of food legumes grown in the region is very low. In order to develop high yielding varieties specifically adapted to the region, a well-planned breeding program was launched in the region following the decentralization approach. The breeding program currently addresses haricot bean, faba bean, field pea, chickpea, pigeonpea, soybean, lentil, cowpea and mungbean. Both conventional and participatory breeding approaches have been adopted to develop varieties acceptable to farmers. Introductions, hybridization and different methods of selection for cultivar development have been used. As a result of a breeding effort different promising lines were identified and recommended/released for general cultivation. In haricot bean, varieties Tabor, Ibbado and Omo-95 were released. All the varieties released in faba bean and field pea expressed good adaptation to the region and, on an average, showed 25.8% and 16.1% yield advantage over the local checks, respectively. Among the varieties evaluated, Messay, NCS-58 and Kuse-2-27-33 of faba bean and Tegegnech, Tulu Dimitu and Milky of field pea, which expressed more than 25% yield advantage over the local checks, were recommended for cultivation in the region. With participatory approach, farmers' selection criteria were well understood and adapted by breeders in selection and evaluation programs. This paper reviews the breeding activities on food legumes in the southern region since 1993.

INTRODUCTION

Food legumes are the main source of protein in the daily diet of the rural and urban population of the region, where the major sources of food are cereals, root and tuber crops. They are important sources of cash for the rural poor. Besides human food, their straw serves as feed for cattle mainly in rural areas, where the grazing land is limited. Also, they play a key role in soil amelioration by the virtue of their nitrogen-fixing ability in the cropping system, and are important component crops in the intercropping of farming systems.

Food legumes are established components of agriculture in southern region. They occupy about 108,559 ha, which is about 14.16 % of the total area under annual crops with 96,461 tons of production during 2001/2002 (CSA, 2002). Common pulses grown in the region are faba bean, field pea, haricot bean, chickpea, lentil, soybean, mungbean, pigeonpea and cowpea.

The average grain yield of faba bean, field pea, haricot bean, chickpea, lentil and soybean was reported to be 10.4, 7.87, 7.80, 7.46, 3.52 and 2.00 q/ha, respectively, which is below the national average (Table 1). This is due to the lack of improved varieties specifically bred to the region, and abiotic and biotic stresses. The national breeding program developed several varieties in many pulse crops with wide adaptation to the country in general, but none of them is popular among the farmers in the region. To overcome this problem, several breeding activities were initiated on a number of crops to develop/select varieties adapted to local conditions, which can maximize productivity of these crops in the region.

Both conventional and participatory breeding approaches were practiced to develop varieties suitable to the region. Currently, the genetic improvement work is being conducted on haricot bean, faba bean, field pea, soybean, chickpea, pigeonpea, mungbean, cowpea and lentil. This paper, therefore, reviews the breeding activities on food legumes in the region since 1993.

Table 1. Area and productivity of food legumes in southern Ethiopia (Regional) and the country (National).

Crop	Area (ha)		Productivity (q/ha)	
	Regional	National	Regional	National
Faba bean	47,008	369,151	10.4	12.1
Field pea	28,104	175,222	7.9	8.4
Haricot bean	26,799	119,879	7.8	8.2
Chickpea	5,177	184,881	7.5	9.7
Lentil	739	60,138	3.5	6.4
Soybean	81	1,769	2.0	9.2
Others	651	34,504		

Source: CSA (2002).

BREEDING OBJECTIVES AND PROCEDURES

Objectives

The food legume breeding program in southern Ethiopia mainly focuses on genetic improvement in grain yield, resistance to biotic and abiotic stresses, and farmer preferences.

Procedures

Development of varieties superior to the existing ones in yielding ability, disease and insect resistance and other characteristics is an ultimate goal of any breeding program. For development of food legume varieties for use by farmers in the region both conventional and participatory approaches were adopted and these are presented below:

Conventional Approach

In conventional breeding, the working germplasm pool constructed from introduction, local collections, selections from introductions and landraces, and hybridization are tested in different stages of trials as given below. Apart from these, evaluation of the adaptation and yield potential of varieties developed elsewhere in the country was done in some crops to recommend varieties best adapted to the region.

Nursery-I: The initial working germplasm pool constructed from different sources is tested for one year at one location. The objective of this nursery is to make sure that the new entries are superior in performance to the existing ones. In this nursery, more attention is given to the reaction of the new entries to diseases and insect-pests, and some agronomic traits. Most of the time, this nursery is non-replicated in an augment design.

Nursery-II: This nursery is conducted at one location for one year and is often referred to as the preliminary yield trial (PYT). The superiority in performance of entries promoted from nursery-I is proven before putting them under multi-location variety trial and at the same time to reduce the number of entries to a manageable size. At this stage, more emphasis is given to grain yield and other agronomic traits.

Pre-regional variety trial (PRVT): This is an initial multi-location variety trial conducted at two to three locations for one year with the objective to evaluate the performance of the new entries at multi-locations.

Regional variety trial (RVT): The entries that are outstanding in yielding potential, resistance/tolerance to diseases and insect-pests, and with some desirable agronomic traits such as seed color, seed size, lodging and shattering resistance, etc (from PRVT of the previous year) are promoted to RVT. It is conducted at least at three locations for two to three years. The RVT is conducted using randomized complete block design with three to four replications depending on the seed availability. The objective of this trial is to assess the stability of the performance of the test entries in different environments, and to select stable and high yielding entries for varietal verification trials.

Variety verification trial (VVT): Variety verification trial is conducted both at on-station and on-farm for one year. One to three new high yielding and stable entries with other desirable agronomic and disease-resistant traits identified from RVT are tested along with standard checks on big plots (10x10 m) without replication. At this stage, the breeder proposes the release of an entry as a variety to the National Variety Release Committee (NVRC). The committee evaluates and decides its fate. If it is released, the seed multiplication and dissemination would follow.

In general, nearly 6 to 7 years (Fig. 1) are required for releasing a variety in food legumes in the region. This variety evaluation procedure is a generalized scheme but not a dogma. When a new breeding cycle is started with a manageable size of finished products with known desirable traits, some of the early stage testing steps may be jumped.

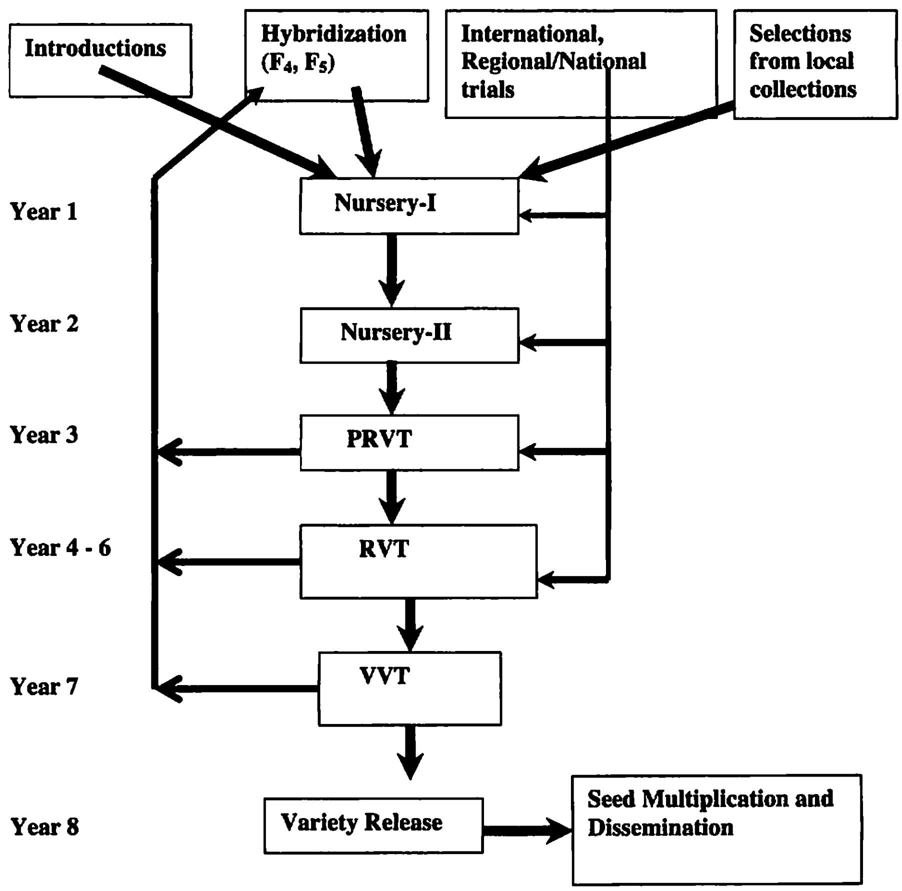


Fig. 1. Variety evaluation procedure for food legume crops in conventional breeding approach in southern Ethiopia.

Participatory Breeding Approach

Participatory breeding was followed on haricot bean in the region. The participatory breeding was started with initial germplasm constructed from introduced pure lines, selections from introductions as well as local collections, and hybridization. The initial germplasm pool may be planted on communal plot or individual farmer's plot or at on-station in the first year. Then, the farmers are invited to evaluate and select the germplasm. Usually, more than 10 farmers representing different strata and gender from a community are selected to participate. The farmers' evaluation and selection procedures adopted are presented below:

Farmers' initial trial (FIT): The genotypes visually selected by the farmers in on-station/communal plot are planted in the field of the host farmer. This is the first trial on which the farmer attempts selection on his/her field. The farmer selects the genotypes based on his/her own selection criteria without interference of breeders. The lines selected by farmers are promoted to the next stage trial. The plot size used is paired rows of 2-m long. The trial is non-replicated with systematic checks every 5 to 10 rows including the first and last plot.

Farmers' preliminary yield trial (FPYT): Those lines selected at farmers' initial trial are promoted to this trial. The selected lines are planted both on individual farmer's plot and communal plots using mother-baby design. The trial at communal plot is mother trial in which all the farmers' selections are planted in a replicated farmer-researcher managed trial. The trial at individual farmer plot is a baby trial wherein each farmer evaluates a subset of lines tested in the mother trial, i.e., at communal plot. Most often lattice design is used for the trial at communal plot, and the villages and farms within villages are used as incomplete blocks in the baby trial. The farmers attempted group selection on the lines planted in the communal plot. The selections are also evaluated by non-selector evaluator farmers using an agreed scale (1 to 5 scale, where 1= worst and 5 = best) set by farmer-selectors. The group selection and evaluation is practiced in subsequent selections, too. At this stage, the yield potential and repeatability of farmers' qualitative traits are assessed. Those genotypes expressing good yielding potential with farmers' preferred traits are then promoted to farmers' advanced yield trial. The plot size is double of the plot size of the initial trial.

Farmer advanced yield trial (FAYT): At this stage, similar evaluation method as in FPYT was practiced. The genotypes visually selected by the majority of the farmers as well as those with very high yield are included in this trial. Lattice design is used for the baby trials (trials at individual farmer's plot), and most often, a randomized block design is used for the communal trial. The plot size is four, 3-m rows for individual farmer's plot, and six, 4-m rows for the communal plot.

Farmer variety verification trial (FVVT): The most preferred varieties pass to this trial. The same procedure is followed as in the conventional approach.

In general, at least five years may be required to release a variety using the participatory approach (Fig. 2).

PROGRESS IN FOOD LEGUME BREEDING

The food legume breeding program in southern region during 1993-2002 evaluated different materials and genotypes of haricot bean, soybean, faba bean, field pea, chickpea, lentil, cowpea, pigeonpea and mung bean for grain yield. Some of the salient achievements are presented below.

Varietal Releases

The regional program has released a number of haricot bean and soybean varieties, whereas, in other crops the elite genotypes identified as superior are in different stages of trials evaluation and release. In addition, adaptation trials were attempted on faba bean and fieldpea to identify and recommend better-adapted and high yielding varieties for the region. The released varieties of haricot bean and soybean for the southern region in Ethiopia are given in Table 2.

Table 2. Characteristics of released haricot and soybean varieties in southern Ethiopia.

Crop	Variety	Yield (kg/ha)	Year of release	Growth habit
Haricot bean	Tabor	2000 – 2500	1998	Indeterminate
	Omo-95	2000 3200	2002/2003	Determinate
	Ibbado	2000 - 2900	2002/2003	Determinate
	Wondo*	2000 – 2500	2000/2001	Determinate
Soybean	Belessa-95	1700 – 2900	2002/2003	Indeterminate
	Awassa-95*	1700 – 2600	2002/2003	Determinate

* Provisionally released.

Yield potential and adaptation of seven nationally released faba bean and 12 field pea varieties were evaluated in southern region for two years (2001 and 2002). All the released varieties of faba bean expressed good adaptation to the region (Table 3). The yield advantages of released faba bean varieties over the farmers' local variety ranged from 16% (for Bulga) to 32.1% (for Messay). On an average, the released varieties expressed 25.8% yield advantage over the farmers' local variety. The yield advantage of highest yielding varieties over the farmers' local variety ranged from 34.2% (Arekite representing Gurage Zone) to more than 60% (Waka and Kakate representing Dawro and Wolyta Zones), respectively. Tesfa in Dawro zone, Messay in Hadiya, Wolyta and Gurage zones, and Kuse-2-27-33 in Sidama zone expressed specific adaptation, and hence were the best varieties for production for the mentioned areas. Messay, NCS-58 and Kuse-2-27-33 provided more than 30% yield advantage over the local variety on a mean yield base and could be recommended for production in the region as having general adaptation.

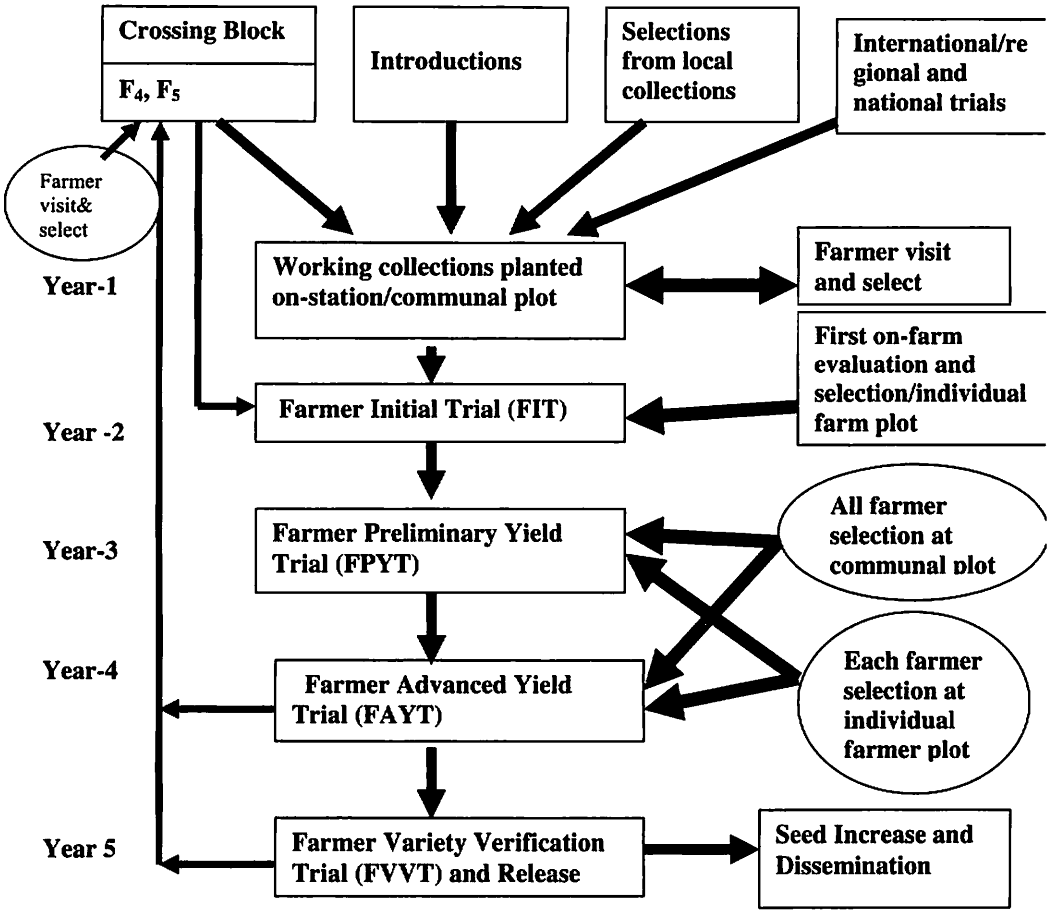


Fig. 2. Evaluation procedures in participatory plant breeding.

Of the 13 released field pea varieties evaluated at different locations in the region, three varieties, Tegegnech, Tulu Dimitu and Milky gave the highest mean yield of 2029, 1897 and 1891 kg/ha, respectively. They provided more than 20% yield advantage over the local variety (Table 4), and expressed good yielding potential in majority of the test locations. Based on it, they could be recommended for cultivation by farmers in the region as varieties having wider adaptability. The yield advantage of the highest yielding varieties over the farmer's variety was more than 39% at all the test locations (Table 4). Tulu Dimitu at Dawro, Milky in Hadiya and Tegegnech in Gurage zones expressed specific adaptation. All the released varieties showed good adaptation in the region, providing an average yield advantage of 16% over the local variety.

Performance of Food Legume Genotypes in the Region

Different genotypes of food legumes with varying maturity duration and growth characteristics have been screened for yield potential, resistance to pests and desirable agronomic characters at different locations in the region. The best yielding genotypes of different food legume species and their yield advantages over respective better checks in different level of yield trials are presented in Table 5.

Table 3. Grain yield advantage of some improved faba bean varieties over local check in southern Ethiopia.

Location	Best variety		% Yield advantage	Local check
	Name	Yield (kg/ha)		yield (kg/ha)
Waka (Dawro)	Tesfa	1403	60.9	872
Hossaina (Hadiya)	Messay	2518	53.4	1641
Kokate (Wolayta)	Messay	1733	66.3	1042
Arekit (Gurage)	Messay	2895	34.2	2158
H/Selame(Sidama)	Kuse-2-27-33	3472	42.1	2444
Southern region	Messay	2155	32.1	1631
(Wider adaptation)	NCS-58	2144	31.4	-
	Kuse-2-27-33	2127	30.4	-

Table 4. Yield advantage of the improved field pea varieties over local variety in southern Ethiopia.

Location	Best variety		% Yield advantage	Local check yield (kg/ha)
	Name	Yield (kg/ha)		
Waka (Dawro)	Tulu Dimitu	2770	39.9	1980
Hossaina (Hadiya)	Milky	3096	41.6	2186
Kokate (Wolayta)	Tegegnech	1496	50.4	994
Arekit (Gurage)	Tegegnech	1388	51.3	918
Southern region	Tegegnech	2029	33.4	1520
(wider adaptation)	Tulu Dimitu	1897	24.8	–
	Milky	1891	24.4	–

Table 5. Some of the best yielding genotypes of different food legume crops in advanced yield trials conducted in southern Ethiopia.

Crop	Genotype	Yield (kg/ha)	% Yield advantage [a]	Year of evaluation	No of locations	Remarks
Haricot bean	RWV-483	1872	20.9	2001/02	3	Climbing
	MAM-38	1509	40.2	2002	2	Bush
	ICA-CAFETERO	1516	130	2002	2	Bush
	MX-8385-79B	2522	16.8	2002	3	Bush
	G-23749	1996	33.4	2002	3	Popping
Soybean	TGX-1893-7F	1883	50.8	2001	2	
	TGX-1895-23F	1752	36.1	2001	3	
	TGX-1895-33F	1785	16.7	2002	4	
Field pea	IFPI-4096	5035	22.3	2002	2	
	TG-50771	848	41.6	2002	2	
	FP COLL-198/99	803	34	2002	2	
Faba bean	FB COLL 63-00	4839	23.6	2002	2	
	TFB-246	4752	21.4	2002	2	
Chickpea	ILC-2261	839	110.3	2001	1	Desi
	ILC-3542	803	101.4	2001	1	Desi
	ICCV-95605	1587	23.7	2001	1	Kabuli
	ICCV-92219	1585	23.5	2001	1	Kabuli
Lentil	FLIP-86-502	837	4.49	2001	1	Early
	FLIP-92-522	1607	23.9	2000		Early
Pigeonpea	ICEAP 00902	5096	18.0	2001	1	Medium-maturing
	ICEAP 00590	3357	57.0	2001	1	Early
	ICEAP 00436	3078	56.3	2001	1	Short
Cowpea	IT-94K-437-1	945	2.8	2002	5	
Mung bean	MH-96-4	3080	20.8	2002	1	
	MH-97-6	3067	20.4	2002	1	

[a] Per cent yield advantage of best genotypes over the better check/grand mean.

In haricot bean, yield advantage of the best yielding genotypes over the respective better checks ranged from 16.8% (for MIX-8385-79B) to 130% (for ICA-CAFETERO). RWV-483 with type IV growth habit (a climber), gave a yield advantage of 20.9%. The popping type, G-23749, gave 33.4% more yield as compared to the remaining genotypes in yield trials. MAM-38 and ICA-CAFETERO were identified as promising genotypes for highland areas.

In soybean, TGX-1893-7F, TGX-1895-23F and TGX-1895-33F were three promising genotypes that expressed more than 15% yield advantage over the better respective checks.

In field pea, apart from the national variety trial, the regional program recently initiated yield trials to select better-adapted varieties to the region. From different genotypes evaluated in different yield trials, IFPI-4096, TG-50771 and FP COLL 198/99 expressed better performance. Similarly in faba bean, FB COLL 63-00 and TFB-246 gave 23.6 and 21.4% yield advantage over their respective better checks, respectively. These are some of the best-adapted and high yielding genotypes of field pea and faba bean in the region.

In chickpea, four genotypes, namely, ILC-2261, ILC-3542, ICCV-95605 and ICCV-92219 expressed 110.3, 101.4, 23.7 and 23.5% yield advantage over the better check in 2002 yield trials, respectively. In lentil, FLIP 86-502 and FLIP 92-522 were identified as the promising materials that gave 4.9 and 23.9% yield advantage over the superior check in the region.

In pigeonpea, cowpea and mungbean (crops with remarkable adaptation to moisture-stress areas), some promising genotypes that recorded better yield advantage were identified, these included ICEAP 00902 in pigeonpea, and MH-96-4 in mungbean, and gave the highest grain yields of 5095 and 3080 kg/ha, respectively, in the region.

Participatory Plant Breeding

The participatory plant breeding approach was attempted on haricot bean in two communities representing lowland and mid-land bean production areas of the region. The farmer selectors represented by the community evaluated and selected bean lines from on-station initial diverse germplasm pool of 147 lines at first selection cycle in 1999. In the following three years (2000, 2001, and 2002), the farmers evaluated their selected lines according to their own selection criteria on their farms and retained promising lines at the end of each selection cycle. The number of lines selected by a farmer ranged from 5–51, and on an average, a farmer selected 15 lines in first selection cycle in 1999. In final selection cycle (in 2002), the number of lines selected by a farmer ranged from 1–4, with an average of two lines. This indicates that the range and average number of lines selected by a farmer decreased from the first to the last selection. Overall, the farmers kept the diversity at trial sites.

The most important criteria used by farmers in their selection of lines from the initial germplasm pool in cycle-1 in 1999 and in subsequent selection cycles were growth habit, plant height, pod load, pod length, pod clearance from the base, early maturity, seed color, seed size, and grain yield. Subsequent interviews with farmers revealed that seed color and seed yield were major decision-making criteria to select or reject a line.

The yield advantage of farmer selections in haricot bean over the better check is presented in Table 6. The two most preferred lines, AFR-702 and OBA-4, were large-seeded and provided 45 and 22.7% yield advantage over the respective brown speckled check, respectively. The small- and medium-seeded DICTA-109 and EAP-8930-14 expressed 31.2 and 27.7% yield advantage over the better check, respectively. The results reveal that farmer selections out-yielded their respective better checks. This indicates that farmers are capable of selecting varieties that give superior yields on their own plots. This is in line with Ceccarelli et al. (2000), who stated that farmers could handle selection choices in a large number of lines and it was possible to transfer the responsibility of selection to farmers in their fields.

Table 6. Grain yield (kg/ha) of most preferred selections in haricot bean during individual and group selections in 2002.

Line	Remeda[a]	Korangoge[a]	Remeda[b]	Korangoge[b]	Awassa[c]	Inseno[c]	Mean	% YA[d]
Large-seeded								
AFR-702	987	1351	1563	-	3556	435	1578	45
OBA-4	1030	991	1458	642	3434	460	1336	22.7
B. speckled(ck)	770	741	-	-	2394	449	1089	-
Small- and medium-seeded								
DICTA-109	1997	1186	1786	764	4158	973	1811	31.2
RAB-585	1398	1003	-	901	3303	723	1465	6.2
EAP-8930-14	1570	963	1191	-	4388	704	1763	27.7
XAN-314	1221	918	-	955	4404	544	1608	16.5
Roba-1	1771	1079	1458	542	1730	636	1203	-
R.wolayta	1267	848	752	900	3918	598	1380	-

a=Communal plot; b= Individual farmer plot; c= On-station plot; d= Per cent yield advantage over the best check.

Linking Formal and Participatory Plant Breeding in Food Legumes

Food legume production in the region is concentrated in low potential/marginal areas. It is increasingly recognized that the marginal areas require different breeding approaches. The low potential areas constitute a myriad of microenvironments, which no breeding program can expect to address effectively with multi-site on-station trials. More decentralized breeding approaches are needed that exploit, rather than avoid, genotype by environment interaction, making use of the specific adaptation and active participation of farmers with their indigenous knowledge.

Ceccarelli et al. (1996) and Kornegy et al. (1996) stated that participation of farmers in the very early stages of selection offered a solution to the problem of fitting the crop to a multitude of both target environments and users' preferences. Participation of farmers in the selection process improves cultivar adoption (Horne and Stur, 1997). Farmers can effectively select from segregating materials and fixed varieties that better meet their needs. Hence, a generalized breeding scheme is proposed to better address micro-niches and farmer preferences in developing food legume varieties in the region.

For preliminary variety trials and segregating materials, farmers should be invited to the station to attempt on-station selection. If the selection is practiced with segregating materials, the selected plants should be handled by breeders as per the method. Farmers are to be involved in selection processes until the selected materials reach homogeneity. The farmers can play a key role in identification of plants which are better acceptable to them. This may help the breeders to concentrate on the families better preferred by the farmers. The selected families of segregating materials may be advanced at on-station and on-farm in alternating fashion. If selection is practiced with finished variations construed from different sources, the selected lines should be promoted to on-station and on-farm replicated trial. For on-farm trial one may use communal plot. Then, both the breeder and the farmer should attempt selection in both conditions. Those materials selected by majority of farmers and breeders in visual selection and high yielding in both conditions should be passed to the preliminary yield trial at on-station. This trial should be a replicated trial as its objective is to ensure that the new selections are better performing as compared to the already existing varieties. Again farmers may be invited to on-station to evaluate the performance of selections at breeders managed on-station trials. Those materials that combine better yield and farmers' acceptable trials are advanced to the multi-location yield trial. At this stage, mother-baby design may be adopted.

The materials advanced to the multi-location trial from PYT are divided into two components: mother and baby. The mother trial is the usual NVT/RVT trial at on-station, in which a complete set of selected cultivars are evaluated in replicated researcher-managed trials at several locations. Baby trial is an on-farm trial in villages or farms within a village wherein each farmer evaluates a subset of the cultivars tested in NVT/RVT at several locations, where variety trials are being conducted. Villages and farms within villages may be considered as separate blocking strata, i.e., used as incomplete blocks in baby trial. The cultivars expressing better performance in mother-baby trial are put in the verification trial to identify variety for release.

FUTURE DIRECTIONS

Food legumes occupy a unique position in Ethiopian agriculture. They are among the main sources of food in southern region; their productivity is low as compared to the national average. Lack of varieties bred to the region and biotic and abiotic stresses are the major causes for low productivity. Thus development and adoption of high yielding varieties is the most important step in increasing food legume production in the region. To achieve this, the breeding program in the region should give due attention in future to the following areas:

1. Development of varieties for different production systems, i.e., for inter-/relay- and mono-cropping.
2. Development of varieties that perform better at low level of soil fertility.
3. Development of drought tolerance varieties.
4. Popularization of the released varieties to farmers' fields using adaptive/minikit trials to create impact.
5. Breeding for grain yield and combined resistance to diseases and insect-pests.
6. Introducing participatory methods into variety development/testing systems.
7. Development of varieties for crops, where there is no variety released in the region.
8. Development of early-maturing varieties.
9. Initiation of strong crossing program in different crops to widen the genetic base of these crops.
10. Inheritance studies to understand the genetic basis of different traits to design appropriate breeding strategies for efficient selection.

REFERENCES

Caccarelli, S., S. Grando, and R.H. Booth. 1996. International breeding programmes and resource poor farmers: Crop improvement in difficult environments, p. 99-116. *In* P. Eyzguirre and M. Iwanaga (Eds.) *Participatory Plant Breeding*. Proc. Workshop on Participatory Plant Breeding, 26-29 July 1995, Wageningen, The Netherlands. IPGRI, Rome, Italy.

CSA. 2002. Report on the preliminary results of area, production and yield of temporary crops (*Meher* season, private peasant holdings). Part I. Ethiopian agricultural sample survey enumeration, 2001/2002. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Horne, P. M., and W.W. Stur. 1997. Current and future opportunities for introduced forage in smallholder farming systems of south-east Asia. *Tropical Grasslands* 311: 359-363.

Kornegy, J., J.A. Beltran, and J. Ashby. 1996. Farmer selections within segregating populations of common bean in Colombia: Crop improvement in difficult environments, p. 151-159. *In* P. Eyzguirre and M. Iwanaga (Eds.) *Participatory Plant Breeding*. Proc. Workshop on Participatory Plant Breeding, 26-29 July 1995, Wageningen, The Netherlands. IPGRI, Rome, Italy.

Breeding Food Legumes for Western Ethiopia

Chemeda Daba[1], Firdissa Eticha[1], Abush Tesfaye[2], and Sintayehu Alamirew[3]

[1]*Bako Agri. Research Center, P O Box 03, Bako, Ethiopia,* [2]*Jimma Agri. Research Center, Jimma Ethiopia,* [3]*Jimma University, College of Agriculture, Jimma, Ethiopia*

ABSTRACT

Food legumes are among the most important pulse crops grown in western and southwestern Ethiopia. Lack of improved, high yielding and adaptive varieties are among the most important constraints for the production of food legumes in this region. This paper gives a brief over view of the results of some breeding research activities conducted by Bako and Jimma Agricultural Research Centers, and by Jimma College of Agriculture since 1992 and 1994 until 2002 for lowland and highland pulses, respectively. Results showed that faba bean variety Bulga-70 showed better yield performance than other released varieties around Arjo and Shambu highlands. Four faba bean varieties Tesfa, Messay, Bulga-70 and NC-58 provided more than 100% grain yield advantage over the local check across three locations over two cropping seasons around Jimma. In field pea, varieties Adi, Dadimos, and Tulu Dimtu showed better adaptation in Arjo, Gedo, and Shambu highlands. Similarly, G22763-2C, Adi, Milky, and Hassabe were identified as high yielders around Jimma. One faba bean variety (EH-930-OV-1 and one field pea variety (EH-90011-1-2) gave better yields across locations (Arjo, Gedo and Shambu), and were proposed for possible release. In haricot bean, Atendaba showed better performance at Gute and Bako. In Jimma area, Roba-1, PAN 134 and A 410 were the top yielders in the medium-size bean, white pea bean and large-seeded bean groups, respectively. In general, red-seeded genotypes gave higher yields than the white-seeded bean types. So far, two outstanding bush beans (EMP-376 and XAN-317) and two climbing bean varieties (812-BRC-28 and 813-BRC-29) were identified for release at Bako. In soybean, of the eight varieties tested at Ambo, Ijaji, Ano, Bako, Gute, and Bilo Boshe during 2001/2 and 2002/3, varieties TGX-13-3-2644, PR-149-64, and IPB-81-EP7 were the top performing. Soybean varieties named as Cheri (IPB-81-EP-7) and Jalale (AGS-217) were released for Bako and similar areas. Three medium-maturity varieties, Tunia, AGS-65 and V-1, were recommended for production around Bako.

INTRODUCTION

Food legumes including faba bean, field pea, and haricot bean are among the most important crops that contribute to the protein supply of farmers and other consumers in western Ethiopia. Faba bean and field pea are adapted to highland cooler areas, while haricot bean is grown in the lowland warmer areas. Faba bean ranks first in terms of area, total production and productivity followed by haricot bean and field pea. No trend of increment was observed in terms of area or production, or productivity for these three crops. This might be attributed to the inadequate supply of improved varieties and other production-related constraints that contribute to low productivity. On the other hand, soybean is a crop of recent introduction to Ethiopia as a result of which its production is limited to few state farms. It is adapted to warmer lowland areas of the region and is currently being produced by private investors in western Oromia. Soybean is a highly efficient producer of protein and oil, having 40% oil and 20% protein content. It is adapted to altitude ranges of 700 – 1700m asl, and well-drained soils with pH range 5.8-7.0 and annual rainfall of 400 to 1000 mm. The aim of this paper is to review the results of some breeding research activities and achievements of Bako and Jimma Agricultural Research Centers, and Jimma University, College of Agriculture, since 1992 for lowland pulses, and from 1994 until 2002 for highland pulses.

BREEDING OBJECTIVES

The main objective of breeding food legumes in western and southwestern Ethiopia is to develop high yielding and disease-resistant/tolerant varieties with desirable agronomic characters.

BREEDING METHODOLOGY

Improvement in grain yield and other important characters is mainly possible through exploiting germplasm with wide genetic variability. The sources of germplasm for crop breeding activities are introductions from respective coordinating research centers and Institute of Biodiversity Conservation and Research. Variety development follows selection and evaluation of germplasm through various stages of breeding.

ACHIEVEMENTS

Faba Bean

Variety trials

Collaborative research activities in faba *bean* started long ago with Holeta Research Center, which coordinated faba bean breeding experiments in the country. Bako Research Center started faba bean improvement research in 1998 at Shambu, Arjo, and Gedo. As a result, 17 promising genotypes were selected for further testing at these locations along with two standard checks, Bulga-70, and CS20DK (BARC, 2002). Of these, genotype EH-930-0V-1 was found to be the best in seed yield with a yield advantage of 19% and 14% over the standard checks, Bulga-70 and CS 20 DK, respectively (Table 1).

Adaptation trials

Crop Improvement Research Division of Bako has introduced some improved/released faba bean varieties from Holeta Research Center to evaluate their adaptability. In 1998, three mid-altitude varieties of faba bean, viz., NC-58, Tesfa, and Mesay were tested at Harato and Getema on farmers' fields. But all these varieties were out yielded by local varieties.

Moreover, three highland varieties, namely, Bulga-70, CS20DK and Kuse were planted on farmers' fields in Shambu and Gedo during 1998/99 and 1999/00. The mean grain yield across years and locations indicated that Bulga-70 was the best variety with a yield advantage of 27% over the local check. This variety is currently recommended for highlands of Arjo, Shambu and Gedo.

In order to identify high yielding and better adaptable faba bean cultivars in Jimma area in southwestern Ethiopia, the previously released six faba bean varieties and one local check were compared during 1999-'00 and 2000-'01 cropping seasons. Based on the average grain yield, all the six varieties out yielded the local check. The top three high yielding varieties which gave more than 100% grain yield over the local check across the three locations over two cropping seasons were Tesfa (2413 kg/ha), Messay (2267 kg/ha), and Bulga-70 (2171 kg/ha).

FIELD PEA

Variety Trials

Sixteen field pea varieties were evaluated in a regional variety trial at Arjo, Shambu and Gedo for three consecutive years. Two high yielding varieties, EH 90-011-1-2 and EH 90-025-1 with good agronomic characters were identified, and recommended for release in 2004.

Adaptation Trials

Nine released field pea varieties were planted along with local checks to see their relative performance at Shambu, Arjo, and Gedo during 2001-02 and 2002-03 seasons. The overall mean grain yield across locations showed that Adi was the top yielder with mean grain yield of 3181 kg/ha (Table 2).

In order to identify high yielding and better adaptable varieties in Jimma area in southwestern Ethiopia, 11 nationally released field pea varieties including the local check were compared during the two cropping seasons (1999-00 and 2000-01) across three locations, namely, Gera, Yebu and Dedo. Based on the average grain yield, all the varieties out yielded the local check. The top high yielders were G22763-2c (2082 kg/ha), Adi (2029 kg/ha), Milky (2018 kg/ha) and Hassabe (1997 kg/ha) (Table 3).

HARICOT BEAN

A. Bushy Bean

Variety trials: Many introductions of haricot bean were evaluated at Bako for their adaptation, high and stable yield, and resistance to disease and pests. At Bako, high emphasis was given to improve food beans. During 2000 cropping year alone a total of 847 accessions were evaluated along with appropriate checks in three separate groups: white, medium different colored and red-seeded beans. Red-seeded bean genotypes were more productive than white beans at Bako (Table 4).

Farmers in western Ethiopia especially around Bako prefer large-seeded beans. In one of the trials, 15 large-seeded bean varieties were tested with the standard check, Brown Speckled at Bako, Gute and Billo-Boshe (BARC 2000, 2001, 2002, 2003). The grain yield obtained across years and locations indicated that G-4327 was the best variety with a yield advantage of 58% over the standard check Brown Speckled. In medium red-seeded beans regional variety trial 15 genotypes were tested with a standard check, Red Wolaita at Bako, Loko, Gute and Billo Boshe. The mean grain yield obtained indicated that EMP-376 and XAN- 317 were promising varieties (Table 5).

Adaptation trials: Eight nationally released haricot bean varieties were tested at Bako and Gute for two consecutive years (BARC 2002, 2003). The mean grain yield across locations indicated that Atendaba was the best yielder (2126 kg/ha) closely followed by Zebra (2070 kg/ha). Location mean indicated that Bako was more productive than Gute (Table 6). Haricot bean varieties Roba-1 (2215 kg/ha), PAN 134 (1960 kg/ha) and A 410 (2203 kg/ha) were the top yielders across locations from the medium-size beans, white pea bean and large-seeded bean groups, respectively, in Jimma area in 1993. However, only A 410 exhibited a significant increase over the standard check. In three consecutive seasons (1996-98), two candidate varieties ICA 15541 and MX 2500-19 were verified on farmers' fields along with Gofta (G-2816) and Brown Speckled as checks. The results indicated that Gofta outyielded all the genotypes with mean grain yield of 1430 kg/ha, while the standard check had the lowest mean yield. In 1999 and 2000, the large-seeded bean genotypes were evaluated in the mid-to high-altitude environments for genotype x environment (GXE) interaction and stability of performance. Highly significant differences were observed for genotypes, environments, and genotype x environment interaction. Joint linear and non-linear regression types of GxE interaction were significant at $p \leq 0.01$. Series of experiments also showed that two genotypes G-13654 and G-3324 were most adaptable in southwestern Ethiopia.

Table 1. Mean seed yield (kg/ha) of faba bean regional variety trial-II across years and locations.

Entry name	2000-2001		2001-2002			2002-2003			2003-2004		
	Shambu	Arjo	Gedo	Shambu	Arjo	Gedo	Arjo	Gedo	Shambu	Arjo	Mean
EH93002-OV-2-1	3215	2661	4431	1518	2290	1489	3071	1274	1636	1017	2260
EH93017-OV-2-1-2	3495	992	2509	1148	2222	1633	3307	1217	1392	1696	1961
EH930123-OV-2-1	2516	1805	3883	1336	1499	1852	3175	1249	1904	1678	2090
EH930-OV-1	4369	1809	4330	1300	3507	1849	2931	1477	1853	1682	2511
EH93015-OV-1-1-1	2709	2831	4428	1410	2657	1769	3009	1106	1547	1570	2304
EH9301800-OV-1-1	2572	3493	4015	1237	2356	1787	2478	1205	1466	1720	2233
EH93018000V-1-1-1	2537	3911	4035	1508	2584	1516	3004	1501	1429	1729	2375
EH9204010V-1-1-1	2159	2744	4216	870	2442	1172	3357	1335	1518	1604	2142
EH92001-OV-1-1-1	2742	2033	3421	943	5362	1444	2337	1698	1831	1678	2349
EH920050- OV-3-11-1	3470	1274	3019	1835	3740	1518	2508	1312	1280	1664	2162
EH920030-OV-1-1	1848	3011	4627	826	2008	2087	2306	1602	1420	1197	2093
EH92005-OV-3-5	3631	1759	3807	1189	1663	1705	3107	1253	1578	1484	2118
Holetta local 90	2109	2674	4320	1446	1774	1901	2844	994	1628	1176	2087
EH91025-23-1	2500	1028	3473	1065	4188	1746	3150	1211	1635	1428	2142
EH92038-OV-1-2	1812	2970	2653	969	2529	1597	3191	1085	1430	979	1922
EH92003-OV-1-2	2271	1341	3952	994	1950	1636	2752	991	1545	1156	1859
EH93010-OV-2-1-1	1249	4234	3648	1080	3874	1675	2196	1155	1484	1489	2208
Bulga-70	1595	2267	4168	842	2601	2221	2933	1512	1648	1198	2099
CS20DK	4149	1511	3580	1124	1952	1876	3202	1536	1638	1382	2195
Local check	1711	2460	2832	814	4129	1888	2448	1265	1034	2403	2098
Mean	2633	2340	3767	1173	2766	1718	2865	1299	1545	1496	2160
CV (%)	37	25	19	33	26	24	32	24.1	27.2	30.9	

Table 2. Mean seed yield (kg/ha) of field pea varieties tested in adaptation trials across years and locations.

Varieties	2001-02		2002-03			Mean
	Shambu	Arjo	Shambu	Arjo	Gedo	
Dadimos	2714	3195	1100	3744	4372	3025
Tulu-Dimitu	2889	2466	1066	3888	4281	2918
Hursa	3223	2795	1415	4088	2844	2873
Tulu-Shanan	3180	2494	1269	3830	3639	2882
Holetta	2049	3182	1492	3340	4454	2903
Tegegnech	2294	3126	1535	4070	3864	2978
Adi	2636	3758	1485	4206	3818	3181
Hayik	2074	3361	595	4311	3527	2774
G22763-2C	2543	2748	1186	4216	995	2778
Local	2259	2806	1114	3055	2774	2402
Mean	2606	2993	1226	3875	3597	
CV	16.47	23.12	23.89	14.35	23.71	
LSD	736	1187	502.	954	1462	

Table 3. Mean seed yield (kg/ha) of 11 field pea varieties tested across years and locations by Jimma University College *during* 1998-1999 and 1999-2000 seasons.

Variety	1998-1999			1999-2000			Mean
	Yebu	Gera	Dedo	Yebu	Gera	Dedo	
G22-7-63-2C	4540	970	2430	1810	1032	1711	2082
Adi	4051	1180	2651	1097	828	2366	2029
Milky	4580	960	2480	1166	833	2086	2018
Hassabe	4170	1100	2250	1408	1019	2033	1997
Markos	4650	940	1840	930	1220	1878	1910
Fp-ex Dz	4950	870	2010	1334	690	1527	1897
Holetta	4940	750	1950	1118	748	1842	1891
Mohanderfer	4210	1000	1990	833	769	1923	1788
Tegenyech	3330	1200	2160	856	913	1853	1719
Nc-95haik	3970	900	1450	967	997	1377	1610
Local check	4280	520	790	1079	384	1024	1346
Mean	4334	945	2000	1145	858	1784	

Table 4. Summary of yield and some agronomic characters of 847 haricot bean accessions evaluated at Bako in 2002 crop season.

Group	Agronomic characters	Range
White (104 entries)	Days to flowering	40-53
	Days to maturity	81-95
	100 seed weight (gm)	12-32
	Yield (kg/ha)	520-2344
Medium different colored beans (455 entries)	Days to flowering	38-51
	Days to maturity	79-96
	100 seed weight (gm)	16-51
	Yield (kg/ha)	591-2560
Red seed beans (288 entries)	Days to flowering	38-51
	Days to maturity	80-97
	100 seed weight (gm)	14-60
	Yield (kg/ha)	572-3231

Table 5. Mean grain yield (kg/ha) of 16 red-seeded bean varieties tested across years and locations.

Varieties	2001			2002			
	Gute	Billo-Boshe	Bako	Gute	Billo-Boshe	Bako	Mean
DICTA 105	2053	1753	1263	1733	2093	833	1621
RAZ-54	2814	1764	1555	1413	1753	1852	1859
VAC-67	2337	1751	1914	1560	1207	1038	1635
EMP-376	2642	2650	2088	2592	2472	2214	2443
DOR-364	1292	1515	1426	1116	2185	1483	1503
DOR-554	2744	1795	1898	1662	1832	1361	1882
EMP-445	2189	1992	2088	2117	2131	1738	2043
DOR-811	1385	1529	1993	1691	1783	1470	1642
DICTA-109	2571	1599	1469	1495	1960	1536	1772
DOR-582	2349	1490	1289	1367	1716	1221	1572
XAN-317	2685	2796	1804	2185	1912	2119	2250
SEQ-35	1964	1680	1507	1646	1783	1358	1656
DOR-517	1842	1878	1792	974	2079	1322	1648
DOR-567	2078	1526	1371	1158	2286	1148	1595
DOR-764	2264	1925	1604	1282	1938	1710	1787
RED WOLAYITA	1961	1284	1365	1394	1381	693	1346
Mean	2198	1808	1652	1587	1907	1444	
CV (%)	22.93	20.76	21.62	19.74	11.18	36.22	
LSD (5 %)	717	534	506	444	304	744	

Table 6. Mean grain yield (kg/ha) of eight improved haricot bean varieties tested for two consecutive years at Bako and Gute.

Variety	2001/2002		2002/2003		
	Bako	Gute	Bako	Gute	Mean
Roaba-1	2374	1341	1928	1351	1749
Melka-Awash	2538	1630	2485	943	1899
Gobe-Rasha	2190	2027	2281	881	1845
Red-Walayita	1808	1660	2618	1168	1814
Atendaba	2799	1166	3621	919	2126
Brown speckled	1894	950	2010	968	1456
Zebra	1994	1696	3361	1229	2070
Awash-1	1880	1145	2136	1097	1565
Mean	2185	1452	2555	1070	

B. Climbing beans

Germplasm Collection and Characterization: Climbing bean collection was made in 1999 in the surrounding areas of Jimma, Bonga, Tepi, Gore, Metu, Bedele, Agaro, and other areas from the markets as well as from farmers' fields. Some of these seeds were conserved in the gene bank at the Institute of Biodiversity Conservation and Research (IBCR). Eighteen accessions were grown and characterized at Jimma University College of Agricultural Research for three years between 1999 and 2001. The mean seed yield of the accessions ranged from 780 kg/ha to 1510 kg/ha for 24050 and 24054 accessions, respectively. Among the characters, days to maturity, 1000-seed weight and number of seeds/plant showed high variability. This wider variability in characters offers a great opportunity for the genetic improvement through selection and hybridization.

Variety trials: Twenty-four climbing bean genotypes were tested at Bako in advanced nursery in 1999 and 2000 crop seasons. Of these, the 14 best genotypes were promoted to pre-regional stage of evaluation and tested at Bako. Again the seven best from these were promoted to the regional variety trial and were evaluated for their yield and disease reaction at Bako, Loko, Gute, and Bilo Boshe (BARC 2001, 2002). The mean seed yield across years and locations showed that two varieties, viz., 812-BRC-28 and 813-BRC-29 were promising (Table 7) and recommended for release. These varieties are suitable for intercropping with maize/sorghum because of their climbing growth habit. They have low leaf load and are not as aggressive as the local check. They also exhibited uniform pod-load along their length.

SOYBEAN

Three maturity groups of soybean, namely, early-, medium- and late-maturing are known to be cultivated in Ethiopia. Early types mature between 90 to 120 days, medium ones between 121 to 150 days, and late types between 151 to 180 days or beyond (Amare, 1990).

Variety trials

Considerable effort has been made to develop high yielding, adaptive and disease-resistant varieties of soybean. During 1999 to 2002, 11 early-maturing soybean varieties were tested at Bako, Loko and Gute. The mean grain yield recorded across years and locations indicated that AGS-217 with mean grain yield of 2155 kg/ha, was the top ranking variety. This variety was released in April 2003 by the name Jalale. From the medium-maturity types AGS-65, Tunia and V-1 were found to be the best yielders with a grain yield advantages of 49%, 44% and 50 %, respectively, over the standard check (Davis). These three varieties were recommended for wider production in western Oromia. Similarly, 11 late-maturing soybean varieties were tested in a regional variety trial at Bako, Loko and Gute. Among these varieties, IPB-81-EP7 was found to be the best in grain yield and agronomic characters and was released in April 2003 by the name Cheri.

Adaptation trials

Eight soybean varieties, including two released (Davis and Clark 63K), one recommended (TGX-13-3-2644), four in pipe line (V-1, IPB-81-EP-7, IPB-14281-EP-7, and PR-149-66), and one local (Ethio-Yugoslavia), were tested for their adaptability at Ambo, Ijaji, Ano, Bako, Gute, and Bilo Boshe during 2001-02 and 2002-03 seasons (BARC 2002, 2003). The mean grain yield recorded across years and locations indicated that TGX-13-3-2644, PR-149-66 and IPB-81-EP7 were top performing varieties (Table 8).

FUTURE RESEARCH PRIORITY AREAS

The following areas would receive priority in food legume research in western Ethiopia:

1. Since breeding of food legumes for specific adaptation started only recently for western and southwestern Ethiopia, future research would focus on strengthening the breeding of these crops.
2. Emphasis would be given to the collection, characterization, and utilization of climbing bean landraces. Also, introductions from CIAT would be used for variety development.
3. Soybean breeding would be strengthened. Since this crop is of recent introduction to Ethiopia, attention would be given to offer training on the utilization aspects and on the popularization of released varieties in collaboration with the Agricultural Research and Extension Division of BARC.
4. Breeders would initiate crossing program for germplasm enhancement for important food legumes in western Ethiopia, viz., faba bean, field pea, haricot bean and soybean.

Table 7. Mean seed yield (kg/ha) of eight climbing bean varieties evaluated in a regional variety trial at Bako, Boshe, Gute and Loko during 2000-01 and 2001-02.

	2000-01				2001-02				
Variety	Bako	Boshe	Gute	Loko	Bako	Boshe	Gute	Loko	Mean
Local check	1875	1450	1225	2100	1325	2475	1900	2925	1909
812-BRC-28	2350	2500	2075	3125	2000	2925	2525	3000	2563
813-BRC-29	1650	2075	2675	2025	1575	2475	1800	3625	2238
793-BRC-23	1225	1625	1800	1600	1000	1200	1750	2325	1566
829-BRC-20	1075	1825	1975	1725	1200	1200	2575	2500	1759
830-BRC-7	1250	1600	1875	2550	1175	1575	1800	2225	1756
850-BRC-21	1675	2100	1800	2200	1650	1450	1975	2225	1884
852-BRC-27	1775	1975	1775	1950	1425	1550	1500	2975	1866
Mean	1609	1894	1900	2159	1419	1856	1978	2725	
CV%	32.09	14.77	29.37	27.83	30.55	27.04	26.53	13.92	
LSD	759	411	820	883	637	737	771	557	

Table 8. Mean seed yield of different soybean varieties tested for two consecutive years at various sites (2001-02 and 2002-03)

	2001-02					2002-03						
Variety	Bako	Gute	Loko	Anno	Ijaji	Ambo	Anno	Bako	Gute	Ijaji	Billo Boshe	Mean
Davis	1341	1470	469	1013	1734	724	844	1802	2364	1068	677	1228
V-1	1659	1461	590	852	1897	1032	1303	2442	2675	950	1080	1449
TGX-13-3-2644	2017	1689	504	1799	2137	1346	2018	2570	2169	1059	1137	1677
IPB-81-EP-7	2308	1532	799	1831	1545	1150	1683	1988	2393	883	718	1530
Clark 63k	918	1247	451	904	1230	994	711	1562	1981	1029	446	1043
PR-149-66	2392	1748	521	2134	1962	1075	1615	2041	2029	787	579	1535
IPB-14281-EP-7	2766	1550	903	1740	1738	1003	1694	1633	1649	651	228	1414
Ethio-Yugoslavia	2051	1698	677	1551	1719	1057	1612	1962	2249	894	936	1492
Mean	1932	1549	614	1478	1745	1048	1435	2000	2189	915	725	

REFERENCES

Amare Belay. 1990. Soybean advanced national observation nursery. p. 33-39. *In* Lowland Pulses Progress Report for April 1984—March 1985. Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia.

BARC. 2000. Crop Improvement Research Division Progress Report. Bako Agricultural Research Center, Bako.

BARC. 2001. Crop Improvement Research Division Progress Report. Bako Agricultural Research Center, Bako.

BARC. 2002. Crop Improvement Research Division Progress Report. Bako Agricultural Research Center, Bako.

BARC. 2003. Crop Improvement research Division progress Report. Bako Agricultural Research Center, Bako.

Breeding Food Legumes for Southeastern Ethiopia

Kedir Nefo, Edossa Fikiru and Tadele Tadesse

Sinana Agricultural Research Center, P.O. Box 208, Bale Robe, Ethiopia

ABSTRACT

In southeastern Ethiopia, food legumes are the second most important crops next to cereals. The breeding program in this area was based on the variation that existed in the locally collected indigenous landraces, local hybridization and exotic germplasm introduced from international institutions (such as ICARDA, ICRISAT, etc). The overall objective was to obtain improved high yielding and adaptive germplasm to the agro-ecologies of the highlands of southeastern Ethiopia. Specifically, improvement of yield and yield components, seed quality, and resistance/tolerance to various biotic and abiotic stresses were considered. As a result of an intensive breeding effort during the past 10 years (1994 to 2003), five field pea, one faba bean and one lentil varieties were released for the region. Wide genotypic and phenotypic variation was observed in indigenous field pea landraces, which was higher within a population than between populations. This indicated the existence of higher opportunity to homogenize and use landraces in the breeding program. Divergence study in the landraces indicated the absence of parallelism between geographic and genotypic diversity. Testing sites within the agroecologies of Bale highlands were clustered for field pea and faba bean. Future directions of food legume breeding program for southeastern Ethiopia are also indicated.

INTRODUCTION

Food legumes cover about 10% of the total crop area in southeastern Ethiopia and are the second most important crops next to cereals. The farming system in this area is a cereal-based cropping system (Chintalapati et al., 2001), with high potential for the production of food legumes. They are generally grown in areas between 1800 and 3000 m asl (Asfaw, 1979), and are important source of low cost alternative protein to animal protein in the cereal-based diets, and provide 18 to 32% protein (Hailu et al., 1994). They also play a significant role in the cropping systems by replenishing soil nutrients through biological nitrogen fixation.

Among the food legumes, faba bean and field pea are important food legumes in southeastern Ethiopia and occupy 48 and 26% of the area covered by food legumes, respectively (CSA, 2002).

The breeding program in this area has been exploiting the variation existing in the locally collected indigenous landraces, and exotic germplasm introduced from international institutions (such as ICARDA, ICRISAT, etc) and new variability created through hybridization.

GENETIC STUDIES

Phenotypic and Genotypic Variability in Indigenous Local Landraces

Variation is the difference among individuals due to genetic composition and/or the environment they are raised in (Allard, 1960). The knowledge of the magnitude of genetic and phenotypic variation in local landraces and the degree of association among agronomic characters is of utmost importance to provide the basis for effective selection.

Based on days to flowering and maturity, field pea germplasm collected from different parts of Ethiopia were placed in three groups (Tesfaye, 1999). About 45.3%, 28.1% and 26.6% of the germplasm were early- (65-70 days), medium- (71-75 days) and late-flowering (76-80 days) types, respectively, whereas about 40%, 53.2% and 10.9% were early-, medium- and late-maturing types, respectively.

Grain yield per plant of Ethiopian germplasm ranged between 33.7 and 49.5 g for the top 15 high yielding entries. About 67% of them were medium-maturing indicating association of high yielding ability with medium-maturity. In these germplasm, the gaps between phenotypic and genotypic coefficient variation for 100-seed weight, biological yield/plot and pods/plant were relatively wide, indicating the importance of environment in determining these traits (Tesfaye, 1999).

Tesfaye (1999) also found wide range of phenotypic and genotypic variation in field pea in number of seeds and pods/plant and grain and biomass yield/plant, plant height, days to flower, and only phenotypic variation in grain yield and biological yield/plot. The results from elsewhere showed wide phenotypic variation in seeds/plant (Dawit et al., 1994; Dev et al., 1996), grain yield/plant (Gupta et al., 1986; Kumaran et al., 1995; Rathore et al., 1993), plant height (Dawit et al., 1994; Singh et al., 1993), days to flowering (Gupta et al., 1986); and wide genotypic variation in number of pods/plant (Dev et al., 1996; Kumaran et al., 1995; Vikas et al., 1996), plant height (Dev et al., 1996), grain yield/plant and days to flowering (Rathore et al., 1993) in field pea. The variation in these traits was higher within populations than between the populations (Tesfaye, 1999), which showed more heterogeneity within landrace populations.

Heritability

It is a measure of the value of selection for particular characters and an index of their transmissibility (Johnson, 1955). Singh (1990) stated that if heritability of a character is very high, e.g. 0.80 or more, selection for such a character is fairly easy. The study conducted on field pea landraces at Sinana by Tesfaye (1999) indicated high heritability estimates in broad sense for days to 50% flowering, days to maturity, reproductive phase, primary branches, numbers of seed, biological yield, and seed yield/plant. The results of Singh et al. (1993) and Dev et al. (1996) showed high heritability in days to flowering. Tesfaye (1999) indicated that the heritability of seed yield, biological yield and harvest index of field pea were higher at individual plant level than at the plot basis, indicating that selection at the individual plant basis was the most effective than at the plot level.

Expected Genetic Advance

The improvement in the mean genotypic value of the selected plants over the base measures the expected genetic progress that would result from selecting the best performing germplasm for a given character (Allard, 1960). The expected genetic advance of 64 field pea germplasm of Ethiopian landraces varied between 3.71% in days to maturity to 56.6% in grain yield/plant (Tesfaye, 1999). Comparatively high expected genetic advances were observed for primary branches, seed yield, biological yield, harvest index and number of seeds/plant (Tesfaye, 1999), suggesting the importance of additive gene effects in these characters. High expected genetic advances were also indicated in primary branches (Singh, 1985); in seed yield, biological yield, and harvest index (Vikas et al., 1996).

High heritability estimates coupled with high genetic advance were observed for primary branches, number of seeds, biological yield and grain yield/plant, and therefore, selection for these characters would prove quite effective (Tesfaye, 1999). Similar findings were observed for primary branches (Kumaran et al., 1995).

Correlations

Correlations between characters are frequent features of plant breeding. They may arise from linkage or developmental genetic interaction, with or without a purely phenotypic component (Simmonds, 1986). The ultimate expression of yield in crop plants is usually dependent upon the action and interaction of a number of important characters (Elias, 1992). Genotypic correlation coefficients provide a measure of genetic association between traits in order to identify the important traits (Pandey and Gritton, 1975).

A correlation study of 16 promising field pea genotypes over four locations for three years in southern Ethiopia revealed a highly significant and positive association of grain yield/plot with days to flowering, days to maturity, plant height, number of pods/plant, and seeds/pod (SARC, 2002). Days to maturity had highly significant ($p < 0.01$) positive association with days to flowering, plant height, seeds/pod and pods/plant. Accordingly, the late-maturing genotypes produced larger number of pods/plant and seeds/pod and had high yield potential.

In another experiment conducted at Sinana station for one season, grain yield/plot of Ethiopian indigenous field pea landraces showed positive and significant phenotypic and genotypic association with harvest index and pods/plot; and with inter-node length and grain yield/plant. On the contrary, significant and negative phenotypic correlation was found between grain yield/plot, days to flowering and primary branches (Tesfaye, 1999).

The phenotypic association of biological yield and primary branches with grain yield/plant was positive and significant (Tesfaye, 1999), which was similar to the finding of Singh (1985). At genotypic level, seeds/plant and 100-seed weight had strong association with grain yield/plant. Seeds per plant also had higher heritability and genotypic advance, indicating the feasibility of its improvement through selection (Tesfaye, 1999).

In general, the correlation of grain yield with other characters did not show similar trend at individual or plot level for most of the characters, except the harvest index, number of seeds/plant, pods/plant and 100-seed weight (Tesfaye, 1999). The traits that showed different trend might be highly influenced by the environment.

Path Coefficient Analysis

The path coefficient analysis measures the direct influence of a variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects (Dewey and Lu, 1959). Tesfaye (1999) in field pea reported that harvest index, pods/plant, seeds/pod, reproductive phase, biological yield, primary branches, pod length and days to flowering had positive phenotypic direct effect; and number of seeds/plant and inter-node length had negative direct effect on grain yield/plant. In the studies, however, harvest index, pods/plant and seeds/pod exhibited positive direct effect on grain yield (Devendra et al., 1995; Golazzewski and Pusio, 1996).

The path coefficient revealed that number of seeds/plant had maximum positive genotypic direct effect on grain yield/plant followed by harvest index, plant height, and biological yield, primary branches (Tesfaye, 1999). Number of seeds/pod exerted maximum negative genotypic direct effect followed by reproductive phase, inter-node length, pod length and pods/plant (Tesfaye, 1999). In the findings of others, number of seeds/plant (Golaszewki and Pusio, 1996) and harvest index had a positive genotypic direct effect on grain yield (Devendra et al., 1995). Number of seeds/pod exerted maximum negative genotypic direct effect followed by the reproductive phase, inter-node length, pod length and pods/plant (Tesfaye, 1999). Generally, most other characters influenced grain yield positively through seeds/plant.

Harvest index (Devendara et al., 1995; Tesfaye, 1999), biological yield, number of seeds/plant, 100-seed weight, and inter-node length exerted positive phenotypic direct effect on grain yield per plot (Tesfaye, 1999), which revealed that these characters were the principal yield attributes for effective selection. However, while selecting high yielding germplasm it is desirable to ensure that advance in one component is not nullified by the deterioration in another.

The characters that had substantial unfavorable genotypic direct effects on grain yield/plot were plant height (Golaszewski and Pusio, 1996; Tesfaye, 1999) days to flowering and maturity, pods/plant, harvest index, primary branches and pod length (Tesfaye, 1999). It is interesting to note that, in addition to their negative direct effects on grain yield, days to flowering and maturity exerted unfavorable indirect effects on grain yield via each other.

The trend of genotypic and phenotypic, direct and indirect effects of the various causal characters on the seed yield was inconsistent at individual plant level and on plot level (Tesfaye, 1999). At genotypic level, biological yield, harvest index, plant height, seeds/plant and primary branches were found to exert favorable direct effect on grain yield when plants were examined individually. On the plot basis, biological yield, reproductive phase, inter-node length, and seeds/plant showed positive direct effects.

At phenotypic level, positive and direct effect was expressed on grain yield by days to flowering, reproductive phase, biological yield, harvest index, pod length, pods/plant, plant height, seeds/pod and primary branches at individual level, while biological yield, harvest index, inter-node length and 100-seed weight had positive direct effects on grain yield at the plot level. Generally, days to flowering, plant height and primary branches contributed directly to grain yield at the individual plant level, but unfavorably affected them at the plot level. On the other hand, inter-node length and harvest index had positive direct effect on grain yield in plants at the plot basis, and directly negatively affected in plants at the individual level. However, biological yield was the direct positive contributor under both the conditions.

Genetic Diversity

Description of germplasm collections for agronomically useful characters is an important prerequisite for effective and efficient utilization of germplasm collections in breeding programs. The 64 germplasm lines evaluated under Sinana condition were clustered into eight groups/clusters based on D^2 values (Tesfaye, 1999). The D^2 values within cluster varied substantially from 1.5 to 5.6, and between clusters from 16.3 to 212.7 showing high divergence among the different germplasm. Maximum genetic recombination and segregation of the progenies is expected from the hybridization of the parents selected from crosses involving parents selected from cluster with largest D^2. However, the breeder must specify the objectives in order to make the best use of the characters when they are divergent. Tesfaye (1999) also suggested that geographic diversity was not necessarily related to genetic diversity. Genetic drift and selection in different environments could cause greater diversity than their geographic differences in field pea (Gupta et al., 1992; Tesfaye, 1999).

A comparison of clusters for different characters showed that clusters differed considerably for the characters like biological yield, grain yield, harvest index, number of seeds and pods/plant; and plant height, 100-seed weight and biological yield/plot (Tesfaye, 1999). This suggested that these characters explained most of the variability in the germplasm collections studied and are important contributors to diversity.

Clustering of Testing Sites

Clustering of testing sites based on performance of faba bean and field pea cultivars was conducted in the highlands of Bale (Sinana, Sinja, Agarfa, Gassera and Adaba) for three consecutive years (1998-2000). Based on the mean grain yield at each location, the locations were categorized into a number of distinct groups.

Faba bean mean grain yield of the locations ranged between 2162 kg/ha at Gassera and 3619 kg/ha at Sinana (Fig. 1). Based on these results, Bale highland was clustered into two distinct testing sites. The three high yielding locations, Sinana, (3619 kg/ha), Adaba (3540 kg/ha) and Agarfa (3515 kg/ha), were clustered in one category, while Sinja (2224 kg/ha) and Gassera (2162 kg/ha) were clustered into another category.

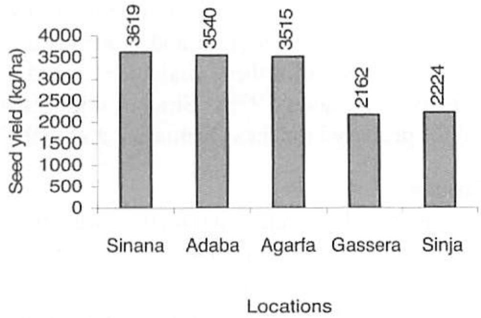


Fig. 1. Mean seed yield of faba bean genotypes used for clustering of the testing environments.

The mean grain yield of field pea ranged from 1390 kg/ha at Agarfa to 5014 kg/ha at Sinana (Fig. *2)*. The sites were more divergent for field pea than for faba bean. Based on the mean grain yield, four distinct clusters were obtained. Sinana (5014 kg/ha), Gassera (3422 kg/ha), and Agarfa (1390 kg/ha) were grouped in separate clusters, whereas the two other locations, Adaba (2379 kg/ha) and Sinja (2109 kg/ha) fell in the same cluster. Although, those locations, which were clustered together, could be considered similar on the basis of traits included for clustering, but it would be better to include other important site parameters like soil, moisture, biotic and abiotic factors to contribute the variation and similarity in yield among locations to some of the casual factors. Moreover, the number of locations that were included during the study was few, and it is suggested that more locations should be included for tangible conclusions for clustering major areas of faba bean and field pea production in southeastern Ethiopia.

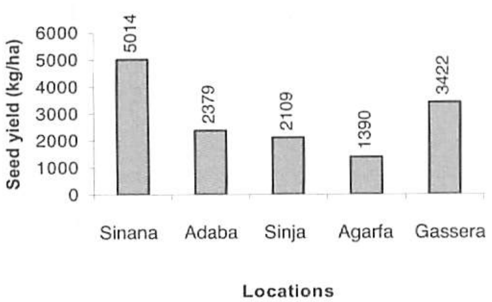


Fig. 2. Mean seed yield of field pea genotypes for clustering of the testing envrionments.

VARIETAL DEVELOPMENT

Germplasm Enhancement

Indigenous landraces, locally hybridized material and introductions of faba bean, field pea and lentil were evaluated for their adaptation, stable high yield, and resistance to diseases and insect-pests. Local landraces were collected, evaluated, and characterized for traits like days to flowering and maturity, number of pods/plant and seeds/pod, plant height, 1000-seed weight, grain yield, and resistance/tolerance to diseases and frost. Introduced exotic germplasm had the largest share of the materials evaluated in all crops. So far, about 563 faba bean, 973 field pea, and 1592 lentil germplasm composed of stable lines, landrace accessions and segregating populations were evaluated at Sinana Agricultural Research Center (SARC).

Selection and Evaluation

The ultimate breeding objective of food legume breeding program was to develop cultivars with high and stable yield well adapted to mid- and high-altitude agro-ecological zones. With this objective, germplasm are grown and evaluated in non-replicated nurseries at the main research stations. The materials selected from the nurseries are advanced to yield trials and then in multi-location trials at different sites representing diverse agro-ecological zones or potential production areas in the southeastern Ethiopia. Those materials that perform well at various locations are verified on larger plots and evaluated by the National Variety Release Committee (NVRC). Selection and evaluation of the materials are based on the breeding objective(s) of the crops. Some of the desirable characters which are integral part of the breeding objectives are mentioned below:

1. Resistance to various diseases including, chocolate spot, Ascochyta blight and rust for faba bean; rust and Ascochyta blight for lentil; and powdery and downy mildew for field pea
2. Early-maturity
3. Large seed size

On the basis of these and other agronomic and quality traits the genotypes that best fit the specific breeding objectives are selected and promoted for further evaluation at the next higher level.

IMPORTANT ACHIEVEMENTS

Released Cultivars

Food legume breeding program in the southeastern Ethiopia made tremendous progress in cultivar release in the past 10 years (1994-2003). Accordingly, five field pea, one faba bean and one lentil cultivars were released for the southeastern Ethiopia and similar agro-ecologies (Table 1). Two of the field pea cultivars, Tulushenen and Tuludimtu, were developed from local collections of the PGRC/E (Plant Genetic Resources Center of Ethiopia, now IBCR) through selections, while Hursa and Dadimos were obtained from exotic introductions. In addition, Weyyitu, a recently released field pea cultivar, was obtained through selection from locally crossed materials. These varieties are high yielding and resistant to powdery and downy mildew, the two serious diseases of field pea in southeastern Ethiopia. Their quality assessment indicated that all of them were better in cooking and swelling abilities after soaking compared with the local variety (Table 2). Furthermore, their seed size ranged from medium (in Tulushenen) to very large (in Dadimos). Shallo faba bean cultivar is liked for its large seed size (as compared to the local variety), high yield, and moderately resistant reaction to chocolate spot, Ascochyta blight and rust, the serious faba bean diseases in southern Ethiopia.

Assano, a recently released lentil cultivar, is high yielding, large-seeded, disease-resistant and early-maturing type for the areas with low rainfall (Table 1).

These improved cultivars have been disseminated to farmers and other government institutions, except the recent releases, through different governmental and non-governmental organizations (NGOs). The mechanisms of dissemination of seed of these released cultivars to the end users should be improved in food legumes as their dissemination is far behind compared to that of cereals.

Table 1. Food legume cultivars released by Sinana Agricultural Research Center for southeastern Ethiopia and similar agro-ecologies.

Crop	Cultivar	1000-seed weight (g)	Grain yield (kg/ha)	Area of adaptation	Days to maturity	Year of release
Faba bean	Shallo (EH 011-22-1)	501-577	2103-5491		112-128	1999/00
	Dadimos (061K-2P-11-3/3(B))	184-228	2643-5987		128-153	1994/95
	Tulushenen (PGRC/E 32121-1(B))	116-173	2756-6139		118-155	1994/95
Field pea	Hursa (KFP-103(B))	151-206	2650-5783	Mid to high altitudes	119-142	1997
	Tuludimtu (PGRC/E 32640-1)	142-200	2238-5901		114-140	1999/00
	Weyyitu (EH 90-006-2)	156-214	2500-6070		118-141	2003
Lentil	Assano (FLIP 88-46L)	41-47	1715-3349		105-124	2003

Table 2. Soakability, cookability and taste acceptance of field pea varieties released from Sinana Agricultural Research Center.

Variety	Non-soakers (%)	Cooking time (minute)	Acceptance*
Weyyitu	10	40	2.4
Tullushenen	44	37	3.5
Tulludimtu	43	40	2.4
Dadimos	2	45	2.5
Hursa	28	45	3.1
Local check	56	45	4.2

1=Liked extremely; 2=Liked very much; 3=Liked moderately; 4= Liked slightly; 5= Neither liked or disliked; 6= Disliked slightly; 7= Disliked moderately; 8= Disliked very much; and 9= Disliked extremely. Source: Food Nutrition Laboratory, Holetta Agricultural Research Center.

FUTURE DIRECTIONS

Ethiopia is one of the centers of diversity for faba bean. Thus, it is desirable to continue the use of indigenous landraces as a basis for varietal improvement and exotic germplasm as donors of desirable genes for tolerance to biotic and abiotic stresses, specific traits contributing to high yield and stability (e.g. independent vascular system, IVS) and auto-fertility). The future efforts in food legume breeding program should be directed towards, but not limited to:

1. Development of early-maturing and high yielding cultivars, especially for faba bean and field pea.
2. Development of plant types with determinate growth habit, especially for faba bean.
3. Development of faba bean cultivars resistant to chocolate spot.
4. Incorporation of pea aphid resistance into field pea cultivars.
5. Breeding for resistance to powdery and downy mildew in field pea improvement should continue but in a strengthened way.
6. Development of cultivars tolerant to moisture stress.
7. Breeding for large-seeded types with and improved quality for export markets.
8. Breeding for good nutritional and processing qualities.
9. Reducing leafiness and height of indigenous field pea landraces.
10. Incorporation of upright growth habit into cultivars to facilitate mechanization.

REFERENCES

Allard, R.W. 1960. Principles of Plant Breeding. John Willey and Sons Inc., New York.

Asfaw Telaye, 1979. Broad beans (*Vicia faba L.*) and dry peas (*Pisum sativaum* L.) in Ethiopia. p. 80-84. *In* GeoffreyC. Hawtin and G.J. Chancellor (Eds.) *Food Legume Improvement and Development*. Proc. Workshop Held at the University of Aleppo, Syria, 2-7 May 1978. IDRC, Ottawa, Ontario.

CSA. 2002. Ethiopian agricultural sample enumeration 2001/02 (1994 E.C.). p. 85,88. *In* Report on the preliminary results of area, production and yield of temporary crops (*Meher* season, private peasant holdings). Part I. Central Statistical Authority (CSA), Addis Ababa.

Chintalapati, Padmavathi, Desta Kefyalew, Kassahun Tesfaye, Gubo Qi, and Andrey Rondionov. 2001. The shift to cereal monocropping, a threat or a blessing? *In* Towards Sustainable Agricultural Production in the Highlands of Southeast Oromia, Ethiopia. Working Document Series 92. ICRA, Ethiopia. .

Dawit Tadesse, Asfaw Telaye, and Geletu Bejiga 1994. Genetic resources in Ethiopia. p. 79-96. *In* Asfaw Telaye et al. (Eds.) *Cool season Food Legumes of Ethiopia*. Proc. First National Cool season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/Institute of Agricultural Research, Aleppo, Syria.

Dev, H., K.B. Rastogi, and S.K. Sharma 1996. Association and path analysis of pod yield and quality traits of powdery mildew resistant advanced breeding lines of pea. Hort. J. 9:63-166.

Dewey, D.R., and K.H. Lu. 1959. A correlation and path coefficient analysis of components of crescent wheat grass seed production. *Agron. J.* 51: 515-518.

Devendra, K., B.P.S. Malik, S.K. Sharma, and D. Kumar. 1995. Path coefficient analysis in peas (*Pisum sativum L.*). *Annals Biol.* 11: 69-72

Elias Urage. 1992. Correlation and performance study of groundnut varieties in Ethiopia. M. Sc. Thesis. Alemaya University of Agriculture, Ethiopia.

Golaszewski J., and I.M.Pusio 1996. Path analysis in estimation of interdependence of some seed yield components of edible field pea. Biuletyn Instytutu Hosowili-I Aklimatyzacji-Roslin 200: 317-322.

Gupta, K.R., V.P Singh, G.P. Lodhi, and J.S. Hooda. 1986. Studies on the variability in phenological and yield traits in peas. Legume Res. 9 : 21-24.

Gupta, V.P, P.K. Rathore, and P. Plaha. 1992. Divergence analysis of some powdery mildew resistant lines of pea. *Crop Improv*. 19: 18-22.

Hailu Beyene, Gezahegn Ayela, and Berhanu Lakew. 1994. Marketing of cool-season food legumes. p. 31-39. *In* Asfaw Telaye et al. (Eds.) *Cool season Food Legumes of Ethiopia*. Proc. First National Cool season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/Institute of Agricultural Research. Alepo, Syria.

Johnson, H.V., 1955. Estimates of genetic and environmental variability in soybeans. *Agron. J.* 47: 314-318.

Kumaran, S.S., S. Natarajan,. and S. Thamburaj 1995. Genetic variability in peas (*Pisum sativum L.*). *South Indian Hort*. 43: 10-13.

Pandey S., and E.T. Gritton. 1975. Genotypic and phenotypic correlations in peas. *Crop Sci.* 15: 353-356

Rathore, P.K., V.P. Gupta, and P. Plaha. 1993. Association of stability parameters in pea. *Crop Improv*. 20: 201-206.

SARC. 2002. Progress report, 1999-2001. Sinana Agricultural Research Center (SNARC), Sinana, Ethiopia.

Simmonds, N.W. 1986. Principles of Crop Improvement. Longman, Singapore.

Singh, B.D. 1990. Plant Breeding: Principles and Methods, Kalyani Publishers New Delhi.

Singh, R.K. 1985. Genotypic variability and correlations in pea. *Indan J. Agric. Sci.* 55: 147-150.

Singh, A.P., G.P.Singh, and A.K. Singh 1993. Variability studies in tall and dwarf peas (*Pisum sativum L.*). *Crop Res. Hiss.* 6: 239-242.

Tesfaye Getachew. 1999. Genetic variability and association of characters in some Ethiopian field pea (*Pisum sativum* L.) Germplasm. M. Sc. Thesis, Alemaya University of Agriculture, Ethiopia.

Vikas, V., S.P. Singh, S. Rajvir, and R. Singh. 1996. Variability and inheritance of some qunatitative characters in peas (*Pisum sativum L.*). *Annals of Biol.* 12: 34-38.

Breeding Food Legumes for Eastern Ethiopia

Chemeda Fininsa and Bulti Tesso

Department of Plant Sciences, Alemaya University, P O Box 138, Dire Dawa, Ethiopia

ABSTRACT

Food legumes constitute an important component of crop production systems in eastern Ethiopia. Common bean and cowpea are important components in various intercropping systems, and faba bean and field pea are rotation crops mainly with barley. Lack of high yielding, major diseases- and insect-pest-resistant, and moisture stress- and frost-tolerant cultivars are priority constrains for low food legumes productivity in the region. Common bacterial blight and rust diseases are the major and destructive diseases of common bean in the region and have received priority in screening genotypes. Common bean variety development for high yield, moisture-stressed and low soil fertility areas, and multiple disease resistance has been attempted. As a result, two food bean cultivars (Gofta, G2816, and Ayenew, GLPX-92) were released for national production in 1997. Ten new selections of food and export-type common bean and one cowpea variety for moisture-stressed and low fertile areas are being verified for release for farmer cultivation. Participatory- and market class-based common bean breeding approach is underway. Based on promising results obtained from multi-location adaptation trials, three faba bean and three field pea varieties were recommended for production in Hararge highlands. In addition, landrace collections of faba bean and field pea from the region are being characterized, evaluated, and selected for regional variety development. Future research should emphasize on identification of moisture-tolerant and disease resistant (resistant to rust, chocolate leaf spot, common bacterial blight) and development of improved breeding lines with resistance to these stresses combined with good agronomic traits.

INTRODUCTION

Food legumes constitute an important component of crop production systems in eastern Ethiopia (Storck *et al.*, 1991; AU, 2000). The region comprises eastern and western Hararge Zones of Oromiya, Somali, and Harari States, and Dire Dawa area. More than 21150 ha of land are under cultivation of six types of food legumes in the region covering about 2.3% of land used for pulses cultivation in Ethiopia (Table 1). A total of 23404 tons were produced from these legumes in 2001 cropping season (CACC, 2001). Common bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna unguiculata* (L.) Walp.) are the major lowland pulses cultivated in the region. These crops, grown in altitude ranges of 1500-2000 m asl, are important components in various intercropping systems in Hararghe. The Hararge highland is one of the major bean production centers in East Africa (Wortmann and Allen, 1994). Common bean is becoming increasingly important in eastern Ethiopia because of the recurrent late onset and early termination of rainfall, which forced farmers to use short duration crops like common bean. Faba bean (*Vicia faba* L.) and field pea (*Pisum sativum* L.) are important cool-season food legumes in higher altitude areas (> 2000 m asl) of eastern Ethiopia. The crops are cultivated mainly in rotation with barley and potato (ICRA, 1996). Barley and potato fields planted in March-April are rotated with faba bean or field pea in early July. Although traditional cultivation of chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik.) and fenugreek (*Trigonella foenum-graecum* L. (Moench)) exists in limited pocket areas in eastern Ethiopia, their potential and production constraints are less known and documented. Cultivation of grass pea (*Lathyrus sativus* L.) is nonexistent, whereas pigeon pea (*Cajanus cajan* (L.) Millsp.) and soybean (*Glycine max* (L.) Merill.), are recent research introductions for crop diversification in the region.

Food legumes are important for farmers in the region as a source of protein in human nutrition, soil fertility management, cash source, intensifying crop production in space and time when used in intercropping systems, as emergency and security crops in times of failures of cereals due to recurrent drought, and as a supplementary animal feed especially for indigenous fattening practices. Land area coverage by food legumes and their production per unit area in eastern Ethiopia are presented in Table 1. The yields are extremely low for common bean (1 t/ha), faba bean (1.3 t/ha), field pea (0.9 t/ha), chickpea (1 t/ha), lentil (0.54 t/ha) and fenugreek (0.57 t/ha) (CACC, 2001). These low crop productivities are due to several biotic and abiotic constraints. Lack of high yielding, major diseases- and insect-pest-resistant, and moisture stress- and frost-tolerant cultivars are major constraints for low food legumes productivity in the region. Unimproved traditional agronomic and management practices such as plowing frequency, seeding rate, fertilization, planting pattern and system, and weeding are also important production constraints.

In an effort to improve the productivity of food legumes in Eastern Ethiopia, the Alemaya University (AU) launched breeding programs on common bean in 1987, and faba bean, field pea, cowpea and soybean in 1996. The general objectives of the breeding programs were to characterize, evaluate and select the food legumes germplasm from collections and introductions for high yield, disease- and insect-pest-resistance/tolerance, moisture stress and frost tolerance, better performance in low fertility areas, and desirable quality characteristics (e.g., food and canning quality). Specifically, common bean variety development for moisture stressed, low soil fertility areas, and multiple disease resistance have been attempted. Faba bean and field pea adaptation and variety development trials are in progress. Cowpea and soybean variety development for the region is underway. The objective of this paper is to review food legume breeding activities in eastern Ethiopia during the last 10 years. The breeding programs and important achievements are highlighted. Research gaps and activities for future direction are indicated.

VARIETAL DEVELOPMENT

Germplasm Enhancement

In the past, improved faba bean and field pea varieties adapted to eastern Ethiopian environmental conditions were not available. Therefore, farmers were growing low yielding and disease susceptible local cultivars. Thus, as a part of the short-term strategy, adaptation trials on the already released varieties were conducted to identify better performing varieties for farmers' use. As a medium-term strategy to develop faba bean and field pea varieties for the region, germplasm collections were made in the major growing areas (Wobera, Garamulata, Chercher, Jarso and Gursum) of Hararghe highlands following the standard germplasm collection procedures. The objective was to purify, characterize and evaluate the landraces for use in regional variety trials and crossing programs.

A total of 61 faba bean landraces were collected during 1998 and 1999. The collected germplasm accessions were purified based on their differences in morphological parameters, and as a result 150 lines were identified. The identified lines were characterized and are being screened in two trial sets for variety development. Similarly, out of 16 field pea germplasm accessions collected, a total of 48 field pea lines were identified. Some of these identified faba bean and field pea lines are now at the stage of pre-regional variety trials for high- and mid-altitude areas in Hararghe. The lines are being evaluated at Goromuti (2525 m asl), Gondola (2700 m asl), and Alemaya (1980m asl).

Germplasm introductions from CIAT were the basis of the initiation of common bean breeding program for eastern Ethiopia. A total of 2912 common bean accessions were acquired from CIAT through the bean national program between 1995 and 2001 for different selection objectives (Table 2).

SELECTION AND EVALUATION

Common Bean

Eastern Ethiopia is diverse in its topography and soil types and characterized by uneven distribution and low annual rainfall. Common bean breeding in the last 10 years was aimed to develop high yielding, disease-resistant, moisture stress- and low soil fertility-tolerant food and export type beans for the region.

Common bean germplasm introduced from CIAT for evaluation in moisture stressed areas were evaluated from nursery to the regional variety trial at Babile and Jijiga for five years. Four better performing genotypes were selected from early-maturing bean trials (Table 3). Among the promising genotypes, MMS-25 and MAM-25 are proposed for production in Babile and Jijiga areas. MMS-25 gave 31.9% higher grain yield over the standard check (Roba-1), and 82.4% over the local check (Red Wolaita) at Jijiga. At Babile, the genotypes yielded 27.6 % and 22.5% higher than the standard and local checks, respectively. Across two sites, they gave a mean yield advantage of 30-39% over the checks. They flowered and matured about 13 and 10 days earlier than the checks, respectively. MAM-25 yielded 42% and 37% more than Roba-1 and Red Wolaita, respectively. Both genotypes are resistant (rating< 3) to rust, common bacterial blight (CBB), web blight, anthracnose and angular leaf spot (ALS) diseases.

Better yielding common bean genotypes for the low fertile soil areas were also screened through BILFA trial. Seven better performing genotypes for low fertile soils of Babile, and Alemaya Rhegosol (Gandajey) were selected (Table 4). However, due to its black seed color, Ikinnimba, the best performing genotype, was not preferred by farmers in the region. Among the selected genotypes on Babile soils, LSA-1 gave 79% higher grain yield over Roba-1 and 6% over Gofta. It gave 0.65t ha^{-1} at Babile Research Station. LSA-1 is also resistant to CBB, web blight and halo blight diseases and has been selected as a candidate food bean variety for release for general cultivation in Babile area.

In an endeavor to develop multiple disease-resistant varieties, the introduced germplasm was screened at four locations (Alemaya, Babile, Hirna and Jijiga) for seven years (1996-2002). Four multiple disease-resistant and better yielding genotypes were selected (Table 5). These genotypes could serve as a source of resistance for crossing or could be released as varieties since they had good yielding potential and qualities. For example, TY-3396-12 is multiple disease-resistant and high yielding food beans. It is a potential variety for production in relatively high rainfall areas of eastern and western Hararge. It gave yield advantage of up to 28% over the currently available food bean varieties in the region.

Table 1. Area under cultivation and production of food legumes in the 2001 cropping seasons in Eastern Ethiopia.

Crop	Area (ha)	Percent of national area	Production(t)	% of national production	Grain yield (t/ ha)
Faba bean	5212.2	1.41	6969.5	1.56	1.34
Field pea	1104.7	0.63	949.5	0.64	0.90
Common bean	11696.4	9.76	12976.9	13.15	1.00
Chickpea	1579.8	0.85	1641.6	0.91	0.98
Lentil	870.1	1.45	418.4	1.09	0.54
Fenugreek	687.3	4.57	448.4	4.47	0.57
Total	21150.6	2.30	23404.3		

Source: CACC (2001).

Table 2. Introduced common bean germplasm for different selection objectives in Nursery-I from CIAT between 1995 and 2001.

Year	No. of entries
1995	480
1996	221
2000	594
2000 (set I) [a]	934
2000 (set II) [b]	386
2001	297
Total	2912

[a] For low- to medium-altitude areas. [b] For high altitude areas.

In addition, food bean lines like G-843 and G-3314 gave higher yields compared to the currently grown food bean varieties such as Red Wolaita, Roba-1, Ayenew and Gofta for many years. These varieties are in pipeline for release in Hararge. Similarly, potential export type beans for different agroecologies of eastern Ethiopia are selected. The genotypes were tested from nursery to the regional variety trial in white pea bean class at Alemaya Fluvisol, Rhegosol and Babile for the last seven years. The selected genotypes, STTT-165-95, STTT-165-96, UTTT-27-4 and UTTT 24-56, are better in their yield performance and resistance to diseases compared to the currently available commercial bean varieties such as Mexican-142 and Awash-1. UTTT-27-4 and UTTT-24-56 are candidate export bean varieties for production areas around Babile and elsewhere with similar environmental conditions, while STTT-165-95 and STTT-165-96 are good candidates for Alemaya and other areas of Hararge.

Table 3. Growth characteristics and yield components of four selected promising early maturing common bean genotypes at Babile and Jijiga in eastern Ethiopia (1998-2002).

Genotype	Days to flowering	Days to maturity	Pods/ plant	Seeds/ pod	100-seed weight (g)	Grain yield (t/ha)
MMS-25	42.9	78.3	4.8	3.8	35.2	0.58
MAM-25	44.4	79.9	5.0	4.2	34.5	0.56
ARA-3	47.8	78.9	4.2	3.8	34.3	0.53
TLP-11	55.9	91.2	5.8	4.1	21.0	0.41
Red Wolaita [a]	50.3	83.6	4.5	4.6	22.0	0.39
Roba-1 [b]	55.9	87.8	5.6	4.8	18.1	0.46
Mean	49.5	83.3	4.9	4.2	27.5	0.49
SE (±)	2.27	2.15	0.2	0.17	3.24	0.03
LSD (0.01)						0.12

[a] Local check; [b] Standard check.

Table 4. Agronomic characteristics, grain yield and yield components of seven selected promising common bean genotypes for low fertile areas in eastern Ethiopia (2000-2002).

Genotype	Days to flowering	Days to maturity	Pods/ plant	Seeds/ pod	100-seed weight (g)	Gain yield (t/ha)	Seed color
Ikinnimba	50	97	9.1	4.4	36.4	1.83	black
A-585	61	102	8.4	5.3	27.6	1.64	cream
XAN-79	53	101	9.7	4.8	23.5	1.56	pinto
ARA-4	57	101	9.0	5.2	24.7	1.44	cream
RWK-5	60	102	8.6	5.3	24.6	1.46	carioca
CNF-5513	61	101	11.7	5.4	16.6	1.36	cream
LSA-191	57	101	8.1	4.6	34.9	1.32	pink
Gofta [a]	52	99	8.6	4.5	33.0	1.74	cream
Mexican 142 [b]	57	102	11.2	4.6	16.0	1.16	white
Roba-1 [a]	60	102	10.1	5.1	18.1	1.04	cream
Mean	56.8	100.7	9.5	4.9	25.5	1.46	
SE (±)	1.24	0.51	0.38	0.12	2.35	0.07	
LSD (0.01)						0.24	

[a] Standard check; [b] Local check.

Table 5. Agronomic performances of four selected promising multiple disease-resistant common bean genotypes in eastern Ethiopia (1996-2002).

Genotype	Days to flowering	Days to maturity	Pods/ plant	Seeds/ pod	100-seed weight (g)	Grain yield (t/ ha-)	Seed color
CTC-1	60	103	10.5	4.7	26.9	1.75	cream
TY-3396-12	58	103	11.0	4.7	25.9	1.72	carioca
RAB-475	60	103	10.8	4.8	24.9	1.57	carioca
ARA-21	61	103	11.1	4.5	22.1	1.48	cream
Ayenew [a]	53	100	9.8	3.9	36.5	1.77	pinto
Roba-1 [a]	62	100	10.9	4.7	18.6	1.12	cream
Mean	58.9	102	10.7	4.6	25.8	1.57	
SE (±)	1.35	0.53	0.19	0.14	2.46	0.10	
LSD (0.01)						0.19	

[a] Standard check.

Cowpea

Cowpea is one of the most important pulse crops in low moisture areas in eastern Ethiopia, and its grains are a rich and cheap source of protein. Its leaves and stems are also useful as supplemental animal feed. The crop has a potential for moisture stressed areas in Babile, Gursum and Jijiga of eastern Ethiopia (AU, 1996). However, the scale of its cultivation and production is not well developed owing to poor performance of available local cultivars and unavailability of improved varieties for the region.

Introduced cowpea germplasm from IITA were evaluated from nursery to the regional variety trial at Babile and Jijiga for seven years. Four better performing genotypes were selected (Table 6). Among the promising genotypes, 84E-129 gave 144.7 % higher grain yield than Black Eye Bean, and 10.3% higher over White Wonder. Both Black Eye and White Wonder are standard checks. Genotype 84E-129 has upright growth habit, which makes it preferable for planting in intercropping systems. In addition, the genotype is cream-colored, suitable for local stew, and has good taste and cooking quality. This line was proposed for release in Babile and Jijiga areas.

Soybean

In spite of the nutritional importance of soybean (high quality protein, oil and carbohydrate content) and its suitability and role in cropping systems for intercropping and sequential cropping, no serious attempt has been made to develop specifically adapted varieties for the region. A soybean selection program for eastern Ethiopia was initiated in 1997. Thirty-six genotypes obtained from Awassa Agricultural Research Center were evaluated and ranked for growth characters, pod load, vigor and disease reaction at Hirna, western Hararge. High variation was recorded in grain yield (1.3 to 2.6 t/ha) and 100-seed weight (1 to 6 g). Based on field performance, 20 genotypes were selected and are advanced to variety trial.

IMPORTANT ACHIEVEMENTS

Released Common Bean Varieties

Two food bean high yielding varieties, Ayenew (*G2816*) and Gofta (*GLPX-92*), were released in 1997 for general cultivation in the country. These varieties have good cooking qualities, are adapted for Hararge highland conditions and other areas, and are moderately resistant to Common bacterial blight (CBB) and rust diseases (Table 7), which are the major economic diseases on common bean in Hararghe highlands (Fininsa and Yuen, 2001) and other major common bean producing areas in Ethiopia (Habtu et al., 1996). Currently, the varieties are commonly grown, popular and adopted by many farmers.

Adapted Faba bean and Field pea Varieties

Seven faba bean varieties released by Holetta Agricultural Research Center (HARC) were evaluated for 3-5 years in Hararge highlands at Goromuti, Gondola, Alemaya and Chinaksen for their adaptation. Three varieties, CS-20-DK, Messay and Bulga 70, were selected on the basis of their superiority, and have been recommended for production in Hararge highlands. Similarly, five field pea varieties released from HARC were evaluated at the same locations for their adaptation, and three, namely, Markos, Tegegnech and G 22763-2C, with superior performance and adaptation were recommended for cultivation (Table 8).

Participatory Common Bean Breeding

The pulses research team of Alemaya University has been actively participating in a participatory plant breeding (PPB) project of common bean supported by CIAT for five years (1998-2003). The objectives of the PPB were to: (i) identify farmers' common bean selection criteria, (ii) target and disseminate more acceptable and productive bean varieties to farmers, (iii) tap indigenous technical knowledge, and (iv) compare and assess impacts and costs of conventional and PPB approaches in developing varieties.

The PPB project was implemented by selecting three farmer groups representing resource- poor, resource-rich and women farmers. The groups were invited to on-station research plots to select common bean lines from a germplasm pool of 250 accessions in 1998. Selection was done at flowering, pod filling and harvesting stages. The groups also planted their selections in their respective villages continuing selections until 2001 by advancing their selected lines. During different stages of selection, the farmers were interviewed about their selection criteria using an open-ended evaluation methodology. Breeders also made their own selections from the same germplasm pool in the same season as per the conventional criteria and procedures, and the selections were channeled through conventional breeding procedures for comparison with the farmers' selections.

Results of the on-station line selection revealed variations among farmer' groups in their preference for the type of bean genotypes, their selection intensity, and criteria (Table 9). There were very few common selections between the groups and the number of lines selected by each group from a total of 250 lines in the germplasm pool (or selection intensity) varied greatly. A total of 40 farmers participated in the selection, and their selection criteria were based on marketability, forage and associated traits, food quality, resistance to abiotic and biotic constraints, and other characters. Of these criteria, pods/plant, drought resistance, grain yield, seeds/pod, seed size, seed color, plant height, pod length, and forage yield were found to be the most important selection criteria for more than 60% of the farmers across the three groups. Pods/plant and drought resistance were common for 100% of the farmers across groups. The resource-poor farmers' group used a total of 34 (85%), resource-rich 21 (53%) and women 28 (70%) selection criteria for bean variety selection.

Women farmers used high frequency of selection for traits associated with food quality such as *shumo* quality (volume when boiled, seed size, and cooking time) and with forage and associated traits (plant height, forage yield, and leafiness). They also placed more emphasis on marketability than the male farmers. This result is in agreement with the actual role of women in eastern Ethiopia. They also considered multiple harvesting as a selection criterion more than the other two groups, indicating their requirement for steady supply of food for their children. The resource-poor farmers concentrated more on constraint-related parameters (disease resistance and insect resistance), maturity-related traits (days to maturity and synchrony of maturity), and stand establishment (germination and plant stand uniformity). Shattering, pod filling and seed plumpness (full and shiny seeds) and pod appearance (clean and attractive) were also used as selection criteria more by resource- poor farmers than the resource-rich male farmers and women farmers. Only very few traits (seed color, stalk strength, suitability for local stew and green leaf persistence) were more emphasized by resource-rich farmers than the women and resource-poor farmers.

The program has proved that farmers are knowledgeable in common bean selection criteria including quality characters, tolerance to moisture stress and resistance to diseases (Jones, 1999; Frew and Farley, 2000; CIAT, 2002). Based on these results and others found elsewhere in Ethiopia it is now believed that the selections made only by scientists at research stations may end up on a shelf unless the breeding program incorporates farmers' perceptions and priorities right from the initial stages. Based on the findings of PPB methods and approaches, the bean improvement program of AU has already started incorporating the key selection criteria of farmers in variety evaluation and selection. This approach can produce varieties that are productive and better accepted by farmers within a short period of time. However, no mechanism has yet been developed to release and register varieties developed through PPB approach with farmers. The current conventional variety release mechanism in Ethiopia does not encourage variety development for specific locations unlike the PPB approach. Also, it does not recognize the diversity need of diversified subsistence farmers. Unless new mechanisms of variety release and registration are developed and recognized, we are afraid that PPB will remain as an unfruitful plant breeding exercise in Ethiopia.

Table 6. Agronomic performance of four selected promising cowpea genotypes at Babile, eastern Ethiopia (1999-2002).

Genotype	Days to flowering	Days to maturity	Pods /plant	Seeds/ pod	100-seed weight (g)	Grain yield (t/ha)
84E-129	70	103	10.8	11.6	13.3	1.26
835-689-4	67	98	12.5	11.2	16.4	1.10
TT-82D-889	70	97	10.2	10.8	15.4	1.04
IT-87-D-272	67	98	8.8	10.7	15.6	1.02
TVU-1977-0D1	62	96	12.8	10.8	10.9	1.02
Black eye bean [a]	62	97	8.0	8.1	20.1	0.51
White Wonder [b]	71	103	8.9	10.2	12.3	1.14
Mean	67.0	98.8	10.3	10.5	14.9	1.01
SE (±)	1.34	1.11	0.70	0.43	1.15	0.09

[a] Local check; [b] Standard check.

Table 7. Characteristics of two common bean varieties better adapted to eastern Ethiopia.

Variety	Seed color	Seeding rate (kg/ha) Row	Seeding rate (kg/ha) broadcast	Growth habit	Maturity period	Adaptation zone (m asl)	Adaptation area	Yield (t/ha)
Aynew (*G2816*)	white/cream fleck	80-100	100-120	III	90-110	1500-2000	Hararghe highland, Jimma, Bako, Pawe	2.5
Gofta (*GLPX-92*)	Cream	80-90	100-120	III	80-100	1700-2000	Hararghe highland, Jimma, Bako, Pawe, Melkassa, Awassa	2.6

Table 8. Agronomic performance of selected faba bean and field pea varieties adapted to Hararge highlands (2000-2002).

Variety	Days to flowering	Days to maturity	Pods/plant	Seeds/pod	100-seed weight (g)	Grain yield (t/ha)
Faba bean						
CS-20-DK	59	125	12	3	430	1.09
Messay	58	124	13	3	447	1.15
Bulga-70	59	124	13	3	426	1.06
Tesfa	58	124	13	3	424	1.20
Local check	58	124	12	3	440	1.05
Field pea						
Markos	66	108	10	6	214	1.53
Tegegnch	66	106	9	5	224	1.76
G-2273-2C	68	108	12	6	154	1.58
Local check	65	106	11	5	155	1.36

Table 9. Frequency of common bean selection criteria used by farmer selectors as identified through participatory plant breeding (PPB) approach in three user groups: resource-poor farmers (RPF), resource-rich farmers (RRF) and women farmers (WF) in eastern Hararge.

		RPF		RRF		WF		Total	
No	Selection Criteria	Count (n=6)	%	Count (n=6)	%	Count (n=10)	%	Count (n=22)	%
1	Pods/plant	6	100	6	100	10	100	22	100
2	Drought resistance	6	100	6	100	10	100	22	100
3	Grain yield	6	100	5	83	10	100	21	95
4	Seeds/pod	6	100	6	100	8	80	20	91
5	Seed size	5	83	5	83	9	90	19	86
6	Seed color	4	67	6	100	7	70	17	77
7	Plant height	3	50	4	17	10	100	17	77
8	Pod length	5	83	0	0	10	100	15	68
9	Forage yield	1	17	3	50	9	90	13	59
10	*Shumo*[a] quality	1	17	3	50	7	70	11	50
11	Growth habit	3	50	1	17	7	70	11	50
12	Pod filling	6	100	3	50	2	20	11	50
13	Stalk strength	3	50	4	67	4	40	11	50
14	Market value	1	17	1	17	8	80	10	45
15	Seed shape	0	0	3	50	5	50	8	36
16	Seed plumpness	4	67	1	17	3	30	8	36
17	Synchrony of maturity	5	83	1	17	1	10	7	32
18	Disease resistance	4	67	1	17	1	10	6	27
19	Insect resistance	4	67	1	17	1	10	6	27
20	Pod appearance	3	50	0	0	2	20	5	23
21	Stand uniformity	5	83	0	0	0	0	5	23
22	Green leaf persistence	1	17	3	50	4	40	8	36
23	Multiple harvesting	1	17	0	0	5	50	6	27
24	Cooking time	0	0	0	0	4	40	4	18
25	Local stew	1	17	2	33	0	0	3	14
26	Shattering	3	50	0	0	0	0	3	14
27	Seed weight	1	17	1	17	0	0	2	9
28	Maturity	2	33	0	0	0	0	2	9
29	Boiled grain volume[c]	0	0	0	0	2	20	2	9
30	Lodging	2	33	0	0	0	0	2	9
31	Green pod consumption	1	17	0	0	1	10	2	9
32	Germination	2	33	0	0	0	0	2	9
33	Days to podding	2	33	0	0	0	0	2	9
34	Leafiness	0	0	0	0	2	20	2	9
35	Height of basal pod	1	17	0	0	0	0	1	5
36	Leaf shedding	1	17	0	0	0	0	1	5
37	Storage life	0	0	0	0	1	10	1	5
38	Rejuvenation[d]	1	17	0	0	0	0	1	5
39	Termite resistance	1	17	0	0	0	0	1	5
40	Vigor	0	0	0	0	1	10	1	5

Note: n refers to the number of farmers in each group who participated in the selection activity. [a] *Shumo* is a boiled grain in Afaan Oromo; [b]Boiled grain volume refers to whether the grain increases in volume after boiling; [c]Rejuvenation is especially for climbing beans.

FUTURE DIRECTIONS

The future directions of breeding food legumes for eastern Ethiopia should emphasize the following:

1. The release of pipeline common bean and cowpea varieties, their distribution to farmers, and follow-up on their adoption.
2. Selection and evaluation of common bean varieties based on market classes.
3. Development of common bean varieties with increased nodulation capacity for enhanced nitrogen fixation.
4. Identification of moisture stress-tolerant traits in common bean and breeding for such environments.
5. Breeding for multiple-disease resistance.
6. Development of high yielding and disease-resistant faba bean, field pea, soybean and cowpea varieties for production in eastern Ethiopia.
7. Initiation of common bean crossing program, and
8. Initiation of chickpea, lentil and fenugreek adaptation and breeding programs.

REFERENCES

AU. 1996. Proceedings of the 13th Annual Research and Extension Review Meeting. Alemaya University. 421 pp.

AU. 2000. Strategic Plan for Research and Development on Crops and Livestock. Alemaya University. 500 pp.

CACC. 2001. Ethiopian agricultural sample enumeration, 2000/2002. Central Agricultural Census Commission (CACC), Addis Ababa.

CIAT. 2002. Participatory plant breeding with women and small farmers in Africa and Latin America. Centro

Internacional de Agricultura Tropical (CIAT), Colombia. 96 pp.

Fininsa, C., and J. Yuen. 2001. Association of bean rust and common bacterial blight epidemics with cropping systems in Hararghe highlands, eastern Ethiopia. *International J. Pest Management* 47: 211-219.

Frew, M., and C. Farley. 2000. Participatory research for improved agroecosystem management: A community-based approach in Alemaya Woreda, eastern Ethiopia. Alemaya University Research Report Series, Occasional Publication, No.2. Alemaya University, Alemaya, Ethiopia. 56 pp.

Habtu, A., I. Sache, and J.C. Zadoks. 1996. A survey of cropping practices and foliar diseases of common bean in Ethiopia. *Crop Protection* 15: 179-188.

ICRA. 1996. Supporting agricultural innovation in two districts of western Hararghe: The role of research, extension and farmers. Working Document Series 52 Ethiopia-1996. International Center for Development Oriented Research in Agriculture (ICRA), The Netherlands. 140 pp.

Jones, A. L. 1999. Technical and institutional issues in participatory plant breeding from perspective of formal breeding: A global analysis of issues, results and current experience. CGIAR System Wide Program on Participatory Research and Gender Analysis for Technology Development and Innovation. Working Document No. 3.

Storck, H., B. Emana., B. Adnew., A. Borowiecki, and S. Woldehawariat. 1991. Farming systems and farm management practices of smallholders in the Hararghe highlands - A baseline survey. Farming Systems and Resource Economics in the Tropics, Vol. 11, Kiel: Wissenschaftsverlag Vauk.

Wortmann, C. W., and D. J. Allen. 1994. African bean production environments: Their definitions, characteristics and constraints. Network on Bean Research in Africa. Occasional Paper Series No. 11 Dare Salaam, Tanzania: CIAT. 47 pp.

Review of Food Legumes Breeding and Genetics Research in Northern Ethiopia

Wondafrash Mulugeta [1], Dawit Tsegaye [2], Beyene Dimtsu[3], and Hailemicheal Shewayrga[4]

[1]Sheno Agricultural Research Center, P.O. Box 112, Debre Berhan, Ethiopia, [2]Adet Agricultural Research Center, P.O. Box 08, Bahir Dar, Ethiopia, [3]Mekele Agricultural Research Center, P.O. Box 492, Mekele Ethiopia, [4] Sirinka Agricultural Research Center, P.O. Box 74, Woldia, Ethiopia

ABSTRACT

Reviewed in this paper is the breeding and genetics research on food legumes since 1994 in northern Ethiopia, where faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (Cicer arietinum L.) and lentil (*Lens culinaris* Medik.) are important. Faba bean and field pea are dominantly produced on Nitosols and Vertisols during the main season, while chickpea and lentil are produced on the residual moisture on Cambisols and Vertisols. The research work on food legumes is carried out at four research centers, namely, Adet, Mekele, Sheno, and Sirinka. Production constraints include drought for lentil and chickpea; chocolate spot and rust on faba bean; Ascochyta blight on chickpea and field pea; powdery mildew on field pea; wilt/root rots on chickpea and lentil; and aphids, water-logging, and frost on all of them. Past research efforts resulted in the release of four improved varieties of pulses. Twelve additional varieties were recommended for variety release trials. Results of evaluation of 32 faba bean landraces in Vertisols at Inewari and Ginchi indicated significant genotypic differences and G x E interactions for most of the characters. Path analysis at phenotypic as well as genotypic level revealed that biological yield and harvest index were the most important traits in determining grain yield per unit area. Breeding for specific adaptation has been suggested. Need for generating basic scientific information on resistance to biotic and abiotic stresses, inheritance of traits and breeding work on quality traits such as seed size, color, protein content and cooking-ability aspects is emphasized.

INTRODUCTION

The food legumes are important crops in northern Ethiopia especially in Amhara and Tigrai regions. Of the food legume crops grown in this part of the country, faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) are important in terms of area and production. They account for 48.8% of the total cultivated land and 56.9% of the total production of cool season food legumes in the country (Table 1). Faba bean and field pea are dominantly produced on Nitosols and Vertisols during the main (*meher*) season, while chickpea and lentil are produced on Cambisols and Vertisols on the residual moisture. Research on food legumes is carried out at four research centers, namely, Adet, Mekele, Sheno, and Sirinka. Production constraints to these crops in the area include drought on lentil and chickpea; chocolate spot and rust on faba bean; ascochyta blight on chickpea, lentil and field pea; powdery mildew on field pea; wilt/root rots on chickpea and lentil; and aphids, water-logging and frost on all of them. Frost damage usually starts at flowering and continues until the podding stage, and hence causes severe damage to the crop yields.

In some parts of the highlands of northern Ethiopia, food legumes are produced during the *belg* or short rainy season. Farmers in these areas practice sequential- or double-cropping system to intensify their production. Nevertheless, the development of early-maturing genotypes for double-cropping has received very little attention. After decentralization of the breeding and genetics work the effort of most research centers in northern Ethiopia have focused on adaptation studies of the nationally-recommended improved varieties. That is part of a short-term strategy to facilitate quick identification, seed multiplication, distribution and popularization of the adapted varieties. The paper reviews the efforts made, and highlights the major achievements and research gaps in food legumes breeding and genetics research in the northern part of the country.

Table 1. Average estimate of area, and production and yield of cool season legumes in private holdings of Amhara and Tigrai Regions, 1995/96-2000/01, *meher* season.

	Crop	Area (000'ha)	% of national area	Production (000'tons)	% of national production	Yield (t/ha)	National Area (000'ha)	National Production (000'tons)	National Yield (t/ha)
1	Pulses	468.24	48.8	3941.9	56.9	0.9	959.6	6927.4	0.9
2	Faba bean	151.16	44.9	1558.8	55.1	1.0	336.6	2827.3	1.2
3	Field pea	69.08	42.9	479.4	47.2	0.8	161.1	1016.2	0.8
4	Chick pea	107.98	64.9	883.2	75.3	0.9	166.4	1172.4	0.8
5	Lentil	38.32	61.7	254.2	82.5	0.6	62.1	308.1	0.6
6	Grass pea	64.84	62.8	511.3	64.2	0.9	103.3	796.8	0.8
7	Fenugreek	8.44	47.0	55.1	58.9	0.6	17.9	93.5	0.6

Source: CSA (1995-2000).

GENETIC STUDIES

Faba Bean

Studies on Vertisols conducted by Wondafrash (2002) showed high phenotypic and genotypic coefficients of variation (PCV & GCV) for grain yield/plant, grain yield/plot, biological yield/plant and biological yield/plot at Ginchi and Inewari, indicating a possibility for genetic improvement through selection. Seed weight recorded the highest heritability at both locations (87.4% at Ginchi and 79.2% at Inewari). Days to maturity, plant height and height of first pod had more than 40% heritability at both locations. Expected genetic advance was high for grain yield/plant, grain yield/plot and biological yield/plot at both locations suggesting that the landraces of faba bean under evaluation were a good source of material to develop high yielding varieties under Vertisol conditions (Wondafrash, 2002).

Study of associations among various traits at genotypic as well as phenotypic level showed that grain yield/plot was positively associated at both locations with plant height, height to first pod, seeds/plant, pod bearing nodes/plant, pods/plant, grain yield/plant, biological yield/plant, biological yield/plot, harvest index /plot, number of branches /plant and number of nodes/plant. Grain yield/plot was negatively correlated with days to maturity, seed weight and reproductive period at Inewari though its association with these three traits was positive at Ginchi. Similarly, reproductive period had positive association with all the traits at Ginchi, whereas its correlation with all the traits except days to maturity was negative at Inewari.

The path coefficient analysis at phenotypic level revealed that biological yield/plot and harvest index were the most important traits determining grain yield/plot at Ginchi.

Path analysis at genotypic level further supported the importance of these two traits in determining grain yield/plot, and also revealed a positive direct effect of grain yield/plant and days to maturity. The analysis showed that the high positive associations of plant height, height to first pod, seeds/plant, pods bearing nodes/plant, pods/plant, biological yield/plant, seed weight, number of branches /plant and number of nodes/plant with grain yield/plot was due to the high positive indirect effect of these traits via biological yield/plot. The residual effect for path analysis at genotypic as well as phenotypic level was low indicating that the major variability in seed yield/plot was accounted for by 15 agronomic traits included in the present study (Wondafrash, 2002).

The path coefficient analysis for Inewari at phenotypic as well as genotypic levels suggested that biological yield/plot and harvest index/plot were also important predictors of grain yield per unit area at this location. At this location, days to maturity had negative association with grain yield/plot at both the phenotypic as well as genotypic level. This was mainly due to its negative indirect effect via biological yield/plot as well as low negative direct effect. The path coefficient analysis for both Inewari and Ginchi at phenotypic as well as genotypic levels suggested that biological yield/plot and harvest index/plot were the most important traits determining grain yield/plot in Vertisols areas (Wondafrash, 2002). Another study indicated the presence of high G x E interaction (Genotype x year and genotype x seedbed management) for 16 faba bean genotypes evaluated under waterlogged Vertisols, but genotypes x seedbed management x years was not significant. This indicated selection of advance genotypes done on broadbed and furrow (BBF) was sufficient to develop future varieties suitable for VertisolVertisols areas.

Chickpea

The work reported by ShARC (2003) indicated highest phenotypic coefficient of variation (PCV) for seeds/pod, pod/plant and 100-seed weight at Inewari, Sirinka and Adet; and highest genotypic coefficient of variation (GCV) for 100-seed weight at the same locations. Heritability was high for 100-seed weight and days to flowering at Inewari, Sirinka and Adet with high Genetic Advance and Genetic Advance as percentage of mean.

At Inewari, days to maturity had negative phenotypic and genotypic correlation coefficient with grain yield but positive at Sirinka and Adet. A similar trend was observed for days to flowering. Considering plant height, shorter varieties did better at Inewari than at Sirinka and Adet (ShARC, 2001). Hundred-seed weight had a positive direct effect and seeds/pod had negative direct effect on grain yield at Inewari, Sirinka and Adet. Thus, selection of genotypes for higher seed weight could be used for indirect selection for grain yield at all locations, because it had high heritability as well.

VARIETIAL DEVELOPMENT

Production Constraints

Faba bean production on Vertisols of northern Ethiopia has shown a declining trend in recent years. The low production is largely attributed to the absence of high yielding varieties resistant to stresses like water-logging and frost. Thus, an attempt was made to select food legume genotypes with better grain yield potential and tolerance to biotic and abiotic stresses compared to those grown by farmers. Host resistance is considered as one of the best options for control of black root rot disease (*Fusarium solani*), which may cause partial/total crop failure on farmers' fields depending on the amount of rainfall in a given season.

Field pea is grown in a wide range of environments and yields of several genotypes tested across location and over years differed due to high genotype x environment interaction. This makes it difficult for breeders to develop widely adapted, stable and high yielding genotypes in Ethiopia (Taye et al., 2000).

Chickpea is mainly grown on Vertisols on residual moisture after the main rainy season (September to

January) as well as in short rainy season (March-June). The crop is grown in rotation with *tef* and wheat. With the past research efforts, it was possible to recommend nationally released varieties and identify promising genotypes for regional release around Inewari, Sirinka, Adet and similar Vertisol areas in Amhara region (ShARC, 2002).

In lentil crop, wilt/root rots, caused by Fusarium, Pythium, Rhizoctonia and Sclerotium species are economically important diseases. Research efforts are underway to develop resistant/tolerant varieties against these diseases.

Frost is a serious problem on cool season food legumes in northern Ethiopia. Its attack occurs between October to January in high altitudes (> 2400 m asl). Although screening for frost resistance was initiated on faba bean and lentil at Sheno (2850 m asl), however, no sources of resistance to this problem were identified except some tolerant ones in lentil.

The germplasm accessions are received from IBRC, whereas improved lines/varieties through international nurseries from international organizations such as International Center for Agricultural Research in the Dry Areas (ICARDA).

Faba bean Evaluation and Selection

Food legumes breeding in northern Ethiopia has been undertaken at two levels, i.e., specific breeding to develop varieties specifically adapted to the northern part of the country, and evaluation in collaboration with the national coordinating centers to develop widely adapted varieties. As a result of a breeding effort made regionally to develop faba bean varieties that are resistant/tolerant to water-logging stress, three varieties (Grarjarso 89-8, Selale Kasim 89-4, and L82094-13) were selected and presented for release. Of these, Grarjarso 89-8 and Selale Kasim 89-4 were accepted for release for farmer cultivation by the name Dagm and Lalo in 2002 to Inewari, Molale and Mehil Meda and similar environments (ShARC, 2002). Stability analysis using the model of Eberhart and Russell (1966) showed that these varieties had regression coefficient close to (b=1.02) and minimum deviation from the regression line (S^2)=0.03 (ShARC 2000).

Results on frost resistance/tolerance in faba bean at Sheno showed that the proportion of frost attack varied from variety to variety; the range damage varying from 49.2 to 68.4%, with a mean of 55.7%. Also, none of the local faba bean collections evaluated for frost resistant/tolerance was found resistant (ShARC, 1998). Similarly, all the 22 promising faba bean breeding lines crossed with Ethiopian materials at ICARDA were found susceptible to frost (a score of 9 on a 1-9 rating scale, where 1= resistant and 9= susceptible) (ShARC, 2001). At Tigrai, three varieties from an adaptation trial, namely, Bulga-70, CS20DK and Messay were recommended (MkARC, 1999) as alternate varieties to the local check.

Field pea Evaluation and Selection

Efforts made to develop specifically adapted field pea varieties to northern Ethiopia, particularly for Gojam and Gonder highlands, resulted in the release of two varieties, namely, Adet-1 and Sefinesh. Recommendations were also made from the results of adaptation trials of the nationally released varieties. In North Shoa, the local variety was found to perform better than the nationally released varieties, however, in Tigrai, three varieties, namely, Adi, Milky and G22763-2C were recommended for better grain and biomass yields as compared to the local cultivar.

Chickpea Evaluation and Selection

Chickpea adaptation trials in Wollo resulted in the recommendation of Akaki and Mariye for production around Chefa, Sirinka, Mersa and similar areas. Almost similar results were obtained in Tigrai.

Lentil Evaluation and Selection

From screening of large number of lentil collections and introductions, some promising genotypes with scores of 3 to 4 on 1-9 rating scale were identified. These included ILL-2626, FLIP-85-7, FLIP-86-41L (Adaa) and FLIP-95-55L (Geletu and Wondafrash, 1999).

CONCLUSIONS AND RECOMMENDATIONS

The northern Ethiopian Food Legume Research Program has been able to release two stable and high yielding faba bean varieties (Dagm) and Lalo) for Vertisol areas of North Shoa and similar agro-ecologies for northern Ethiopia and the country. Similarly, Adet Regional Agricultural Research Centre AdARC, through its regional variety trials in the potential field pea growing areas of northwestern Ethiopia (Gojam and Gondar), released two field pea varieties, namely, Adet-1 and Sefinesh in 1997 for production in mid- and high-altitude areas of northwest Ethiopia and other similar agro-ecologies. These varieties had a yield potential of 2.6, and 2.7 t/ha, respectively. Other food legume varieties released and recommended for northern Ethiopia during 1994-2002 are summarized in Table 2.

As a short-term strategy, most research centers in northern Ethiopia after decentralization of their research work focused on evaluation and recommendation of improved varieties from the nationally released varieties from the respective coordinating centers. However, for the medium- and long–term, there is a need to follow specific breeding to target different agro-ecological zones and the prevailing biotic and abiotic stresses. This must be supported with an effective germplasm exchange among federal, regional and higher learning institutions in the country and with international agricultural research centers elsewhere. Frost in cool season food legumes remains a major production constraint in northern Ethiopia, necessitating the need to introduce and evaluate germplasm from areas where the problem seriously recurs annually. There is also a need to artificially induce the stress in cooperation with international research centers in order to establish effective and efficient screening methodology to get useful results. Similarly, there is a need in future to study inheritance of traits and conduct breeding work on quality traits such as color, size, protein content and cooking aspects.

Table 2. Cool season food legumes varieties released, recommended, promising and in pipeline in North Ethiopia (1994-2002).

No.	Variety	Year of release	Yield (t/ha)	Altitude (m asl)/Soil type/ Region	Institute/Center
Faba bean					
1	Dagm (Grarjarso 89-8) RR	2002	3.5	2600-3000 Vertisol	ARARI[1]/ Sheno
2	Lalo (Selale Kasim89-4) RR	2002	3.6	2600-3000 Vertisol	ARARI/Sheno
3	Selale Selale Kasim 91-13) R	2002	2.3	2000-2800 Vertisol	EARO[2]/Holetta
4	Wayu (Wayu 89-5) R	2002	2.9	2000-2800 Vertisol	EARO/Holetta
5	Bulga-70 R	1999	4.1	Tigrai region	TRARI[3]/Mekele
6	CS-20DK R	1999	4.1	Tigrai region	TRARI/Mekele
7	Messay R	1999	4.0	Tigrai region	TRARI/Mekele
5	EH-91026-8-2	PL	2.8	Nitosol	ARARI/Adet
6	PGRC/E 25041-2-2	PL	2.8	Nitosol	ARARI/Adet
Field pea					
1	Moh x305 Ps210928-2 (Sefinesh) RR	1997	2.5	Mid-high altitude	ARARI/Adet
2	G22763-2C x 305 PS210736-2 (Adet1) RR	1997	2.6	Mid-high altitude	ARARI/Adet
3	Field pea landraces R	1999	1.6	High-altitudes	ARARI/Sheno
Chickpea					
1	Shasho /ICCV-93512 (kabuli) R	1999		2600,Vertisol- Inewari	EARO/Debre zeit
2	Ararti/FLIP89-84C(kabuli) R	1999		2600, Vertisol- Inewari	EARO/Debre zeit
3	Akaki/DZ-10-9-2(Desi)R	1995			EARO/Debre zeit
4	Worku/DZ-10-16.2(Desi) R	1994		1900-2600	EARO/Debre zeit
5	Mariye R	1985			
6	ICC14400	PL	2.9	Mid-altitude	ARARI/Adet
7	ICCV-91014	PRL	3.6	Mid-high altitude Vertisol, Inewari and Adet	ARARI/Sheno
8	ICCV-92010	PRL	3.4	Mid-high altitude Vertisol, Inewari and Adet	ARARI/Sheno
9	ICCV-92006	PRL	3.5	Mid-high altitude Vertisol, Inewari and Adet	ARARI/Sheno
Lentil					
1	Alemaya (FLIP89-63L) R	1997/98		1600-2000, Vertisol, Inewari	EARO/Debre zeit
2	Gudo (FLIP84-78L) R	1995		1600-2000, Vertisol, Inewari	EARO/Debre zeit
3	aAdda (FLIP86-14L) R	1995		1850-2450. Vertisol, Inewari	EARO/Debre zeit

RR= Regionally released (4); R= Recommended (14); PL= Pipe line (3); PRL= Promising line (3), Amara [1]ARARI= Amhara Regional *Agricultural Research* Institute; [2]EARO= Ethiopian Agricultural Research Organization, [3]TRAI= Tigral Agricultural Research Institute. Source: dARC, MkARC, ShARC and SrARC (1994-2002).

REFERENCES

AdARC. 1994-2002. Research progress report, Adet Agricultural Research Center (AdARC), Adet, Ethiopia.

CSA. 1995-2000. Agricultural sample survey statistical bulletins. Central Statistics Authority (CSA), Addis Ababa, Ethiopia.

Eberhart, S.A., and W.A. Russell. 1966. Stability parameters for comparing varieties. *Crop Science* 6: 36-40.

Geletu Bejiga, and Wondafrash Mulugeta. 1999. Evaluation of lentil genotypes for resistance to frost in Ethiopia. NVRSRP Newsletter No. 2: 19-21.

MkARC. 1994-2002.Research progress report, Mekele Agricultural Research Center (MkARC), Mekele, Ethiopia.

ShARC. 1994-2003. Research progress report, Sheno Agricultural Research Center (ShARC), Sheno, Ethiopia.

SrARC. 1994-2002. Research progress report, Sirinka Agricultural Research Center (SrARC), Sirinka, Ethiopia.

Taye G., T. Getachew, and G. Bejiga. 2000. AMMI adjustment for yield estimate and classification of genotypes and environment in field pea (*Pisum sativum* L.). *J. Genet. & Breeding* 54: 189-191.

Wondafrash Mulugeta. 2002. Variation and association among seed yield and related traits in faba bean (*Vicia faba* L.) landraces of Ethiopia under Vertisol conditions. M. Sc. Thesis. Alemaya University, Ethiopia.

Section III. Soil Fertility and Crop Management

Cropping Systems, Soil Fertility and Crop Management Research on Cool-season Food Legumes in the Central Highlands of Ethiopia: A Review

Getachew Agegnehu[1], Asnake Fikre[2] and Ayalew Tadesse[3]

[1]*Holetta Agricultural Research Center, Addis Ababa, Ethiopia,* [2] *Debre Zeit Agricultural Research Center, Addis Ababa, Ethiopia,* [3]*Sheno Agricultural Research Center, Sheno, Ethiopia*

ABSTRACT

In the central highlands of Ethiopia, inappropriate agronomic practices, poor internal drainage, soil acidity and associated low phosphate availability are major constraints affecting the productivity of the cool-season food legumes (CSFLs). Production practices differ across the major CSFL growing areas. Availability of soil moisture, genotype and location are main factors determining optimum planting date. Planting early- to mid-August on black soils (Vertisols) at the seed rate of 110-120 kg/ha progressively increased grain yields of large-seeded chickpea genotypes. Similarly, sowing from first week of July to mid-July resulted in a significant yield increment in early-maturing lentil varieties. The yield and β-N-oxalyl-L-α, β-diaminopropionic acid (β-ODAP) content of grass pea was significantly affected by planting date and application of zinc sulfate. Planting grass pea in early-August resulted in a considerable reduction in ODAP concentration, whereas the yield decreased as the planting date was delayed. Twice plowing before planting and one properly timed hand-weeding resulted in optimum yield of faba bean, while chickpea and lentil responded only to weed control but not to plowing frequency. Substantial increments in seed and biomass outputs of CSFLs were recorded on Vertisols due to improved surface drainage compared to the planting on flatbeds. The application of lime as calcium carbonate at the rate of 1, 3 and 5 t/ha on Nitisols increased mean grain yield of faba bean by about 45, 77 and 81%, respectively, over the non-treated plots. Similarly, 23/20-32/30 kg N/P/ ha on Nitisols resulted in the highest net benefit for faba bean and field pea, whereas chickpea and lentil didn't respond to fertilizer application. The application of mulch and potash to reduce the effect of frost on faba bean didn't result in a significant effect on grain yield. Faba bean and field pea as precursor crops significantly increased grain yield of barley compared to continuous barley. Mixed cropping of faba bean with wheat and barley resulted in higher land equivalent ratio (LER) of 15 and 19%, respectively. In conclusion, a concerted effort will have to be made to extend the available technologies in order to improve the productivity of CSFLs.

INTRODUCTION

Faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), lentil (*Lens culinaris* Medik.) and grass pea (*Lathyrus sativus* L.) are important cool-season food legumes (CSFLs) of low-input 'break' crops in the highlands of Ethiopia. These crops are very useful in a crop rotation system that is dominated by cereals. They cover 86% of the pulses area and provide 88% of the total production in the country (Hailu *et al.*, 1994). In Ethiopia, CSFLs are cultivated predominantly by the traditional farming community, and their yields are very low (Asfaw et al., 1994). Although Ethiopia is the major producer of these crops, their productivity is affected by several biotic and abiotic factors. Specific zones of production are mainly functions of elevation, humidity and temperature. However, in terms of agro-ecological zones, the major production area is between 9 and 16^0 longitude (Asfaw et al., 1994).

Soil and seedbed requirements, erosion, acidity and low phosphate availability, lack of drainage, inadequate soil moisture, seed rate, sowing date, method and depth of sowing, fertilizer and weed control practices are major factors affecting the productivity of CSFLs (Hebblethwaite et al., 1983; Asfaw et al., 1994). Although chickpea, lentils and grass pea are mainly produced on Vertisols, they are constrained by impeded drainage in Vertisols, which receives high rainfall during the main rainy season (Jutzi, 1988; Jutzi and Mesfin, 1989). As a result, fields remain waterlogged during the main rainy season, and crops such as chickpea are mainly sown after the main rainy season on the residual moisture. The traditional management of Vertisols in the highlands varies from one place to another, depending on the amount and duration of rainfall, slope, extent of drainage problems, soil fertility and farm size. Experimental findings showed that improved drainage practice markedly increased productivity of crops grown on Vertisols (Mesfin & Jutzi, 1989; EARO, 1998; Getachew, 2001). Date of sowing has a profound influence on the crop performance since it determines the kind of environmental conditions to which the various phenological stages of the crop are exposed (Saxena, 1987). It also affects the ODAP concentration in grass pea seeds.

Inadequate seedbed preparation and weed control practices are the most important causes of low yields of faba bean (Alem et al., 1990; Rezene, 1992, 1994; Asfaw et al., 1994). In most cases, seeds of CSFLs are broadcast and covered by the local plow. Amare and Adamu (1994) reported that two to three plowings with the local plow or one disc plowing followed by two disc harrowing significantly increased grain yields of faba bean. Rezene (1992) also reported that using the improved Nazareth moldboard plow gave higher yields and reduced weed populations compared to the local plow. Though CSFLs are sensitive to weed competition from seedling establishment to early-flowering stage they are usually cultivated under no-weeding or late-weeded conditions. The estimated yield loss due to weeds in faba bean is about 24% (Rezene, 1994). The critical period of weed competition in CSFLs varies from 3 to 8 weeks after emergence.

In the tropics, multiple cropping is a common practice to minimize risks associated with mono-cropping. Multiple cropping provides a balanced diet, higher returns and protects soil against erosion, reduces labor peaks, and minimizes crop failure risks such as the adverse effects of disease, insect-pests and weeds (Beets, 1982; Gomez and Gomez, 1983). Traditionally, the most important intercropping systems in Ethiopia include cereal–cereal association, cereal–legume association, and trees + annual crops association (Kidane et al., 1990).

FABA BEAN

Cropping Systems

Cropping sequence: A study conducted in northern Shoa to identify the best combination of precursor crops for barley production indicated that field pea and faba bean had a significant (P<0.01) effect on straw and grain yields of barley (ShARC, 2001). Faba bean and field pea as precursor crops increased grain yield of barley by 20-117% and 34-102%, respectively, compared to continuous barley. Likewise, the yield of wheat after faba bean was higher by about 69% compared to the yield of wheat after wheat (Hailu et al., 1989). Results of rotation trials elsewhere also indicated higher yields of cereals following food legumes as compared to cereals after cereals, or even after a fallow (Buddenhagen, 1990). It is assumed that N is largely responsible for the yield jump compared with cereal after cereal since the legume crop uses less soil N. Barley after legume without any nitrogen fertilization yielded as much as continuously cropped barley supplied with 60 kg N/ha (Papastylianou, 1990).

Mixed cropping: An experiment was conducted for two seasons (2001-2002) to assess the possible advantages of mixed cropping of cereals with faba bean (HARC, 2003). The analysis of variance for faba bean showed that there were highly significant (P<0.01) differences between treatments. The mean grain yields of faba bean over three years decreased with decreased proportion of faba bean in the mixture (Table 1). Although the yield reduction was not as high as faba bean, barley and wheat grain yields were also affected with increased proportion of faba bean in the mixture. The decreases in barley grain yield due to the increase proportion of faba bean were 7 and 26% for 12.5% and 62.5% faba bean mixture, respectively, compared with the grain yields obtained from pure barley. Contrarily, the mixing of barley with different proportion of faba bean (12.5, 25, 37.5, 50 and 62.5%) resulted in decrease in grain yields of faba bean by 90, 79, 66, 63 and 56%, respectively, compared with seed yield of pure faba bean (Table 1).

Intercropping of species, which differ in the time of their maximum demands on the environmental resources, extends the duration of resource exploitation (Willey, 1979). Growing faba bean and barley in association resulted in higher production compared with monoculture of each crop. The highest mean grain yield of 3018 kg/ha was obtained in a mixed proportion of barley and faba bean (100:37.5), respectively, compared with the pure crop of each species (2480 for barley and 2692 kg/ha for faba bean). A study by Ageeb et al. (1989) showed that intercropping of faba bean with maize and sorghum resulted in different effect on different sowing dates. It succeeded in reducing the incidence of root rot/wilt diseases with early planting. Similarly, Niguse and Reddy (1995) reported higher land equivalent ratio (LER) of 46 and 31% and net-returns of 3869 and 3405 Birr/ha from beans planted simultaneously with maize in two-row maize and one-row bean patterns at Melkassa and Awassa, respectively. Mixed cropping of faba bean and field pea at Holetta also showed that the total LERs for all mixtures was greater than in the pure crop situation (Amare, 1995).

The LER values calculated for individual component crop indicated that mixed cropping affected faba bean more than it did barley and wheat, since the normal seed rate of both crops was used (Table 1). The LERs in barley ranged from 0.93 to 0.74. In contrast, LERs for faba bean were from 0.10 (12.5%) to 0.44 (62.5%). The total LERs for mixed cropping ranged from 1.03 (12.5%) to 1.19 (37.5%).

Table 1. Effects of mixed cropping on component grain yields of barley and faba bean, and land use efficiency, 2001-2002.

Treatment (T)	Grain yield (kg/ha) Barley	Grain yield (kg/ha) Faba bean	Land Equivalent Ratio (LER) Barley	Land Equivalent Ratio (LER) Faba bean	Total
Pure barley	2480a°	-	1.00a	-	1.00c
Pure faba bean	-	2692a	-	1.00a	1.00c
Barley (100%) + F. bean (12.5%)	2309ab	274e	0.93ab	0.10e	1.03bc
Barley (100%) + F. bean (25%)	2100bc	564d	0.85b	0.21d	1.06bc
Barley (100%) + F. bean (37.5%)	2115b	903c	0.85b	0.34c	1.19a
Barley (100%) + F. bean (50%)	1863dc	989bc	0.75c	0.37bc	1.12ab
Barley (100%) + F. bean (62.5)	1833d	1184b	0.74c	0.44b	1.18a
LSD (%)	237.78	240.03	0.096	0.09	0.11

°Means followed by the same letters are not statistically different at 5% level. Source: HARC (2003).

The grain yields of faba bean decreased with decreased proportion of faba bean in the faba bean wheat mixture (Table 2). Wheat grain yields were also affected with increased proportion of faba bean in the mixture. The decreases in wheat grain yield due to the increased proportion of faba bean, i.e. for the lowest 12.5% and highest 62.5%, were 6 and 20%, respectively, compared with the grain yields obtained from pure wheat. Contrarily, the mixing of wheat with different proportions of faba bean (12.5, 25, 37.5, 50 and 62.5%) resulted in a decrease in grain yields of faba bean by 92, 81, 70, 68 and 63%, respectively, compared with grain yield of pure faba bean.

The range of LER for wheat was from 0.94 to 0.80 (Table 2) in contrast with the LER for faba bean, which ranged from 0.08 (12.5%) to 0.36 (62.5%). The total LER for mixed cropping ranged from 1.02 (12.5%) to 1.21 (37.5%). Wheat mixed cropped with faba bean resulted in higher production per unit area than monoculture of each crop. Likewise, Jensen (1986) reported that yield increments were obtained from the intercropping of faba bean with spring wheat, and pea with barley. Such intercrops exploited the environmental resources more efficiently than the pure crop stands. Intercropping legumes with cereals may be advantageous compared to cultivating in pure stands, because the components can utilize different sources of N (Willey, 1979). The cereal may be more competitive than legumes for soil mineral N, but the legumes can fix N symbiotically, if effective strains of Rhizobium are present in the soil.

Seed Rate

The Ethiopian farmers, in general, use lower seed rates than research recommendations which result in lower grain yields. Results of seed rate trial on faba bean (cv. CS-20-DK) for two cropping seasons at Sheno Agricultural Research Center (ShARC) indicated that the seed rates of 250 and 320 kg/ha resulted in yield advantages of 26 and 77%, respectively, compared with the seed rate of 180 kg/ha (ShARC 2002). The maximum biomass and straw yields of faba bean were also obtained from the highest seed rate of 320 kg/ha˙. Similarly, on-farm verification of seed rate and hand-weeding operations between Sheno and Angolela areas showed that broadcasting the same faba bean cultivar at a rate of 370 kg/ha gave higher grain and biomass yields.

Tillage and Weed Control

An experiment conducted on farmers' fields to determine the effect of tillage frequency and weed control on faba bean showed that aboveground biomass and grain yields of faba bean were significantly ($P<0.05$) affected by tillage frequency in all seasons (HARC 2002). Similarly, the mean grain yields of three years were significantly ($P<0.05$) affected by the frequency of tillage and weed control. The analysis of variance indicated that there was interaction between tillage and weeds control factors (T×W) for total biomass and grain yields in two out of three seasons. The highest mean grain yield was recorded from two and three plowings before planting accompanied by one properly timed hand-weeding. There was no significant difference in yields between two and three plowings before planting. The highest grain yield was recorded in 2001, and the yield advantage obtained due to tillage frequency was 71 and 89% from two and three plowings before planting, respectively (Table 3). Similarly, plowing once, twice and thrice before planting increased mean grain yield of faba bean by 26, 52 and 54%, respectively, compared with no plowing before planting. Experimental findings at Holetta also showed that repeated plowings before planting significantly increased grain yields of faba bean (IAR, 1991). The grain yield of faba bean also significantly ($P<0.05$) responded to weed control; one properly timed hand-weeding increased the mean grain yield by 19% compared to the unweeded check.

A similar experiment was carried out around Debre Zeit. Although both tillage and weed control practices had a positive influence on faba bean yield their effect was not statistically significant. Plowing once, twice and thrice increased mean grain yields of faba bean over three seasons by 8, 7 and 10%, respectively, compared with the control. Likewise, weeding once resulted in a yield advantage of 12% compared to the unweeded check. The soil type, distribution and abundance of weed flora and seedbed preparation for the preceding crop might have contributed for non-significant differences in the treatments. In conclusion, the optimum mean grain yields of faba bean over three seasons were obtained from twice plowing before planting coupled with one properly timed hand-weeding in Wolmera, and plowing once before planting with one hand-weeding in the Debre Zeit area.

Table 2. Effects of mixed cropping on grain yields of wheat and faba bean and land use efficiency, 2001-2002.

Crop mixture	Grain yield (kg/ha)		Land Equivalent Ratio (LER)		
	Wheat	Faba bean	Wheat	Faba bean	Total
Pure wheat	3813a	-	1.00a	-	1.00b
Pure faba bean	-	1832a	-	1.00a	1.00b
Wheat (100%) + F. bean (12.5%)	3601ab	139d	0.94b	0.08e	1.02b
Wheat (100%) + F. bean (25%)	3394bc	352c	0.89bc	0.19d	1.08b
Wheat (100%) + F. bean (37.5%)	3482b	542b	0.91b	0.30c	1.21a
Wheat (100%) + F. bean (50%)	3198cd	574b	0.84cd	0.31bc	1.15a
Wheat (100%) + F. bean (62.5)	3039d	667b	0.80d	0.36b	1.16a
LSD (5%)	301.2	141.3	0.06	0.07	0.10

°Means followed by the same letters are not statistically different at 5% level. Source: HARC (2003).

Table 3. Tillage and weed control effects on biomass and grain yields of faba bean in Wolmera area.

Factor	Total biomass (kg/ha)			Adjusted grain yield (kg/ha)			Mean
	1999	2000	2001	1999	2000	2001	
Tillage (T)							
No plowing before planting	3070c	2772c	2546c	1549b	1298c	1289c	1378c
Once plowing before planting	4157b	3169bc	3495bc	1956a	1502bc	1764bc	1741b
Twice plowing before planting	4573ab	4555a	5014ab	2006a	2060a	2211ab	2092a
Thrice plowing before planting	4893a	4056ab	5265a	2130a	1791ab	2443a	2122a
LSD (5%)	501.36	893.40	1611.4	315.29	431.80	587.81	273.03
Weed control (W)							
No weeding	4185a	3053b	4081a	1884a	1358b	1782a	1675b
Hand-weeding	4162a	4222a	4079a	1936a	1967a	2071a	1991a
LSD (5%)	NS	631.73	NS	NS	305.33	NS	193.06
T×W	**	*	NS	*	*	NS	NS
CV (%)	9.81	20.06	32.27	13.48	21.2	24.9	22.34

* Significant at P=0.05, ** P=0.01, NS = Not significant, °Means followed by the same letters are not statistically different at 5% level. Source: HARC (2002).

Management of Vertisols through Seedbed Preparation

High moisture level limits faba bean production on Vertisols as the crop is highly sensitive to waterlogged conditions. The problem of black root rot (*Fusarium solani*) is widely prevalent in the Vertisols where it is mainly associated with waterlogging (Beniwal and Dereje, 1987). An experiment conducted for four years to investigate the effects of different drainage methods on the yield and some yield components of faba bean showed that the mean grain yields of four years were significantly ($P<0.05$) affected by drainage conditions (Getachew, 2001). The highest grain yield was recorded from broad-bed and furrow (BBF) drainage system followed by ridge and furrow system. Likewise, BBF prepared with broad-bed maker (BBM), an animal drawn implement, resulted in higher grain and straw yields of faba bean from Vertisols of Debre Zeit and Wereilu (ILRI, 1990). Planting on BBF avoids waterlogging due to a greater uniformity of drainage structure established, compared to faba bean grown on traditionally hand-made BBFs (Jutzi, 1988; Getachew et al., 1988).

The grain yields recorded from camber-bed (CB), BBF, Ridge and furrow (RF) and CB drainage systems in the respective years (1997-2000) were higher by 41, 98, 17 and 24% compared to flatbed planting (Getachew, 2001). The highest grain yield was recorded from RF in 1999 crop season. This was because of the late start of the 1999 main rainfall season its distribution and amount was low, and the moisture retained in the soil under BBF and CB conditions was easily drained as compared to RF and flatbeds. A highly significant difference in grain yield due to drainage methods was recorded in 1998 crop season. Grain yields obtained from BBF, RF and CB were higher by 98, 60 and 42%, respectively, over flatbed. Results of similar work carried out at Sheno (Mesfin, 1979) and Holetta (Desta & Hailu, 1989) resulted in substantial increments of faba bean grain yields under drained conditions compared to flatbeds. At Holetta, CB increased grain yields of faba bean over flatbeds by 49 and 50% under no fertilizer and fertilizer conditions, respectively (Desta and Hailu, 1989). In general, both total above-ground biomass and grain yields recorded in the 1999 harvest were higher than the results of the other comparable crop seasons under all drainage conditions, which indicated that the effects of different drainage methods on most of agronomic characters were significant only under waterlogged conditions. The results of similar experiments in chickpea and lentil indicated a substantial increase in grain and biomass yields as a result of improved surface drainage compared to flatbed planting (ILRI, 1990; EARO, 1998; Getachew, 2001).

Similar experimental findings showed that highland pulses performed best on well-drained black clay soils. This was confirmed from research results at Sheno and Angolela area of northern Shoa in which faba bean sown on BBF gave 31 and 71% mean grain yield advantages in 1997 and 1998 crop season, respectively, over flatbed with 3 m wide open drainage furrows (ShARC, 1999).

Soil Fertility and Plant Nutrition

Phosphate fertilizer and lime: The effects of two rates of fertilizer (0 and 23/20 kg N/P/ha) as diammonium phosphate (DAP) and four rates of lime in the form of calcium carbonate (0,1, 3 and 5 t/ha) were studied on Nitisols of Holetta. The combined analysis of variance over three years indicated that mean grain yield of faba bean was highly significantly ($P<0.001$), affected by fertilizer and lime application (Table 4). However, there was no interaction between fertilizer and lime application for seed yield. The application of 23/20 kg N/P/ha increased mean seed yield of faba bean by 29% over the control. Similarly, the application of lime at the rate of 1, 3 and 5 t/ha resulted significantly in linear response with mean seed yield advantages of 45, 77 and 81% over the control (Table 4). Mahler et al. (1988) also found that seed yields of legumes were optimal between soil pH values of 5.7 and 7.2, and grain yields of field pea could be increased by 30% due to the application of lime to soils with pH values less than 5.4.

Table 4. Effect of phosphate fertilizer and lime application on the grain yield of faba bean at Holetta, 1998-2000.

Factor	Seed yield (kg/ha) 1998	1999	2000	Mean
N/P kg/ha (F)				
0	978b	713b	1489b	1073b
18/20	1464a	1188a	1527a	1380a
F test	***	***	NS	***
LSD (5%)	132.3	115.4	314.1	135.6
Lime (L) (t/ha)				
0	918b	615c	904c	813c
1	1238a	944b	1364b	1182b
3	1364a	1076ab	1879a	1439a
5	1364a	1167a	1886a	1472a
F-test				
Rate	***	***	***	***
Linear	***	***	***	***
Quadratic	**	*	*	**
LSD (5%)	187.0	163.2	444.3	191.7
F×L	NS	NS	NS	NS
CV (%)	14.7	16.5	28.3	27.2

*, **, ***= Significant at 0.05, 0.01 and 0.001 probability level, respectively, NS = Not significant, °Means in a column with different letters are significantly different (P < 0.05). Source: HARC (2001).

Phosphate fertilizer: The effect of phosphorus fertilizer on grain yield and some yield components of faba bean were studied at different locations. The results of the study indicated that the application of phosphate fertilizer significantly (P<0.01) increased grain yields of faba bean over the control, and the magnitude of response varied with the fertilizer rates (Table 5). The application of 9/10, 18/20 & 27/30 kg N/P/ha resulted in significant linear response with mean grain yield advantage of 24, 66 and 80% over the control (Table 5). Similarly, Amare et al. (1999) showed that P fertilizer application increased faba bean grain yield significantly (P<0.01) in linear response at all locations. However, the effect of N was not significant. Faba bean grain yield response to N was noted in Holetta Nitisols (Angaw and Asnakew, 1994). The study of maximum uptake for a crop yielding 5-6 t/ha is 70-80 kg P_2O_5 and 250-300 kg K_2O/ha (IFA, 1992). It was found that response of faba bean to phosphate application was dependent on the residual P fertility level of the soil (Hebblethwaite et al., 1983; Getachew et al., 2001). Number of pods per plant and total biological yield of faba bean also responded to the application of P fertilizer. The study of Cadish (1990) indicated that the supply of P increased dry matter production of tropical forage legumes by 193% and N concentration in shoot tissue by 10% and percentage of N derived from the atmosphere by 15% in an Oxisol in Colombia. This increment resulted in 259% more N being fixed at 75 kg P/ha than at 5 kg P/ha.

FIELD PEA

Seeding Depth

The effect of seeding depth and sowing date on field pea varieties was studied for three years (1997-1999) on Holetta Nitisols to determine the optimum seeding depth and its interaction with variety and sowing date. Five seeding depths (0, 5, 10, 15 and 20cm) and three field pea varieties, namely, Tegegnech, G22763-2C and local land-race, were studied under two sowing dates. Analysis of variance showed that there was no interaction for grain yield among factors studied (sowing date, variety and depth). Seedlings from different depths appeared at different times on the soil surface. Seeds placed on the surface were easily eaten by wild animals.

The combined analysis of variance over three years indicated that mean seed yield of field pea was significantly (P<0.01) affected by variety and seeding depth (Table 6). Seeds placed on the surface resulted in lower yield as compared to the other comparable seeding depths. The highest seed yield was obtained from the placement of seeds at a depth of 10 cm. Similar results were obtained by Hebblethwaite et al. (1983). However, on very heavy soils seed yields of faba bean sown at a depth of 5-7 cm were higher by 24% compared with plants sown at a depth of 10-11 cm. With regard to varieties, the highest seed yield was obtained from G 22763-2C compared with the other two.

Table 5. Effect of phosphate fertilizer on number of pods per plant, total biomass and grain yield of Faba bean in Wolmera, 1999-2001.

	Number of pods per plant			Total biomass (kg/ha)		Seed yield (kg/ha)			
Factor	1999	2000	2001	2000	2001	1999	2000	2001	Mean
N/P (kg/ha)									
0/0	5.9c°	6.2	6.9b	2965b	2917b	1065c	783c	1000c	949c
9/10	7.7b	7.1	7.2b	3216ab	3250b	1505b	931b	1108c	1181b
18/20	9.8a	8.0	10.2a	3323ab	4302a	1700a	1178a	1856b	1578a
27/30	-	7.2	11.9a	3840a	3986a	-	1212a	2209a	1711a
F-test									
Rate	**	NS	**	*	**	**	**	**	**
Linear		NS	**	*	**		**	**	**
Quadratic		NS	NS	NS	NS		NS	*	NS
Cubic		NS	NS	NS	*		NS	**	NS
LSD (5%)	0.9	NS	1.9	815.4	618.0	71.2	141.2	130.30	186.9
SE	0.3	1.0	0.6	254.9	200.6	15.9	44.1	42.3	64.4
CV (%)	11.5	24.2	19.5	18.7	15.7	3.5	10.5	7.8	16.0

°Means in a column with different letters are significantly different (P < 0.05).
*, ** = Significant at 0.05 and 0.01 probability level, respectively; NS = Not significant.
Source: Getachew et al. (2001).

Table 6. Effect of seeding depth on early- and late-planted field pea varieties at Holetta 1997-1999.

Factor	Seed yield (kg/ha)			
	1997	1998	1999	Mean
Sowing date (S)				
Early	1024	1553	1341	1306
Late	1357	1237	2202	1599
F test	NS	NS	*	*
SE	118.3	63.7	151.4	67.5
Depth (D) in cm				
0	734c°	815b	1170b	906b
5	1239b	1588a	1890a	1572a
10	1247b	1551a	2037a	1612a
15	1292ab	1552a	1918a	1587a
20	1440a	1467a	1842a	1583a
LSD (5%)	152.1	261.4	287.7	155
S×D	*	NS	**	NS
Variety (V)				
Tegegnech	1240	1501a	1753	1498a
G 22763-2C	1167	1595a	1793	1518a
Local	1166	1088b	1768	1341b
LSD (5%)	NS	202.5	NS	120
CV %	19.1	28.1	27.6	26.5

°Means in a column with different letters are significantly different ($P < 0.05$), *, ** = Significant at 0.05 and 0.01 probability level, respectively; NS=Not significant.
Source: HARC (2000).

Soil Fertility and Plant Nutrition

Phosphate fertilizer: The effect of phosphate fertilizer on grain yield and some yield components of field pea were studied on farmers' fields in Wolmera area. Mean grain yields of field pea significantly ($P<0.01$) responded to P fertilization. The application of 9/10, 18/20 and 27/30 kg N/P/ha in the form of diammonium phosphate (DAP) resulted in significant linear response with mean grain yield advantages of 55, 103 & 152%, respectively over the control (Table 7). Total biological yield of field pea was also positively influenced by the application of phosphate fertilizer. The highest mean grain yield (2064 kg/ha) of field pea was recorded from the application of 27/30 kg N/P/ha. Angaw and Asnakew (1994) also reported similar results and found that response of both the local and improved cultivars of field pea was very high to fertilizers at many locations. Likewise, the application of 10, 20 and 40 kg P/ha increased field pea grain yield by 21, 48 and 58%, respectively, compared with the nofertilizer-applied plots (IAR, 1996), which is in agreement with the findings in Wolmera area.

A partial budget analysis was conducted for faba bean and field pea by taking mean grain yields of three years. Under lower price (ETB 1.25/kg) assumptions, treatment 18/20 kg N/P/ha resulted in the highest net benefit while treatment 27/30 kg N/P/ ha gave the highest net benefit under improved price for faba bean. For field pea, under both price (ETB 1.48 and 2.22/kg) assumptions, the treatment 27/30 kg N/P/ha gave the highest marginal rate of return (MRR) of 188 and 332% suggesting that it was the most profitable rate. With improved price (ETB 1.99/kg) the three treatments (9/10, 18/20 and 27/30 kg N/P/ha) became profitable for faba bean. Field pea is grown on *dimile* soils, considered as very poor soils, whereas faba bean is grown on *dila* soils, considered reasonably fertile. Hence, the economic analysis suggests that the marginal benefits would be higher if fertilizer was used at the rate of 27/30 kg N/P/ha on *dimile* soils for field pea, and at the rate of 18/20 kg N/P/ha on *dila* soils for faba bean production.

CHICKPEA

Planting Dates and Seed Rates

The responses of chickpea to sowing date and seed rates vary with the type of varieties and the prevailing weather conditions of the specific growing environments. Research results on planting date and seeding rate, using large-seeded type (cv. Worku), on Vertisols at Debre Zeit, Akaki and Chefe Donsa showed that there were consistent and significant ($P<0.05$) yield differences among planting dates. The earliest planting date (first week of August) gave the highest mean grain yield of chickpea at all locations (Table 8). Similarly, chickpea planted in early- to mid-August resulted in the highest yield (Million, 1994). Fifty percent yield reduction was recorded due to the delayed sowing date. The increase in seed rate from 90 to 120 kg/ha progressively increased grain yields of chickpea (DZARC, 1996). The optimum seed rates for large-seeded chickpea varieties such as Worku were found to be 110-120 kg/ha.

Table 7. Effect of phosphate fertilizer on number of pods per plant, total biomass and grain yield of field pea in Wolmera, 1999-2000.

Factor	Number of pods per plant			Total biomass (kg/ha)		Grain yield (kg/ha)			
	1999	2000	2001	2000	2001	1999	2000	2001	Mean
N/P (kg/ha)									
0/0	3.6c°	5.4	7.4	5000b	2155c	448c	1014c	999d	820d
9/10	4.9b	5.5	7.5	5080b	3215b	565b	1738b	1506c	1270c
18/20	6.5a	6.1	8.6	7235a	4025a	712a	2465a	1807b	1661b
27/30	-	5.9	9.0	5825ab	4095a	-	1980ab	2147a	2064a
F-test									
Rate	**	NS	NS	*	*	**	**	**	**
Linear		NS	NS	NS	**		**	**	**
Quadratic		NS	NS	NS	NS		**	NS	NS
Cubic		NS	NS	*	NS		NS	NS	NS
LSD (5%)	0.6	NS	NS	1700.0	938.3	34.6	565.4	235.6	201.1
SE	0.2	0.7	0.6	491.4	208.5	10.6	163.4	52.3	67.7
CV (%)	10.5	23.5	10.0	17.0	8.7	5.2	18.2	4.6	14.8

°Means in a column with different letters are significantly different ($P < 0.05$), *, ** = Significant at 0.05 and 0.01 probability level, respectively; NS = Not significant. Source: Getachew et al. (2001).

Table 8. Effect of planting dates and seed rates on mean grain yield of large-seeded chickpea variety (Worku), 1995/96.

	Seed rate (kg/ha)				
Planting date	90	100	110	120	Mean grain yield (kg/ha)
Debre Zeit					
2/8/95	1800	2100	2300	2300	2100a°
17/8/95	900	1200	1400	1400	1200b
2/9/95	800	700	1100	900	800b
Mean	1100b°	1300ab	1600a	1500a	
Akaki					
3/8/95	3100	2500	2900	3300	3000a
18/8/95	2300	2800	3400	3300	2900ab
2/9/95	2600	2700	2800	3100	2800b
Mean	2700b	2700b	3000a	3200a	
Chefe Donsa					
4/8/95	1100	900	1300	1400	1200a
19/8/95	800	1200	1000	1200	1100a
3/9/95	500	600	900	800	700b
Mean	800b	900b	1000a	1100a	

°Means in a column/row with different letters are significantly different (P < 0.05). Source: DZARC (1996).

The bulk of chickpea production in Ethiopia comes from farmers' fields where the crop is sown by broadcast. The results of a study on the same seed rates and locations using two varieties (DZ-10-11 and Mariye) indicated that there were significant (P<0.05) grain yield differences among seed rates at Akaki. The highest mean grain yield of 2400 kg/ha was obtained from a seed rate of 110 kg/ha at Akaki, while at Debre Zeit and Chefe Donsa the highest grain yields was obtained from the seed rate of 120 kg/ha (DZARC, 1996). This revealed that the use of higher seed rates increased the yield obtained from broadcast sown chickpea.

Tillage and Weed Control

The frequency of tillage and weeding operations are the major factors affecting the production and productivity of CSFLs in the highlands of Ethiopia. A study on the frequency of tillage and weed control for two cropping seasons (1999-2000) at Akaki and Debre Zeit indicated that there were statistically significant (P<0.01) differences between weeding operations but not among frequency of tillage (Table 9). Weeding once increased grain yield of chickpea by 30 and 75% at Akaki and Debre Zeit, respectively, compared to the non-weeded check. The analysis of variance indicated that there was no interaction between the two effects.

LENTIL

Sowing Date

The response of lentil to planting date varies from genotype to genotype and from location to location depending upon the prevailing meteorological conditions. This is more serious in low rainfall areas where it fluctuates from season to season. An experiment was conducted in low rainfall (< 500 mm) areas of Koka and Adulala from 1996-98. The results of the study showed that the total biological and grain yields of the early-maturing lentil variety (Chekol) were significantly (0<0.05) influenced by planting date (Table 10). Planting lentil on 18 July resulted in the highest mean grain yield followed by the first planting date (8 July). Similarly, results at Mehal-Meda showed that the sowing date and seedbed preparation method significantly affected lentil grain yield and other agronomic characters. Planting lentil in early-July on BBF resulted in yield advantage of 158% compared to early-August planting on BBF (ShARC, 2002).

Table 9. Effect of tillage and weed control practices on mean seed and total biological yields of chickpea, 1999-2000.

	Akaki		Debre Zeit	
Factors	Grain yield (kg/ha)	Biomass (kg/ha)	Grain yield (kg/ha)	Biomass (kg/ha)
Tillage (T)				
T1	2691	6230	1898	4106
T2	2743	6254	1975	4294
T3	2653	6165	2024	4014
T4	2545	5979	1836	4094
T5	2548	6017	1660	4156
LSD (%)	NS	NS	NS	NS
Weeding (W)				
W1	2288	5537	1365	3438
W2	2984	6721	2391	4828
F-test	**	**	**	**
T×W	NS	NS	NS	NS
CV (%)	24.9	18.9	21.5	15.3

*, ** = Significant at 0.05 and 0.01 probability level, respectively; NS = Not significant. Source: DZARC (2001).

Table 10. Mean grain and biological yields of lentil variety (Chekol) as influenced by planting date in moisture-stress environments, 1996-1998.

Factor	Grain yield (kg/ha)	Biomass (kg/ha)	Plant height (cm)
Location			
Koka	587	2652	36.3
Adulala	893	2251	27.8
F-test	*	*	*
Sowing date			
8 July	899a°	2896a	33.3ab
18 July	971a	3234a	34.4a
28 July	725b	2445b	32.1b
7 August	364c	1231c	28.5c
SE	86.2	261	1.74
CV(%)	23.3	21.3	10.9

°Means in a column with different letters are significantly different (P < 0.05), *Significant at 0.05 probability level.
Source: Million and Geletu (1998).

Tillage and Weed Control

The response of lentil to frequency of tillage and weed control practices was studied for three years (1998-2000) at Akaki, Debre Zeit and Chefe Donsa. Results showed that the mean grain and total biological yields of lentil were significantly affected by weeding operations but not by frequency of tillage at Akaki and Debre Zeit (Table 11), which was similar to the results obtained in chickpea. Weeding one time, increased mean grain yields of lentil by 14.8, 44.1 and 3.4% at Akaki, Debre Zeit and Chefe Donsa, respectively. Analysis of variance indicated that there was no interaction between factors for grain and biological yields (Table 11).

Soil Fertility and Black Clay Soil Management

Seedbed preparation method and phosphorus fertilizer: The results of a field experiment conducted on Vertisols at two locations to assess the effects of phosphorus and drainage on lentil yield showed that the crop significantly responded to improved drainage, but its response to P was not significant (Tekalign et al., 1998). From the results, it could be concluded that the use of BBFs as improved drainage method is more important than applying P fertilizer to increase the grain yield of lentil. Similarly, trial results at Sheno indicated that higher grain and biological yields of lentil were recorded on BBFs compared to lentil yields obtained on flatbeds (ShARC, 2002).

Phosphorus fertilizer: The response of lentil to phosphorus was studied from 1998-2000 on Vertisols at Chefe Donsa and Akaki, and on medium light soils of Ude area using the variety Adaa. The analysis of variance showed that lentil was not differently responsive in yield to variable P levels applied (Fig 1). Similarly, the results of an experiment conducted during the same season on the effect of N and P fertilizers on lentil at Inewari showed that the effect of either N and P, or their interaction was not significant on all the variables considered. Angaw and Asnakew (1994) also showed that there were no apparent lentil grain yield differences due to the application of P fertilizer.

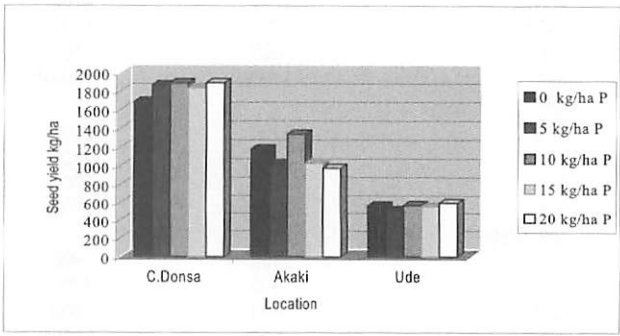


Fig. 1. Response of lentil to phosphorus fertilization at three locations, 1998-2000. Source: DZARC (2001).

Grass pea

Planting Date

The major restriction of grass pea production is due to 'lathyrism', a neurodegenerative disorder caused by excessive consumption of grass pea seeds over a prolonged period thereby resulting in irreversible paralysis of lower limbs. Field trials were conducted at Inewari and Debre Zeit to investigate the impact of sowing date on grain yield and ODAP content of grass pea. Four planting dates, i.e., 10 and 25 August and 10 and 25 September for Debre Zeit, and 5 and 20 August and 5 and 20 September for Inewari areas were used with two varieties (IVAT-LS-B10-520 and a local cultivar) (Table 12). Plant height, grain yield and total biomass were significantly different among planting dates. However, there were no significant differences in grain yields due to varieties. Garin yield and biomass decreased as the planting date was delayed.

Table 11. Effect of tillage and weed control on mean grain and total biological yields of lentil during 1998-2000.

	Akaki		Debre Zeit		Chefe Donsa
Factors	Grain yield (kg/ha)	Biomass (kg/ha)	Grain yield (kg/ha)	Biomass (kg/ha)	Grain yield (kg/ha)
Tillage (T)					
T1	917	3337	469	2578	1423
T2	1000	3620	528	2746	1145
T3	937	3446	450	2422	1017
T4	881	3361	457	2520	1290
LSD (%)	NS	NS	NS	NS	NS
Weeding (W)					
W1	869	3204	390	2095	1198
W2	998	3679	562	3038	1239
F-test	*	*	**	**	NS
T×W	NS	NS	NS	NS	NS
CV (%)	29.1	24.0	30.2	16.7	24.0

*, ** = Significant at 0.05 and 0.01 probability level, respectively; NS = Not significant.
Source: DZARC (2001).

Table 12. Planting date and variety effects on plant height (PH), grain (GY) and total biological yields (TBY) of grass pea at Debre Zeit, 2000-2002.

Treatment	2000/01 PH (cm)	2000/01 GY (kg/ha)	2000/01 TBY (kg/ha)	2001/02 PH (cm)	2001/02 GY (kg/ha)	2001/02 TBY (kg/ha)
Planting date						
Aug.10	85.2	2850	14410	76.0	1243	5046
Aug.25	77.4	2156	11528	68.6	1422	4954
Sept.10	71.9	2568	11910	50.7	1096	2639
Sept.25	63.8	1771	10833	46.4	926	2639
LSD(5%)	28.6	1503	4674	2.8	612	4091
Variety						
Ivat-LS-B10520	71.5	2471	12240	57.8	1219	4016
Local	77.6	2201	12100	63.0	1124	3623
LSD (5%)	NS	NS	NS	11.0	202	835
CV (%)	15.4	25.1	10.7	7.5	21.0	15.4

NS = Not significant. Source: DZARC (2002).

On the other hand, the ODAP content showed an increasing trend with the delay in planting date for both varieties with the local cultivar having the highest ODAP (Fig. 2). The ODAP% was significantly and negatively correlated with plant height, grain yield and 1000-seed weight. It showed a significant positive correlation with days to flowering. Similarly, a significant positive correlation with days to maturity was reported by Asfaw et al. 1994).

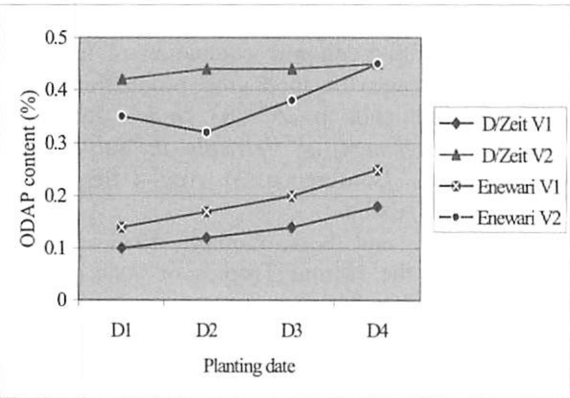


Fig. 2. Mean *β-ODAP* content (%) of grass pea as influenced by planting date and variety at Debre Zeit and Inewari, 2000-2002. Source: DZARC (2002).

The effect of zinc sulfate in relation to planting dates was studied on the ODAP content of grass pea varieties at Inewari during 2001/02. The results showed that the ODAP content of grass pea was significantly affected by the application of zinc and planting date (DZARC, 2002). As the rate of $ZnSO_4$ increased the concentration of the ODAP decreased.

FUTURE RESEARCH DIRECTIONS

The role of CSFLs in cropping systems of the highland areas of Ethiopia should be emphasized. Both short- and long-term cropping sequence experiments in different environments with different food legumes involving N-budget component should be carried out. Then, for each area a reasonable calculation will be made of the proportion of cereal production that could have a food legume rotation based on actual markets and socio-economic considerations.

More research should be conducted on intercropping of cereals and food legumes in various potentially useful configurations to determine the potential advantages that might occur in total yield due to N-fixation. The presence of N-leakage to intercropped cereals from the N-fixation needs proof.

Low pH and associated low phosphate availability is one of the major limiting factors for CSFL production in the highland Nitisol areas of the country, where faba bean and field pea are mainly grown. As soil pH declines important microelements such as boron and molybdenum become deficient. Hence, such soils need to be ameliorated using physical, chemical and biological methods.

Practical improvements and adaptation of mechanical devices for sowing, applying fertilizer and pesticides, cultivation and harvesting are a constant part of evolving agricultural development. Therefore, simple equipments that suit the system should be developed for CSFLs. High yielding varieties suitable for mechanization should be developed.

The inefficient traditional practice of crop culture should be replaced with improved crop management techniques for continuous crop production. During high rainfall seasons, water-logging problem is severe and crop damages are common on Vertisols. Thus, emphasis should be given to drainage methods, time of planting, varieties and crop management techniques to improve the productivity of CSFL on the highland areas of the country. In summary, the available technologies and improved agronomic practices developed in the country regarding the production of CSFLs should be demonstrated and extended to users to increase their adoption.

REFERENCES

Ageeb, O.A., F.A. Salih, and M.A. Ali. 1989. The effect of sowing date, watering interval and intercroppng with sorghum and maize on the yield of faba bean. *FABIS Newsletter* No. 24: 8-10.

Alem Berhe, S.P.S. Beniwal, Amare Gizaw, Asfaw Telaye, Hailu Beyene, and M.C. Saxena. 1990. On-farm evaluation of four management factors for faba bean production in the Holetta Zone of west Shewa. *Ethiopian J. Agricultural Science* 12: 17-28.

Amare Ghizaw. 1995. Mixed cropping of faba bean and field pea in Ethiopia. p. 56-60. *In* Proc. First Conference of the Agronomy and Crop Physiology Society of Ethiopia. 30-31 May 1995, Addis Ababa, Ethiopia.

Amare Ghizaw, and Adamu Molla. 1994. Faba bean and field pea agronomy research. p.199-229. *In* Asfaw Telaye et al. (Eds) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR: ICARDA, Aleppo, Syria

Amare Ghizaw, Tekalign Mamo, Adamu Molla, Zewdu Yilma, and Yeshanew Ashagre. 1999. Nitrogen and phosphorus effects on faba bean yield and some yield components. *J. Agronomy & Crop Science* 182: 167-174.

Angaw Tsigie, and Asnakew Woldeab, A. 1994. Fertiliser response trials on highland food legumes. p. 279-292. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR: ICARDA, Aleppo, Syria.

Asfaw Telaye, Geletu Bejiga, and Alem Berhe. 1994. Role of cool-season food legumes and their production constraints in Ethiopian agriculture. p. 3-16. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR: ICARDA, Aleppo, Syria.

Beets, W, C. 1982. Multiple cropping and tropical farming systems. Gower Publishing CompanyLimited, Gower House, Croft Road, Aldershit, Hamphire, England.

Beniwal, S. P. S., and Dereje Gorfu. 1987. Diseases of faba bean in Ethiopia. EPC Newsletter 33: 32 (Abstr.).

Buddenhagen, I. W.1990. Legumes in farming systems in Mediterranean climates. p. 3-29. *In* A.E. Osman et al. (Eds.) *Developments in Plant and Soil Sciences*. Proc. Workshop on the Role of Legumes in the Farming Systems of the Mediterranean Areas, June 20-24 1988. UNDP/ICARDA, Tunis.

Cadish, G. 1990. Influence of P and K on growth and symbiotic nitrogen fixation of *Centrosoma spp*. and other tropical forage legumes. Ph. D. Thesis, Swiss Federal Institute of Technology, Zurich, Switzerland.

Desta Beyene, and Hailu Regassa. 1989. Research work on the management of Vertisols in Ethiopia: Experience of IAR. p. 165-171. *In* Vertisol Management in Africa. Proc. No. 9. International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand.

DZARC. 1996. Annual report of the period 1994/95, Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 2001. Annual report of the period 1998-2000, Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 2002. Annual report of the period 2000-2002, Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

EARO. 1998. Progress Report No. 8 on Resource Management for Improving and Sustaining Crop and Livestock Production on Highland Vertisols in Ethiopia. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.

Getachew Agegnehu. 2001. Cool-season food legumes research on the highland Vertisols of Ethiopia. p. 171-183. *In* Paulos Dubale et al. (Eds.) *Advances in Vertisols Management in Ethiopian Highlands*. Proc. International Symposium on Vertisol Management, 28 Nov.- 1Dec. 2000, Debre Zeit, Ethiopia.

Getachew Agegnehu, Amare Gizaw, and Chilot Yirga. 2001. On-farm fertilizer trial on faba bean and field pea around Holetta. p. 280-291. *In* Gemechu Keneni et al. (Eds.) *Towards Farmers' Participatory Research: Attempts and Achievements in the Central Highlands of Ethiopia*. Proc. Client Oriented Research Evaluation Workshop, 16-18 Oct. 2001, Holetta Agricultural Research Center, Holetta, Ethiopia.

Getachew Asamenew, S. C. Jutzi, Abate Tedla, and J. McIntire. 1988. Economic evaluation of improved Vertisol drainage for food crop production in the Ethiopian highlands. p. 263-283. *In* S.C. Jutzi et al. (Eds.) *Management of Vertisols in Sub-Saharan Africa*. Proc. Conference, 31 Aug–4 Sept. 1987. ILCA, Addis Ababa.

Gomez, A. A. and K.A. Gomez. 1983. Multiple Cropping in the Humid Tropics of Asia. Ottawa. Ont., IDRC-176e. 248 pp.

Hailu Beyene, Workneh Negatu, and Shelemew W/Mariam. 1994. Smallholder production practices and constraints in Ethiopia. p. 19-30. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR: ICARDA, Aleppo, Syria.

Hailu Gebre, Amsal Tarekegn, and Endale Asmare. 1989. Beneficial 'break' crops for wheat production. *Ethiopian J. Agricultural Science* 11: 15-25.

Hebblethwaite, P.D., G.C. Hawtin, J.W. Latman. 1983. The husbandry of establishment and maintenance, p. 271–312. *In* P.D. Hebblethwaite (Ed.) Faba Bean (*Vicia faba L.), A Basis for Improvement*. Cambridge University Press, UK.

HARC. 2000. Annual research report. Holetta Agricultural Research Centre (HARC), Holetta, Ethiopia.

HARC. 2001. Annual research report. Holetta Agricultural Research Centre (HARC), Holetta, Ethiopia.

HARC. 2002. Progress report of the period 1999-2001. Holetta Agricultural Research Centre (HARC), Holetta, Ethiopia.

HARC. 2003. Annual research report. Holetta Agricultural Research Centre (HARC), Holetta, Ethiopia.

IAR. 1991. Research results of 1990 crop season. Asfaw Telaye (Ed.). Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia.

IAR. 1996. Holetta Research Center Annual Report, 1995. Institute of Agricultural Research (IAR)/Holetta Research Center (HRC), Addis Ababa, Ethiopia.

IFA. 1992. World fertilizer use manual. D.J. Halliday and M.E. Trenkel (Eds.). International Fertilizer Industry Association (IFA). BASF Aktiengesellscaft, Germany. 632 pp.

ILRI. 1990. Annual research report. International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia.

Jensen, E.S.1986. Intercropping faba bean with maize in Denmark. *FABIS Newsletter* No.16: 25-28.

Jutzi, S.C. 1988. Contribution of Vertisols to national food self-sufficiency: Actual and potentials. *Ethiopian J. Agricultural Science* 10: 67-70.

Jutzi, S.C., and Mesfin Abebe. 1989. Improved agricultural utilization of Vertisols in the Ethiopian highlands, an inter-institutional approach, p.173-183. *In* P.M. Ahn and C.R. Elliott (Eds.) *Vertisol Management in Africa*. Proc. No. 9. International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand.

Kidane Georgis, Amare Abebe, Adhanom Negasi, Legesse Dadi, Woldeyesus Sinebo. 1990. Cereal/legume intercropping research in Ethiopia. p. 167-175. *In* S.R. Waddington et al. (Eds.) *Research Methods for Cereal/Legume Intercropping*. Proc. Workshop on Research Methods for Cereal/Legume Intercropping in Eastern and Southern Africa. CIMMYT, Mexico, D.F.

Mahler, R. L., M.C. Saxena, and J. Aeschlimann. 1988. Soil fertility requirements of pea, lentil, chickpea and faba bean. p. 279-289. *In* R.J. Summerfield (Ed,) *World Crops: Cool Season Food Legumes*. Proc. International Food Legumes Research Conference on Pea, Lentil, Faba Bean and Chickpea. Washington, USA, 6-11 July 1986.

Mesfin Abebe. 1979. Studies on soil fertility and drainage. Summary of research activity at Sheno sub-station 1968-78. IAR, Addis Ababa.

Mesfin Abebe, and S. C. Jutzi. 1989. The joint project on improved management and utilization of dark clay soils in Ethiopia, retrospect and prospects. p. 385-398. *In* P.M. Ahn and C.R. Elliott (Eds.) *Vertisol Management in Africa*. Proc. No. 9, International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand.

Million Eshete. 1994. Chickpea and lentil agronomy research, p. 230-251. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/ IAR: ICARDA, Aleppo, Syria.

Million Eshete, and Geletu Bejiga. 1998. Effect of planting date on yield and other agronomic characters of the early lentil variety Chekol in low rainfall areas in Ethiopia. *NVRSRP Newsletter* No. 1: 19-20.

Niguse T/Michael and M.S. Reddy. 1995. Maize/bean intercropping effects on component yield, land use efficiency and net-returns at Awassa and Melkassa. p.51-55. *In* Proc. 1st Conference of the Agronomy and Crop Physiology of Ethiopia, 30-31 May 1995, Addis Ababa, Ethiopia.

Papastylianou, I. 1990. The role of legumes in the farming systems of Cyprus. p. 39-49. *In* A.E. Osman et al. (Eds.) *Developments in Plant and Soil Sciences*. Proc. Workshop on the Role of Legumes in the Farming Systems of the Mediterranean Areas, June 20-24, 1988. UNDP/ICARDA, Tunis

Rezene Fessehaie. 1992. Evaluation of improved tillage implements for faba bean production on Nitisols of Holetta. p. 18-19. *In* Nile Valley Regional Program Cool-season Food Legumes Annual Report 1990/91, Ethiopia, ICARDA/NVRP-DOC 018, Cairo, Egypt.

Rezene Fessehaie. 1994. Weed research in cool season food legumes. p. 252-274. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/ IAR: ICARDA, Aleppo, Syria.

ShARC. 1999. Annual report of the period 1997/98. Sheno Agricultural Research Centre (ShARC), Sheno, Ethiopia.

ShARC. 2001. Annual report of the period 1999-2001. Sheno Agricultural Research Centre (ShARC), Sheno, Ethiopia.

ShARC. 2002. Annual report of the period 2001/02. Sheno Agricultural Research Center (ShARC), Sheno, Ethiopia.

Saxena, M .C. 1987. Agronomy of chickpea. p. 207-232. *In* M.C. Saxena and K.B. Singh, (eds.). *Chickpea*. CAB International/ICARDA.

Tekalign Mamo, Selamyihun Kidanu Mesfin Abebe, Teklu Erkosa, and Miressa Duffera. 1998. Lentil response to phosphorus and different methods of seedbed preparation on Vertisols. *LEN S Newsletter* No. 25: 42-44.

Willey, R.S. 1979. Intercropping - its importance and research needs. Part 1. Competition and yield advantages. Field Crop Abstracts 32:1-10.

Soil Fertility and Crop Management Options of Food Legumes in South-eastern Highlands of Ethiopia

Asefa Taa[1] and Kedir Nefo[2]

[1]*Oromiya Agricultural Research Institute (OARI), P.O. Box, 5762, Finfinnee, Ethiopia,* [2]*Sinana Research Center, Oromiya Agricultural Research Institute (OARI), P. O. Box 208, Robe (Bale), Ethiopia*

ABSTRACT

Faba bean and field pea are the important pulse crops in smallholder farmers' fields in the highlands of southeastern Ethiopia. The research conducted on agronomic practices on these crops at Kulumsa and Sinana Research Centers in the past 12 years are discussed. Research conducted to evaluate the response of field pea varieties to nitrogen (N) and phosphorus (P) fertilizer indicated that field pea responded to phosphorus application. The analysis revealed that P_2O_5 at the rate of 28.2 and 23 kg/ha provided economical grain yield, respectively. Seed rates greater than 100 kg/ha showed reduction in grain yield in field pea and a seed rate of 75 kg/ha was found economical and was recommended for the Bale highlands. Faba bean has been recommended as a break crop for the highlands of Arsi to avoid the problems associated with wheat monoculture. Results indicated that a 2-year rotation was preferred over a 3-year rotation as it reduced the N requirement of the succeeding wheat crop. Double cropping of bread wheat following field pea in the first rainy season increased total farm output compared to either fallow practice or bread wheat following barley. This practice has been recommended to farmers, particularly in districts receiving bi-modal distribution of rainfall in the Bale highlands.

INTRODUCTION

Food legumes cover about 10% of the total crop area in southeastern Ethiopia and are the second most important crops next to cereals (Table 1). The farming system in this area is cereal-based cropping system (Chintalapati et al., 2001) with high potential for field pea and faba bean production. Faba bean and field pea are generally grown in areas between 1800 and 3000 m asl (Asfaw, 1979), and account for about 84% of the area allotted to food legumes in southeastern Ethiopia. They are the most important and widely grown pulse crops, accounting for about 58 and 26% of the area covered by food legumes, respectively (Table 1). They supplement a low cost alternative to animal protein to the cereal-based diets, by providing between 18 to 32% protein (Hailu et al., 1989). They could be used as break crops where cereal after cereal mono-cropping system is dominating (Chintalapati et al., 2001) and can replenish soil nutrients through biological nitrogen fixation, reduce diseases and reduce weeds, and serve as a source of cash earnings.

Table 1. Estimates of crop land area for private peasant holding, 1997/98 (1990 E.C.) southeastern Ethiopia (Bale and Arsi Zones).

Type of crop	Total area (1000 ha)
Cereals	617.33
Food Legumes	
Faba bean	41.15
Field pea	18.22
Haricot bean	4.58
Chickpea	4.13
Lentil	2.40
Sub-Total	70.48
Oil Seeds	78.10
Others	25.41
Permanent	24.68
All Crops	825.49

Source: CSA (1997).

Field pea (*Pisum arvense*) is grown mainly in the "*genna*" (*belg*) season (Alemayehu and Franzel, 1987). In bi-modal areas of Bale highlands, few peasant farmers utilise both rainy seasons to produce two crops on the same piece of land; most prefer to alternately fallow their land during one of the two annual cropping seasons (Alemayehu and Franzel, 1987), probably due to the narrow window of the time separating the two seasons. The current practice, however, necessitates frequent ploughing of the land during the fallow season to control weed growth, requiring a significant input of human labor and ox-power, and rendering the soil surface susceptible to erosion. Furthermore, increasing population pressure in southeastern highlands necessitates the conversion of land from semi-permanent pasture to arable cropping (Alemayehu and Franzel, 1987).

A number of studies have indicated that cultivation of N_2 fixing legumes benefits the yield of the succeeding cereal (Senaraine and Hardarson, 1988). The residual N benefits from legumes are usually evident in the available soil mineral N pool. The soil N available for a subsequent crop is influenced by the amount of plant residues retained, the availability of N from the plant residues, the rate of mineralization of soil organic matter, and the extent to which soil N was depleted by the preceding crop; any differences in the contribution to soil N from preceding crops would be largely due to differences in N release from live or decomposing roots and nodules (Papastylianou, 1987). Thus, inclusion of grain legumes in cropping sequences generally increases soil nitrate, grain yield, total N accumulation and N-use efficiency of a subsequent cereal crop compared with a continuous cereal crop with inorganic fertilizer applied (Badaruddin and Meyer, 1994).

Crop rotation with pulses can increase crop yields by controlling weeds, insects, and diseases and preventing soil erosion, and by maintaining soil fertility through nitrogen supply (Bullock, 1992). Most

Bale farmers rotate bread wheat with barley and sometimes with emmer wheat. Such high proportion of continuous cereal after cereal mono-cropping could result in yield reduction, particularly where soil fertility and weed control practices are sub-optimal and soil-borne diseases are common (Tanner et al., 1991).

The increased yield of cereal crops following legumes has been attributed mainly to changes in soil N content (Baldock et al., 1981), However, the beneficial effects of including grain legumes in cropping sequence can also be attributed to changes in other soil properties and reduced toxic substances in crop residues (Barber, 1972); reduced diseases and insect problems (Baldock et al., 1981); or the release of growth promoters from the legume residues (Ries et al., 1977). In other findings, the increase in the amount of N partitioned to the grain of wheat following a legume crop compared with continuous wheat was associated with a prolonged period of supply of N in the wheat crop from decomposing legume residues.

EXPERIMENTAL RESULTS

Effect of Nitrogen and Phosphorus Fertilizer Rates on Agronomic Parameters of Field Pea

Experiments conducted at Sinana, Gassera, Agarfa and Goba districts to evaluate the effect of nitrogen and phosphorus on field pea indicated that nitrogen fertilizer had no effect on measured agronomic parameters at any of the sites. Contrarily, Under Bale highlands, phosphorus fertilizer had significant effect on grain yield and most other agronomic parameters (Table 2). The effect of phosphorus, however, varied from location to location. At Agarfa, the highest P_2O_5 gave higher grain yield than 0 and 23 kg P_2O_5/ha, while at Sinana on-farm and Gassera, plots that received different rates of phosphorus gave more grain yield than the control. In another experiment conducted during "*genna*" at Sinana and Gassera, 18-46 N- P_2O_5/ha gave the highest grain and biomass yield (Table 3). On the other hand, phosphorus fertilizer had no significant effect at Sinana on-station, and in Goba district.

Phosphorus rates had quadratic trend with seeds and pods/plant, harvest index and seeds/m^2. Phosphorus at the rates of 66.67 and 66.18 kg P_2O_5/ha helped produce the highest number of seeds/pod and pods/plant. Phosphorus at the rate of 50 kg P_2O_5/ha gave the highest harvest index. Aguitar and Hunt (1991) found that 1000-kernel weight was related to harvest index. The rate and duration of grain filling determined kernel size, and was primarily controlled by the availability of assimilates and the capacity of the developing grain to use those assimilates (Ma et al., 1990). There was also a linear relationship between crop growth rate and seeds/m^2 (Egli and Yuzhen-wen, 1991).

Phosphorus rates had quadratic relationship with grain yield. Optimum grain yield was obtained at 67.22 kg P_2O_5/ha. In some cases, grain yield was strongly associated with 1000-seed weight and seeds/plant (SnARC, 2000), the latter contributed about 97% to the total variation in grain yield. In other cases, Shibles et al. (1975) observed that much of the yield variation across environments was associated with seeds/unit area. Similarly, application of phosphorus increased grain yield by increasing number of seeds/plant rather than 1000-seed weight.

Cost-benefit analysis: Continuous economic analysis indicated that economical grain yield of field pea was obtained at 28.22 kg P_2O_5/ha. Discrete economic analysis, however, indicated that fertilizer at the rate of 23kg P_2O_5/ha resulted in economical grain yield (Table 4). Economical optimum fertilizer rate was lower than optimum biological rates because economic optimum rate takes into account the cost of input factors. The economic optimum fertilizer in continuous analysis was higher than discrete analysis because continuous model predicted the rates of phosphorus between applied rates. This showed that continuous model helped in reducing cost of conducting another experiment to recommend actual rates, which requires large number of treatments.

Table 2. Effect of phosphorus on grain yield and agronomic parameters combined over seasons and locations of Bale highlands in *bona* (*meher*) and *genna* (*belg*) seasons, 1998 and 1999.

Phosphorus fertilizer rate (kg/ha)	Grain yield (kg/ha)	Pods/plant	1000-seed weight (g)	No. plants/m^2	No. seeds/plant	Harvest index (%)	No. seeds/pod	Plant height (cm)	Straw yield (kg/ha)
0	795C	4.3B	182.81AB	99	19.06	27.77B	4.21	90.44D	2260C
23	1115B	5.4A	186.98A	99	22.2	31.42A	4.11	106.25C	3177BC
46	1189A	5.6A	183.17AB	96	22.54	31.80A	4.17	113.04B	3664AB
92	1208A	5.6A	180.53A	98	23.08	29.21B	4.13	117.91A	4118A
Mean	1126	5.30	183.4	98	21.72	30.05	4.15	106.91	3405
SD* (0.05)	23.93	0.14	Ns	1.45	0.94	0.72	ns	0.67	198
CV %	24.87	21.4	12.07	23.11	21.79	29.5	15.19	8.18	33.42

Source: SnARC (2000).

Table 3. Effect of different level of fertilizer application on agronomic parameters of the field pea crop grown in the first cropping season (*genna*) of 1997 and 1998 (mean of nine trials).

Treatment (N/P_2O_5)	Grain yield (kg/ha)	Biomass yield (kg/ha)	Plant height (cm)	1000- grain weight (g)	Harvest index (%)
0-0	933c	2466 c	75 b	161	38.1
9-23	1481 b	3710 b	86 a	166	39.7
18-46	1669 a	4292 a	90 a	170	39.1
Mean	1336	3445	83	165	38.8
C.V.(%)	15.1	15.5	9.9	7.0	13.7
Prob.[b]	***	***	***	NS	NS
$LSD_{(0.05)}$	180	385	6.8	NS	NS

***= Significant at 0.1% level; NS= non-significant. Means within the same column followed by the same letter or by no letters do not differ significantly at the 5% level of the LSD test. Source: Feyissa et al. (1999).

Table 4. Cost-benefit analysis of fertilizer application in field pea.

Grain yield (kg/ha)	Phosphorus rate (P2O5 kg/ha)	Adjusted yield	Cash cost (Birr/ha)	Family cost (Birr/ha)	Total cost (Birr/ha)	Net benefit (Birr/ha)	MNB[1]	MC[1]	MRR[1]
795	0	715.8	0.0	0.0	0.0	1646.4			
1115	23	1003.5	100.0	5.00	105.0	2203.1	556.6	105.0	530
1189	46	1070.1	200.0	10.00	210.0	2251.2	48.2	105.0	46
1208	92	1087.2	400.0	15.00	415.0	2085.5	439.1	205.0	D

MNB=Marginal Net Benefit, MC=Marginal Cost, MRR=Marginal Rate of Return. Source: SnARC (2000).

Effect of Seed Rate on Field Pea Yield and its Components

Seed rate of field pea significantly influenced number of pods and seeds/plant, total grain yield, biomass yield, harvest index, 1000-seed weight and straw yield (Table 5). As seed rate increased, seeds/plant and 1000-seed weight were linearly and curvilinearly decreased, respectively. This implies increase in number of plants/unit area has negative impact both on the number and size of seeds produced. Straw yield was curvilinearly increased by seed rates. The negative impact of higher seed rates on the performance of seeds brought the slight grain yield reduction at the seed rate greater than 100 kg/ha. Since 100 kg/ha seed rate was not better than 75 kg/ha, the minimum seed rate of 75 kg/ha gave economical and feasible seed rates than others. It is recommended for field pea production in Bale highlands (SnARC, 2000).

Effects of Pulses in Crop Rotation System

Continuous monoculture of wheat or rotation with barley is the most common practice in most wheat producing regions of Ethiopia. In high potential areas such as the highlands of Arsi and Bale, rotation of wheat with dissimilar species is uncommon because of the high yield obtained from improved varieties of wheat and attractive wheat prices in the local markets. But, continuous cereals production can result in yield decline particularly where soil-borne diseases are common. Hence, the beneficial effects of rotation on wheat have been examined at different locations. A crop rotation experiment was conducted from 1984-1989 at two locations representing wheat production zones on clay soil (Kulumsa) and Vertisols (Arsi Robe) in southeastern Ethiopia. At both locations, seven different six-year rotations were used, comparing monoculture bread wheat with three rotations consisting of wheat grown 1 year out of 2 and 3, with wheat grown 2 years out of 3. The break crops were faba bean, rapeseed (*Brassica napus* L.), oat (*Avena sativa* L.), vetch (*Vicia dasycarpa* Ten), and forage mixtures. *Noug* (*Guizotia abssinica*) was substituted for rapeseed at Robe. Six different fertilizer levels were compared within each rotation; the highest levels were 36-46 and 55-69 kg $N\text{-}P_2O_5$/ha on the clay loam and Vertisols, respectively. Data analysis in 1989 indicated a highly significant effect of both rotation and fertilizer on wheat grain yield at both locations (Table 6). At both Kulumsa and Arsi Robe, wheat after faba bean gave the largest yield increment relative to monoculture wheat (1396 kg/ha or + 75% ; 1451 kg/ha or 114%, respectively).

Another long-term crop rotation experiment in wheat was conducted at Asassa and Kulumsa from 1992-2000 to evaluate interactions among wheat-based cropping sequences and annual application of inorganic nitrogen and phosphorus fertilizers. Break crops were faba bean, Ethiopian mustard (*Brassica carinata*) and barley (*Hordeum vulgare*). A continuous wheat treatment was included as a check (Tanner et al., 1994). Two rates each of N (30 and 60 kg/ha) and P (0 and 20 kg/ha) was used in a factorial combination. This experiment was designed in such a way that each phase of a specific rotation was present in the experiment every year to avoid assessing the effects of the rotational crops under different seasonal conditions. Results in different years indicated that wheat grain yield and crop parameters were enhanced by rotation with non-cereals than rotation with cereals at both locations (Amanuel et al., 1996; Tanner et al., 1998). Wheat following faba bean gave higher grain yields, but responded lower to applied inorganic nitrogen fertilizer (Table 7) indicating availability of more N to the wheat crop through atmospheric N_2 fixation by the legumes. Yield increments of wheat due to a precursor rapeseed were also remarkable. Soil NO_3 content was also increased in wheat rotations with non-cereals particularly in wheat after faba bean rotations (Amanuel et al., 1996). Research results from Sinana also revealed that wheat sown after pulses gave higher grain yield than after cereals and linseed in *bona* growing seasons of both 1996 and 1998. Growing bread wheat after pulses gave yield advantages of 243.5 kg/ha (7.4%) and 480 kg/ha (13.3%), respectively (Tilahun et al., 2000). Higher advantage obtained in 1998 than in 1996 implies the gradual and sustainable effects of pulse crop rotation. This advantage might be attributed to nitrogen fertilizer source obtained from the pulse residues in the subsequent season (Amanuel et al., 1996; Tanner et al., 1991, 1998; Mooleki and Siwale, 1998).

In general, pulses are the most beneficial break crops. The effect of both precursors on grain yield and yield components were observed gradually. Therefore, long-term investigation of rotation effect under Sinana conditions and extending the recommendation to the user is essential.

Table 5. Effect of seed rate (kg/ha) on agronomic parameters and yield (kg/ha) of field pea in bona (meher) season, 1997-1999.

Seed rate levels	No. pods/plant	No. seeds/ plant	Grain yield	Biomass yield	Harvest index	1000-seed weight	Straw yield
75	5.7ABC	24.5A	864ABC	3709B	18.3AB	137.7A	2845B
100	5.7AB	24.5A	915A	3940AB	19.3A	134.3AB	3025AB
125	5.4BC	22.6B	854BC	4084A	16.6BC	131.1BC	3230A
150	5.7A	22.6B	864B	4177A	16.6BC	129.6C	3303A
175	5.4C	21.6B	815C	3968AB	16.4C	128.2C	3153A
Means	5.9	23.5	864	3975	17.4	132.2	3111
LSD (0.05)	0.3	1.8	55.4	303.2	1.7	4.3	285
CV %	15.7	20	16.83	20.05	25.79	8.49	24.09

Source : SnARC (2000).

Table 6. Grain yield of wheat as affected by crop rotation at two sites in southeastern Ethiopia, 1989).

	Crop rotation						Grain yield (kg/ha)	
Treatment	1984	1985	1986	1987	1988	1989	Kulumsa	Arsi Robe
1	Fb+	W	O/V	W	*	W	2840AB #	2095ABC
2	O/V	W	*	W	Fb	W	3179A	2686A
3	*	W	Fb	W	O/V	W	2548BC	2614AB
4	Fb	W	W	O/V	W	W	2267CD	1451BC
5	O/V	W	W	*	W	W	1992D	1292C
6	*	W	W	Fb	W	W	2541BC	1396C
7	W	W	W	W	W	W	1813D	1255C
Mean							1813	1827
LSD (0.1)							503	1164

+ Crop : O/V= Oat/Vicia forage mixture; W= Wheat; Fb= Faba bean, *= Rapeseed at Kulumsa, and *noug* at Arsi Robe, #= Figures followed by the same latter are significantly different at the 1% probability level. Source: Amanuel and Tanner (1991).

Table 7. Mean grain yield and yield component of wheat by application of N and P as affected by crop rotation at Kulumsa and Asassa, 1995-1999.

	Grain yield (kg/ha)		Yield increment due to higher N and P rates			
			N		P	
Cropping sequence	Kulumsa	Asassa	Kulumsa	Asassa	Kulumsa	Asassa
FbW	4500A	3260AB	46	-60	380	580
FbWW	4430A	3450A	250	0	140	360
FbWW	3750B	2780CD	310	260	160	420
RpW	3800B	3000ABC	730	240	650	230
RpWW	3770B	2870BCD	850	470	550	280
RpWW	3440BC	2480D	780	390	-30	610
BaW	3330C	2630CD	850	140	270	460
BaWW	3250C	2620CD	660	390	-30	330
BaWW	3230C	2410D	550	610	110	250
CW	3130C	2400D	620	450	150	230
Meam	3660	2790	---	---	---	---
C.V%	10.9	14.5	---	---	---	---
LSD (0.05)	389	491	306	205	254	309

FbW= Faba bean wheat; FbWW= Faba bean wheat wheat; RpW Rape seed wheat; RpWW = Rape seed wheat wheat; BaW= Barley wheat; BaWW= Barley wheat wheat: CW= Continuous wheat.
Source: Amanuel et al. (2001). (Not cited under References).

Use of Pulses in Double-Cropping System

Leguminous species in a double-cropping system could exert positive effects on the vigor, growth and grain yield of succeeding wheat and/or barley crops. Tanner et al. (1994) reported, on the basis of on-station trials conducted at the SnARC that double cropping was feasible in the Sinana district, and the best agronomic and economic results were obtained in *bona* season with bread wheat following a *genna* season field pea crop. Bread wheat following field pea in a double-cropping system exhibited superior growth at all developmental stages relative to wheat following barley (de Boer et al., 1993; Tanner et al., 1994, Feyissa et al., 1999). Field pea-wheat double-cropping sequence provided more stable and the highest net benefit to farmers than either the barley-wheat or fallow-wheat sequences (Feyissa et al., 1999). Double cropping of bread wheat with leguminous field pea in Bale highlands was also the most beneficial *genna* season precursor (Feyissa et al., 1999). Similar results were found in other parts of Ethiopia (Amanuel and Tanner, 1991; Hailu et al., 1989).

It is apparent that double-cropping of wheat with field pea is a feasible option in the Sinana and Gassera districts of the Bale Region the best agronomic and economic results were obtained with *bona* season bread wheat following a *genna* crop of field pea. This practice could minimise several negative aspects of the fallow system: (i) soil erosion could be reduced by maintaining a crop vegetative cover in both annual cropping seasons, (ii) the rate of expansion of cultivation onto pasture land could be reduced by intensifying production on the currently cropped areas, (iii) weed control could be facilitated by rotating non-cereal crops with the *bona* wheat crop, (iv) human and ox-labour could be utilised more efficiently in a double-cropping system than in a fallow-wheat system, and (v) the double-cropping system has the potential to increase the total quantity of crop residues available for livestock feed. However, the ultimate adoption of double-cropping by individual farmers will be dictated by their perception of the capacity to increase farm income while diversifying the risk of crop failure (Shapiro et al., 1992).

Integrated Crop Management

Crop growth is commonly affected, among other factors by soil physical and chemical properties. Two set of experiments were conducted at Kulumsa and Asassa Research Centers from 1993-2000 to examine the effect of stubble management, tillage practice, cropping sequence on wheat yield under mechanized and ox-plow tillage systems. Results indicated that faba bean-wheat (Fb-W) or faba bean-wheat-wheat (Fb-W-W) treatments were superior to continuous wheat (CW) (Table 8). The effects of these factors were also examined in 1994 on soil physical and chemical properties under mechanized and ox-plow tillage system. Results indicated that soil organic matter was increased by partial removal or complete retention of stubble and reduced by stubble burning at both sites (Asefa et al., 1996). Soil organic matter was higher in minimum tillage combined with partial removal of stubble. Regarding cropping sequence, effect of faba bean precursor crop increased soil NO_3 content under both tillage systems on research station and on the farmers' field (Asefa et al., 1996).

Table 8. The effect of faba bean as a preceding crop on wheat yield (kg/ha), (1993-2000).

Trial	Treatment	1993	1994	1996	1997	1999	2000	Mean
Kulumsa Mechanized	Faba bean	2470A	1101A	6201A	4500A	4055A	3279A	3899
	Wheat	2003B	904B	5139B	4118B	3573B	3573B	3081
	Significance	***	**	***	**	**	***	
Kulumsa Ox-plow	Faba bean	2424	1791A	5982A	4845	4143	3985A	3795
	Wheat	2478	1134B	5447B	4775	3705	3499B	3498
	Significance	NS	*	***	NS	NS	**	
Asassa Mechanized	Faba bean	1438	1764A	4532A	3210	4861A	2917A	3120
	Wheat	1417	1405B	3332B	3256	3239B	2399B	2508
	Significance	NS	***	***	NS	***	**	
Asassa Ox-plow	Faba bean	1779A	2035	4278A	3287	4553A	3204A	2190
	Wheat	1545B	1920	3754B	3021	3191B	2463B	2583
	Significance	***	NS	***	NS	***	***	

Note: *; **; *** statistically significant at 01<P<0.05; 0.01<P<0.05, 0.01<P<0.001, respectively.

Fb = Faba bean rotation with wheat (1 year in 3); Wheat = Continuous wheat.

Values within a column for each trial followed by the same letter(s) are not significantly different at the 5% level of the LSD test (or 10% level where indicated by the probability). Source: Asefa (2001).

REFERENCES

Aguitar-Marlscal, I., and L.A. Hunt. 1991. Grain yield and spike number in winter wheat in humid continental climate. *Crop Science* 31: 360-363.

Alemayehu Mamo and Steven Franzel. 1987. Initial results of informal survey, Sinana Mixed Farming System Zone, Bale Region, IAR, Addis Ababa.

Amanuel Gorfu, and D.G. Tanner. 1991. The effect of crop rotation in two wheat production zones of southeastern Ethiopia. p. 491-496. *In* D.A. Saunders (Ed.) *Wheat for the Non-traditional Warm Areas.* CIMMYT, Mexico, D.F.

Amanuel Gorfu, D.G. Tanner, Kefyalew Girma, Asefa Taa, and Duga Debele. 1996. Soil nitrate and compaction as affected by cropping sequence and fertilizer level in southeastern Ethiopia. p. 175-176. *In* D.G. Tanner et al. (Eds.) *The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa.* Addis Ababa, Ethiopia: CIMMYT.

Asefa Taa. 2001. Effect of stable management, tillage and cropping sequence on sustainable wheat production in southeastern highlands of Ethiopia. PhD Thesis, University of the Free State, Bloemfontein, South Africa. p. 283.

Asefa Taa, Douglas G.Tanner, Kefyalew Girma, Amaneal Gorfu, and Duga Dabele. 1996. Influence of stubble management, tillage and precursor crop on soil physico-chemical properties in southeastern Ethiopia. p. 104-111. *In* D.G. Tanner et al. (Eds.) *The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa.* Addis Ababa, Ethiopia CIMMYT.

Asfaw Telaye. 1979. Broad beans (*Vicia faba* L.) and dry peas (*Pisum sativum* L.) in Ethiopia. p. 80-84. *In* Geoffrey C. Hawtin et al. (Eds.) *Food Legume Improvement and Development.* Proc. Workshop held at the University of Aleppo, Syria, 2-7 May 1978. IDRC, Ottawa, Canada.

Badaruddin, M., and D.W. Meyer. 1994. Grain legume effects on soil nitrogen, grain yield and nitrogen nutrition of wheat. *Crop Sci.* 34: 1304-1309.

Baldock, J.Q, Higgs, L.R, Paulson, W.H. Jacobs, J.A., and W.D. Schradewer. 1981. Legume and mineral N effects on crop yield in several crop sequences in the upper Mississippi Valley. *Agron. J.* 73: 885-890.

Barber, S.A. 1972. Relation of weather to the influence of hay crops on subsequent corn yields on chalmers silt loam. *Agron. J.* 64: 2-10.

Bullock, D.G. 1992. Crop rotation. *Critical Rev. Plant Soil* 11: 309-326.

Chintalapati, P. Kefyalew Desta, Tesfaye Kassahun, Cubo Qi, and A. Rotionov. 2001. The shift to cereal monocropping, "A threat or blessing?" towards sustainable agricultural production in the highlands of South-east Oromia, Ethiopia. ICRA 2001, Working Document Series 92, Ethiopia.

CSA. 1997. Report on average producers' prices of agricultural products in rural areas. Statistical Bulletin 188. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

de Boer, R.F., G.R. Steed, J.F. Kollmorgen, and B.J. Macauley. 1993. Effects of rotation, stubble retention and cultivation on take-all and eyespot of wheat in northeastern Victoria, Australia. *Soil and Tillage Research* 25: 263-280.

Egli, D.B., and Yuzhen-wen. 1991. Crop growth rate and seeds per unit area in soya bean. *Crop Sci.* 31: 439-442.

Feyissa Tadesse, Tilahun Geleto, Kedir Nefo, and D.G. Tanner. 1999. On-farm evaluation of sequential double cropping with bread wheat in the Bale highlands of Ethiopia. Paper presented in African Crop Sciences Society Meeting, 11-14 October 1999, Casablanca, Morocco.

Hailu Gebre, Amsal Tarekegn, and Endale Asmare. 1989. Beneficial break crops for wheat production. *Ethiopian J. Agricultural Science* 11: 15-24.

Ma, Y. Z., C.T. Mackowns, and D.A.Vansanford. 1990. Sink manipulation in wheat compensatory changes in kernel size. *Crop Sci.* 30: 1099-1105.

Mooleki, P., and J. Siwale. 1998. The impact of crop rotation on the grain yield of rainfed wheat in northern Zambia. p. 350-356. *In* D.G. Tanner et al. (Eds.) *The Tenth Wheat Workshop for Eastern, Central and Southern Africa.* Addis Ababa, Ethiopia: CIMMYT.

Papastylianou, I 1987. Effect of preceding legume or cereal on barley growth and nitrogen yield. *J. Agric. Sci. Camb.* 108: 623-626.

Ries, S.K., V. Wert, C.C. Sweeley, and R.A. Leavitt. 1977. Triacontanol: A new naturally occurring growth regulator. Science 195: 1339-1341.

Shapiro, B.I., B.W. Bronsen, and D.H. Doster. 1992. Adoption of double-cropping soybeans and wheat. Southern J. Agricultural Economics 24: 33-40.

Senaraine, R., and G. Hardarsan.1988. Estimation of residual N effect of faba bean on two succeeding cereals using N-15 methodology. Plant and Soil 110: 81-98.

SnARC. 2000. Progress report for 1998/99 cropping year, Sinana Agricultural Research Center (SnARC), Sinana, Ethiopia.

Shibles, R.M., I.C.Anderson, and A.H. Gibson. 1995. Carbon assimilation in soya bean. p. 151-190. *In* L.T. Evans (Ed.) Crop Physiology. Cambridge Univ. Press, London.

Tanner. D.G,, Amanuel Gorfu, and Kassahun Zewude. 1991. Wheat agronomy research in Ethiopia. p. 101. In Hailu Gebremariam et al. (Eds.) Wheat Research in Ethiopia: A Historical Prospective. IAR/CIMMYT, Addis Ababa, Ethiopia.

Tanner, D.G., Zewdu Yilma, Lemma Zewdie, and Girma Gebru. 1994. Potential for cereal-based double cropping in Bale Region of southeastern Ethiopia. African Crop Science Journal 2: 135-143.

Tanner, D.G., H. Verkuji, Asefa Taa, and Regassa Ensermu. 1998. An agronomic and economic analysis of a long-term wheat based crop rotation trial in Ethiopia. p. 213-248. In The Tenth Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Tilahun Geleto, Kedir Nefo, and Feyisa Tadesse. 2000. Crop rotation effects on yield and yield components of bread wheat in the Bale highlands of southeastern Ethiopia. 2000. *In* D.G. Tanner and W. Mwangi (Eds.) *The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa.* Addis Ababa, Ethiopia: CIMMYT.

Soil Fertility and Crop Management Research on Food Legumes in Northern and Western Ethiopia

Minale Liben[1], Tolera Abera [2] and Besufekad Tadesse[3]

[1] *Adet Agricultural Research Center, P.O. Box 08, Bahir Dar, Ethiopia,* [2] *Bako Agricultural Research Center, P,.O. Box 03, Bako, Ethiopia,* [3] *Sirinka Agricultural Research Center, Sirinka, Ethiopia.*

ABSTRACT

Faba bean (*Vicia faba*), field pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and grass pea (*Lathyrus sativus L)* are important food legumes, and low input 'break' crops in northern Ethiopia. The results of limited agronomic studies at Adet, Bako, Sirinka and Pawe Research Centers showed the importance of the improved practices for maximizing yield of legumes. Poor soil fertility and poor crop management practices are the major production constraints for production of food legume crops in northern and western Ethiopia. Several experiments were conducted in the region to determine the optimum fertilizer rates for faba bean and to improve cultural crop management practices for field pea, chickpea and grass pea. The results of fertilizer trial on faba bean indicated that agronomic parameters such as plant height and grain yield were linearly increased with an increase in phosphorus levels in Yilmana-Denssa, Farta and Dabat in northwestern, and Kon in northeastern Ethiopia. However, the highest grain yield was obtained from the combination of the two nutrients (N/P) with the highest interaction level of the treatment. The economic analysis indicated that lower level 18/23 kg N/P_2O_5/ha was more profitable in Yilmana-Denssa, Dabat and Kon areas, whereas 27/69 kg N/P_2O_5/ha was more economical for faba bean production in Farta. Results of a crop rotation study at Bako indicated that haricot bean was the most effective break crop for increasing maize yield. The study indicated that optimum sowing date for the chickpea variety Mariye was from mid- to end-September, which was also optimum for grass pea with 40-50 kg/ha seeding rate under Adet and Woreta conditions. For bushy and climbing-type haricot bean, mid-June to early-July and late-May to early-June, respectively, were also recommended planting dates in Pawe conditions. Grain yields of field pea increased as seeding rate was decreased to 75 kg/ha in both broadcasting and row planting methods. For faba bean production, a seed rate of 250 kg/ha was recommended for Shambo conditions.

INTRODUCTION

Faba bean (*Vicia faba*), field pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and grass pea (*Lathyrus sativus)* are important food legumes in Ethiopia, and are mainly cultivated between 1700-2400 m asl where the mean annual rainfall ranges from 700 to 2000 mm (Amare and Adamu, 1994). They are break crops in cereal rotations, especially with wheat, barley and *tef.* Chickpea and grass pea are predominantly grown under residual moisture (August-December) on black soils, whereas faba bean and field pea are grown in main rainy season (June-November) on well-drained and fertile soil. Ethiopia is the largest faba bean producer next to China (Asfaw et al., 1994). The share of pulse crops in terms of area coverage and production to the country's total is about 13% and 9%, respectively. Among the pulses, faba bean, chickpea and field pea are the major food legume crops produced accounting for about 5%, 2% and 2% of the country's crop area coverage, and 4%, 2% and 1% of the total production with average yields of about 1.2, 1.0 and 0.8 t/ha, respectively (CSA, 2002).

In Amhara Region, pulse crops rank second in area coverage and production, next to cereals, and contribute 17% of the crop area and 14% of the production. Faba bean, chickpea and field pea are also the major food legume crops in the region. The average productivity of these crops is similar to the national average (CSA, 2002). In northwestern Ethiopia (Gojam and Gondar), faba bean, field pea, chickpea and grass pea account for 23.4%, 21.7%, 37.1% and 44.2%, of the total annual pulse production of the country, respectively (CSA, 2001).

Smallholder farmers grow the crops as source of cash income and dietary protein supplement in daily food consumption. However, the productivity of these crops is extremely low, mainly due to traditional methods of crop management practices and poor soil fertility. Limited studies in the region showed the need for improved agronomic practices for maximizing the food legume yields. The objective of this review is to synthesize agronomic research findings on faba bean, field pea, chickpea and grass pea, conducted by Adet, Bako, Sirinka and Pawe Agricultural Research Centers, and to suggest future research priorities.

SOIL FERTILITY

Nitrogen and Phosphorous Fertilizers Responses on Faba Bean

Considerable research has been carried out on the nitrogen and phosphorous requirements of faba bean on red-brown soils of Yilmana-Denssa, Farta and Dabat (northwestern Ethiopia), and Kon (northeastern Ethiopia) areas, where cereals (wheat/barley) are as precursor crops. The treatments for northwestern Ethiopia were factorially arranged with three N levels (0, 18 & 27 kg/ha) and four P_2O_5 levels (0, 23, 46 & 69 kg/ha), whereas for Kon (northeastern Ethiopia) five levels of phosphorous (0, 23, 46, 69 and 92 kg/ha) and 18 kg N/ha blanket application as a starter dose together with the test treatments. The results indicated that there was a progressive increase in faba bean grain yield with incremental levels of phosphorous at all the locations, whereas the responses to nitrogen was low (Table 1). This is probably due to nitrogen fixing capacity of the crop. It was reported that faba bean fixed more nitrogen (135 kg N/ha) than lentil and chickpea (Murinda and Saxena, 1983). Small starter nitrogen dose could result in better nodulation and higher nitrogenous activity implying that improved early growth and improved subsequent activity of the Rhizobium. However, the highest grain yield of 1746, 2399 and 1878 kg/ha in Yilmana-Denssa, Farta and Dabat was obtained, respectively, with the interaction of 27/69 kg N/P_2O_5/ha (Table 1).

At Kon, the response to fertilizer on yield was significant though the experiment in 2000 suffered from high and prolonged moisture stress As a result, faba bean yield was drastically reduced with the highest grain yields of 840 kg/ha from treatment of 18/46 kg N/P_2O_5/ha. In 2001 cropping season, 3790 kg/ha grain yield was obtained from the treatment of 18/92 kg N/P_2O_5/ha (Table 2 and 3). The highest grain yield on nitrogen by phosphorus interaction is probably due to the uptake enhancement effect of one nutrient by the other (Taye et al., 2002). However, the economic analysis showed that 18/23 kg N/P_2O_5/ha was more profitable in Yilmana-Denssa, Dabat and Kon areas, whereas 27/69 kg N/P_2O_5/ha was more economical in Farta area. Plant height was linearly increased with an increase in phosphorus levels at the three locations (Table 4).

Table 1: Effect of N and P_2O_5 on the grain yield of faba bean combined over years.

	Yilmana-Denssa Grain yield (kg/ha)				Farta Grain yield (kg/ha)				Dabat Grain yield (kg/ha)			
P_2O_5	N levels (kg/ha)				N levels (kg/ha)				N levels (kg/ha)			
(kg/ha)	0	18	27	Mean	0	18	27	Mean	0	18	27	Mean
0	1092	1274	1188	1185	1501	1590	1522	1538	1383	1332	1556	1424
23	1340	1481	1471	1431	1596	1851	1800	1749	1419	1679	1607	1568
46	1607	1581	1608	1599	1937	2140	1978	2018	1473	1398	1629	1500
69	1704	1614	1746	1688	2167	2255	2399	2274	1532	1694	1878	1701
Mean	1436	1488	1503		1800	1959	1925		1452	1526	1667	
CV%			28.6			27.5				33.63		
LSD5%	N	P_2O_5	N x P_2O_5		N	P_2O_5	N x P_2O_5		N	P_2O_5	N x P_2O_5	
	NS	128	NS		NS	172	NS		136	171	NS	

Source: AdARC (2000).

Table 2. The effect of different levels of phosphorous fertilizers on faba bean plant height, grain yield, and biomass yield at Kon, 2000.

N -P_2O_5 level (kg/ha)	Plant height (cm.)	Grain yield (kg/ha)	Biomass yield (kg/ha)
18-0	37.98b	394b	450c
0- 46	35.8b	407b	450c
18-23	48.27a	707a	786ab
18-46	51.92a	840a	969a
18-69	43.60ab	644a	664bc
18-92	49.20a	758a	756ab
CV%	16.20	31.1	29.8
LSD (P<0.05)	8.68	234	244

Note: Means followed by the same letter are non-significantly different at 5%. Source: SrARC (2002).

Table 3. The effect of different levels of phosphorous fertilization on faba bean plant heigt (cm), grain yield (kg/ha), and biomass yield (kg/ha) at Kon, 2001.

N -P_2O_5 levels (kg/ha)	Plant height (Cm.)	Grain yield (kg/ha)	Biomass yield (kg/ha)
18-0	61.00c	2282b	4653c
0- 46	68.67ab	2911ab	5625bc
18-23	65.33bc	3292a	6458ab
18-46	70.83ab	3381a	7257a
18-69	66.83abc	3105ab	6215abc
18-92	73.50a	3790a	7604a
CV%	8.47	22.22	19.73
LSD (P<0.05)	6.9	837	1497

Note: Means followed by the same letter are non-significantly different at P = 0.05. Source: SrARC (2002).

Table 4. Effect of N and P_2O_5 on plant height (cm) of faba bean over years.

	Yilmana-Denssa				Farta				Dabat			
P_2O_5	N levels (kg/ha)				N levels (kg/ha)				N levels (kg/ha)			
(kg/ha)	0	18	27	Mean	0	18	27	Mean	0	18	27	Mean
0	80.7	86.2	84.3	83.7	97.1	102.5	101.1	100.3	89.6	90.5	92.3	90.8
23	89.1	88.7	89.3	89.0	102.5	101.5	101.3	101.8	91.7	95.0	93.2	93.3
46	91.6	92.5	98.7	94.3	106.3	105.7	103.3	105.1	95.1	94.4	97.9	95.8
69	95.0	98.9	96.5	96.8	105.9	111.3	114.5	110.6	93.7	98.4	99.5	97.2
Mean	89.1	91.6	92.2		102.9	105.2	105.1		92.5	94.6	95.7	
CV %			9.62				11.64				10.32	
LSD5%	N	P_2O_5	N x P_2O_5		N	P_2O_5	N x P_2O_5		N	P_2O_5	N x P_2O_5	
	2.1	4.3	NS		NS	NS	NS		NS	3.6	NS	

Source: AdARC (2000).

Crop Rotation

Crop rotation with legumes is one of the cheapest methods for soil fertility maintenance. Legumes are universally regarded as beneficial to crop rotation, on the general assumptions that they improve soil fertility by adding nitrogen to the soil. Enhanced cereal yields following legumes have been attributed to chemical and biological factors for higher levels of biological nitrogen fixation.

An experiment was conducted at Bako from 1999 to 2002. In the first year the field was planted with *noug* (*Guizotia abyssinica*), haricot bean (*P. vulgaris*), tef (*Eragrostis teff*) and maize. In the second year, maize was planted on the field where precursor crops were planted. The results showed that maize planted after haricot bean with full and half recommended fertilizer rate obtained higher grain yields (8231 and 6484 kg/ha) followed by *noug* and tef (Table 5). When haricot bean was planted as the precursor crop for two consecutive years and followed by maize, the maize grain yields were the highest. Based on one- and two-year rotations, haricot bean was the best break crop among the tested crops for highest maize production (Table 5 and 6).

Table 5. Effects of one year rotation with full and half recommended fertilizer rate on the yield of maize and break crops at Bako, 2001.

Break crops	Grain yield of maize (kg/ha): Full recommended fertilizer rate	Half recommended fertilizer rate	Mean
Noug	7594	6229	6912
Haricot bean	8231	6484	7358
Tef	6569	5839	6204
Maize mono-crop	5545		5545
LSD(5%)	1749		
CV %	14.8		

Recommended rate: 110/20 kg N/P/ha; half recommended rate: 55/10 kg N/P/ha. Source: BARC (2002).

Table 6. Effects of two years rotation with full and half recommended fertilizer rate on the grain yield of maize and break crops at Bako, 2002.

Break crop	Grain yield of maize(kg/ha): Full recommended fertilizer rate	Half recommended fertilizer rate	Mean
Noug	4309	3338	3824
Haricot bean	4466	4428	4447
Tef	4158	3124	3641
Maize mono-crop	2957		
LSD(5%)	724		
CV %	10.64		

Recommended rate: 110/20 kg N/P ha^{-1}; half recommended rate: 55/10 kg N/P ha^{-1}. Source: BARC (2004).

DEVELOPMENT OF IMPROVED CROP MANAGEMENT

Land Preparation

Suitable land preparation is one of the most important crop management strategies for increasing crop production. The experiment was conducted at Shambo (western Ethiopia) during 1997-1999, to determine the optimum number of plowing(s) for faba bean production. The results showed that thrice oxen plow of the land with "*maresha*" (a local plow) gave significant yield advantage as compared to the minimum tillage (Table7).

Table 7. Effect of plowing frequency on the seed yield (kg/ha) of faba bean at Shambo (Western Ethiopia)

Plowing frequency	Year: 1997	1998	1999	Mean
Plowing once	1585	1144	867	1199b
Plowing twice	1286	1156	900	1114b
Plowing three times	1421	1663	1055	1180b
Plowing four times	1731	1439	1327	1499a
Mean	1506	1351	1037	1298
CV%	33.48	25.66	13.37	32.83
LSD(5%)	NS	367.8	146.8	261.11

Note: Means followed by the same letter are non-significantly different at 5%.

Plant Density/Planting Methods

Field pea: Optimum seed rate is of paramount importance to obtain the potential yield of a crop. A plant population by planting methods study was carried out for two years (1997 and 1998) at Adet Agricultural Research Center using the improved field pea variety (Mohanderfer). The results showed that there was a significant grain yield difference among the seed rates. The highest grain yield of 847 kg.ha was obtained from the lowest seed rate of 75 kg/ha and vice versa. In general, there was a linear grain yield increase as the seed rate decreased up to 75 kg/ha. Differences between planting methods and interactions of planting method with seed rates did not significantly affect the grain yield. However, the highest grain yields, 837 kg/ha and 856 kg/ha were obtained at the seed rate of 75 kg/ha in broadcasting and row planting methods, respectively (Table 8).

Table 8. Effect of plant density and planting methods on the grain yield (kg/ha) of field pea at Adet.

Planting Method (PM)	Seed rate(SR): 75	100	125	150	175	Mean
Broad casting	837	756	642	596	560	678a
Row planting	856	613	672	526	453	624a
Mean	847a	685b	657b	561bc	507c	
CV%			23.72			
LSD 5%		SR 120	PM NS		SR x PM NS	

Means followed by the same letter are non-significantly different at P= 0.05. Source: AdARC (1998).

Faba bean: A seed rate experiment on faba bean was carried out at Shambo from 1997 to1999. The experiment comprised of three seeding rates (starting from 150 kg/ha at 50 kg interval). From three year results, the seed rate of 250 kg/ha was agronomical optimum, and was recommended for faba bean production at Shambo area (Table 9).

Table 9. Effect of seeding rate on the grain yield (kg/ha) of faba bean at Shambo (western Ethiopia).

Treatment Seed rate	Year 1997	1998	1999	Mean
150 kg/ha	1292	1388	1062	1247^{B}
200 kg/ha	1461	1345	997	1268^{B}
250 kg/ha	1764	1319	1053	1379^{A}
Mean	1506	1351	1037	1298
CV%	7.49	21.63	17.34	16.6
LSD (P=0.05)	75.14	NS	NS	82

Note: Means followed by the same letters are non-significantly different at 5%.

Mixed Cropping of Faba bean with Field pea

A study was conducted on seed rate proportion of faba bean and field pea in mixed cropping at Shambo from 1997-1999 crop seasons to determine the optimum proportion of faba bean and field pea in a mixed cropping system (Tolera and Daba, 2001). Five different proportions of faba bean (cv. CS-20-DK) and field pea (cv. G22763-2C) and one farmers' local practice (0:100; 25:75; 50:50; 75:25; 100:0 and 82:18 of faba bean and field pea proportions) were laid in RCBD with four replications. The combined data analysis for the three years revealed that higher yield of faba bean and field pea in mixed cropping was obtained from higher proportion of faba bean than field pea. Increasing the seed rate proportion of field pea in mixed cropping gave greater yield advantage of field pea with adverse effects on faba bean grain yields. Reducing field pea proportion in the mixture and increasing faba bean proportion showed better grain yield of both crops. A proportion of 75:25 faba bean and field pea was the most suitable for mixing both crops resulting in higher seed yield and total land equivalent ratio (LER) of 55%, and was found agronomically compatible and economically profitable for the area.

Planting Date and Rate

Chickpea and grass pea: A sowing date experiment on the improved chickpea variety Mariye was carried out in 1995 and 1996 at Adet and Woreta. The experiment had comprised of six sowing dates at 15-day-interval starting 15 August. Highest chickpea grains yields of 821 and 1406 kg/ha were obtained in 15 and 30 September plantings at Adet in 1995 and 1996, respectively. The figures for the same planting dates at Woreda were 953 and 1415 kg/ha (Table 10). The reduction in grain yield as a result of early- and late- plantings was probably due to excess and shortage of moisture, respectively. Therefore, the optimum planting date for chickpea Mariye variety for Adet and Woreta conditions was from mid- to end-September (Alemayehu et al., 1998). In a similar experiment on grass pea, the main and interaction effects of sowing dates and seeding rates were examined for three years for Adet and Woreta conditions.

The experiment consisted of four sowing dates at 15-day interval starting from 30 August and four seeding rates (starting from 30 kg/ha at 10 kg interval). The result revealed that among the planting dates the highest grain yield was obtained at both locations from the middle to late- September plantings. Differences in grain yield among the seeding rates were not significant at Adet, whereas the interactions of planting date with seed rates were significant. The highest grain yield of 1642 kg/ha was obtained from 30 September planting with 40 kg/ha seed rate at Adet conditions (Table 11). In Woreta conditions, the highest grain yield of 928 kg/ha was recorded from 15 September planting with 50 kg seeding rate (Table 12).

Also, a sowing date trial was conducted for two consecutive years (2000-2001) at Pawe to determine the optimum planting time for bushy and climbing-type haricot bean. Differences in planting date of bushy and climbing-type beans were observed at Pawe conditions. The optimum planting date for bushy-type (Roba-1) was from mid-June to early-July (Table 13), whereas it was from late-May to late-June for the climbing-type local bean (Table 14).

Table 10. Effect of sowing date on the yield of chickpea (kg/ha) at Adet and Woreta (combined over years).

Planting date	Location: Adet	Woreta
15 August	-	-
30 August	174	272
15 September	821	953
30 September	1406	1415
15 October	708	-
30 October	-	-

Source: Alemayehu et al. (1998).

Table 11. Effect of sowing date and seed rate on the yield of grass pea (kg/ha) at Adet (combined over years).

Sowing date (SD)	Seed rate (SR) (kg/ha) 30	40	50	60	Mean
30 Aug.	869	713	1043	987	903c
15 Sept	950	1185	1343	1447	1231b
30 Sept	1537	1642	1281	1477	1484a
15 Oct	446	323	390	743	476d
Mean	951a	966a	1014a	1164a	
C.V%			44.44		
LSD 5%		SD	SR	Sd x Sr	
		*	NS	*	

Means followed by the same letter are non-significantly different at P=0.05.
Source: AdARC (1999).

Table 12. Effect of sowing date and seed rat on the yield of grass pea (kg ha^{-1}) at Woreta (combined over years).

Sowing date	Seed rate (kg/ha) 30	40	50	60	Mean
30 Aug.	90	104	338	147	170^{c}
15 Sept.	864	885	928	792	867^{a}
30 Sept.	757	675	917	838	797^{a}
15 Oct.	281	458	449	505	423^{b}
Mean	498^{b}	531^{b}	658^{a}	571^{ab}	
C.V%				44.95	
			SD	SR	Sd x Sr
LSD 5%			*	*	*

Means followed by the same letter are non-significantly different at P=0.05.
Source: AdARC (1999).

Table 13. Effect of sowing date on the grain yield (kg/ha) of bushy-type haricot bean (Roba-1) at Pawe, 2000-2001.

Sowing date	2000	2001	Mean
June 10	922.9	260.1	591.5
June 20	753.1	321.9	537.5
June 30	796.4	394.7	595.5
July 10	584.9	222.0	403.4
July 20	384.4	138.2	261.3
July 30	301.6	95.6	198.5
August 10	217.7	112.1	164.9
Mean	565.8	220.7	393.2
CV%	58.5	25.7	
LSD (P=0.05)	589.7	101.0	

Source: PARC (2002).

Table 14. Effect of sowing date on the yield (kg/ha) of climbing-type haricot bean (local) at Pawe, 2000-2001.

Sowing date	2000	2001	Mean
May 25	1078.1	1197.2	1137.7
June 4	891.1	1331.1	1111.1
June 14	816.1	984.3	877.3
June 24	1101.6	914.7	1008.1
July 4	138.8	465.2	302.0
July 14	183.9	184.6	184.2
July24	366.8	136.9	251.9
Mean	653.8	738.3	696.0
CV%	30.8	25.7	40.6
LSD (P=0.05)	359.1	605.9	332.0

Source: PARC (2002).

FUTURE DIRECTIONS

In future, the research in northern and western Ethiopia should focus on the following:

1. For making fertilizer recommendations for major food legumes fertilizer experiments should consider soil tests and crop response calibrations.
2. Improved production technologies, such as frequency of tillage, seeding depth, time and frequency of weeding should be developed for different agro-ecologies.
3. Suitable intercropping practices involving legumes and cereals, and crop rotation studies should be conducted.

REFERENCES

AdARC. 1998. Progress Report. Adet Agricultural Research Center (AdARC), Adet, Ethiopia.

AdARC. 1999. Progress Report. Adet Agricultural Research Center (AdARC), Adet, Ethiopia.

AdARC. 2000. Progress Report. Adet Agricultural Research Center(AdARC), Adet, Ethiopia.

Alemayehu Assefa, Minale Liben, and Yeshanew Ashagrie. 1998. Effect of planting date on the yield of chickpea (Mariye variety) in northwestern Ethiopia. *In* Kidane and Yohannes (Eds.) *Crop Management Options to Sustain Food Security.* Proc. Third Conference of the Agronomy and Crop Physiology Society of Ethiopia. 29-30 May 1997, Addis Ababa, Ethiopia.

Amare Gizaw and Adamu Mola. 1994. Faba bean and field pea agronomy research. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 Dec., Addis Ababa, Ethiopia.

Asfaw Tilaye, Geletu Bejiga, and Alem Berhe. 1994. Role of cool season food legumes and their production constraints in Ethiopian agriculture. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 Dec., Addis Ababa, Ethiopia.

BARC. 2002. Progress report. Bako Agricultural Research Center (BARC), Bako, Ethiopia.

BARC. 2003. Progress report. Bako Agricultural Research Center (BARC), Bako, Ethiopia.

BARC. 2004. Progress report. Bako Agricultural Research Center (BARC), Bako, Ethiopia.

CSA. 2001. Estimates of total area of production for temporary crops. Central Statistical Authority (CSA), Addis Ababa.

CSA. 2002. Estimates of total area of production for temporary crops. Central Statistical Authority (CSA). Addis Ababa.

Murinda M.V., and M.C. Saxena. 1983. Agronomy of fababeans, lentils and chickpeas. *In* M.C. Saxena and S. Varma (Eds.) *Proc. Fababeans, Kabuli Chickpeas and Lentils in the 1980's.* An International Workshop, 16-20 May 1983. The International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.

PARC. 2002. Progress report. Pawe Agricultural Research Center (PARC), Pawe, Ethiopia.

SrARC. 2002. Progress report. Sirinka Agricultural Research Center (SrARC). Sirinka, Ethiopia

Taye Bekele, Yesuf Assen, Sahlemedhin Sertsu, Amanuel Gorfu, Mohammed Hassena, D.G. Tanner,Tesfaye Tesemma, and Takel Gebre. 2002. Optimizing fertilizer use in Ethiopia. Correlation of soil analysis with fertilizer response in Hetosa woreda, Arsi Zone. Addis Ababa: Sasakawa-Global 2000.

Tolera Abera, and Daba Feyisa. 2004. Determination of the optimum proportion of faba bean and field pea in mixed cropping at Shambo. Paper presented at 10th Biannual Conference of Crop Science Society of Ethiopia.

Soil Fertility and Crop Management Research of Lowland Food Legumes in the Rift Valley

Girma Abebe[1], Waga Mazengia[2] and Olani Nikus[1]

[1]*Nazareth Agricultural Research Center, P.O. Box 436, Nazareth, Ethiopia,* [2]*Awasa Agricultural Research Center, P.O. Box 6, Awasa, Ethiopia.*

ABSTRACT

Food legumes play an important role in the livelihoods of human population in Ethiopia. They are second in land coverage and production next to cereals in the country. The land covered by highland food legumes was seven times higher than lowland food legumes in 2002. At the national level, the productivity of highland food legumes range from 660 kg/ha (of fenugreek) to 1211 kg/ha (of faba bean) as compared to the lowland food legumes, which range between 830 kg/ha (haricot bean) and 916 kg/ha (soybean). In the Rift Valley of Ethiopia, the two main lowland food legumes are haricot bean and soybean, with productivity of 397 to 1007 kg/ha and 377 to 810 kg/ha, respectively. On the other hand, the national average yields of haricot bean and soybean are 823 and 916 kg/ha, respectively. However, the average yield of haricot bean on research plots is more than 2000 kg/ha in the Rift Valley, indicating a wide gap in average yield between farmers' fields and research plots. The productivity of haricot bean in the country at large is very poor mainly due to low soil fertility status particularly for N and P, terminal moisture stress, weeds, diseases and insect-pests. Bean is compatible with numerous other crops in mixed cropping systems. The major cropping systems in the Rift Valley include bean intercropping with maize, sorghum, root crops or bean grown as a sole crop. A number of research results are available on food legumes. This paper reviews agronomic research results on lowland food legumes in the past 10 years in the Rift Valley of Ethiopia.

INTRODUCTION

Food legumes are important sources of cash and protein providing a significant portion of protein needs in the country. Food legumes are second in land coverage and production next to cereals (CSA, 2002). Of the total cultivated land in the year 2002, 12.7% was allotted to food legumes, which contributed to 8.9% of the total production. Of the total land covered by food legumes, the share of highland food legumes was 88% and that of lowland food legumes was 12%. Highland food legumes were also higher in production (90.2%) than lowland food legumes (9.8%). Productivity of highland food legumes in the country ranges from 660 kg/ha (fenugreek) to 1211 kg/ha (faba bean) and that of lowland food legumes range between 830 kg/ha (haricot bean) and 916 kg/ha (soybean).

The two main lowland food legumes in the Rift Valley of Ethiopia are haricot bean and soybean. The productivity of haricot bean in the Rift Valley is between 397kg/ha in Afar and 1007 kg/ha in South Omo and that of soybean is between 377 kg/ha in Gamo Gofa and 810 kg/ha in Wollayita (CACC, 2002). The national average yields of haricot bean and soybean are 823 and 916 kg/ha, respectively. There is wide gap in productivity of the crops between on-farm and research plots.

Bean production areas in Ethiopia can be broadly classified in to central, eastern, southern and western agro-ecological zones based on altitude, rainfall, soil, production system, and geographical location. Central zone is the main bean producing area in the Rift Valley. The eastern zone comprises the second largest bean producing area. Belay et al. (1998) also classified bean growing areas into three major regions of homogeneous environment, viz, humid, sub-humid and semiarid. The major bean producing areas of the Rift Valley fall under sub-humid and semiarid regions, the farmers usually grow white beans, which are mainly grown for export purposes. Subsistence farmers in this area usually grow beans in pure stands (Kidane et al., 1990), whereas in other principal bean growing areas it is usually intercropped with cereals, i.e., maize, sorghum or tree crops (Abdissa and Setegn, 1994; Gemechu, 1990; Kidane et al., 1990; Raya, 1988).

Despite the importance of the crop to farmers and national economy, average yields obtained by farmers are very low. These low yields may be attributed to combinations of several production constraints among which low soil fertility, periodic low moisture stress, diseases and insect-pests, weeds and untimely field operations play a major role (Kidane et al., 1990; Raya, 1988).

The soils of the dryland regions of Ethiopia are generally poor in their inherent fertility. Low soil fertility status particularly for N and P is common problem in all the agro-ecological zones. Beans are poor nitrogen fixers and require external supply of nitrogen (Lynch and Piha, 1988). The contribution of different bean cultivars to soil N is negligible if all plant parts are harvested (Jasdanwala and Chege, 1993). On the other hand, the use of inorganic fertilizers could not be of much avail to exploit the crop production potential of these soils. The low response of these crops to inorganic fertilizers is because of low and erratic rainfall (Asnakew, 1991). Beans are sensitive to moisture stress and temperature, and responses differ among cultivars (Rice et al., 1986). Rainfall of 300 to 500 mm is considered suitable for growth and yield of beans depending on other climatic conditions (FAO, 1979). Although the sub-humid areas are optimal in terms of rainfall use efficiency for bean production, terminal moisture stress is often a problem with late-planting (Belay et al., 1998). In the semi-arid areas, potential yields are low and variable due to moisture deficiency stress. Date of planting is often critical in the dry sub-humid and semi-arid regions of the country, and as a result there is always a yield loss associated with delay in planting after the onset of rainfall. Therefore, in the northern and central Rift Valley and eastern region, bean varieties of terminal drought resistance and determinate growth habits are important (Belay et al., 1998). Yield losses also occur due to diseases and insect-pests (Tsedeke, 1990). Bean stem maggot and weeds are peculiar problems of southern region.

To address these problems, several agronomic experiments were undertaken during the past 10 years on cultural practices, cropping systems and soil fertility management for obtaining better yields of lowland food legumes. This paper reviews the available agronomic research results on food legumes in the Rift Valley areas of Ethiopia to enable researchers to determine future research direction and needs, and farmers or producers to benefit from the results.

RESULTS OF AGRONOMIC STUDIES

Cultural Practices

Planting date and plant density study for haricot bean: Field trials consisting of four planting dates and five plant densities (100, 200, 300, 400, 500 thousand seeds/ha) were conducted at two locations, Awassa (Fluvi utrisol) and Melkassa (sandy loam). Planting date had significant effect ($P < 0.001$) on grain yield of haricot bean (Table 1). In general, early-planting resulted in nearly 41% grain yield increase over the late-planting. Plant density also had significant effect ($P < 0.001$) on grain yield, pods/plant and seeds/pod, while seed weight was not affected by plant density. There was a positive curvilinear relationship between grain yield and plant density (data not presented). Seed rates of 400,000 seeds/ha resulted in a 39.5% grain yield increase over 100,000 seeds/ha at Awassa, whereas at Melkasa 500,000 seeds/ha yielded 71% higher than 100, 000 seeds/ha. The results indicated that improved cultural practices could increase common bean yield by a factor of 2- to 3- fold in Ethiopia.

Table 1. Effect of planting date on grain yield (kg/ha) of common bean, 1987-1988.

Seeding date	Awassa			Melkassa		
	1987	1988	Mean	1987	1988	Mean
1st*	2438	3657	3048	867	2592	1730
2nd	2738	3028	2883	574	2364	1469
3rd	2885	3165	3025	482	2249	1366
4th	2322	2746	2534	323	1386	855

1st planting dates were June12 (1987) and June 7 (1988) for Awassa; and July 6 (1987) and July 4 (1988) for Melkassa. The other planting dates were at 10-day interval. Source: Unpublished results from Areka Agricultural Research Center (ArARC).

An experiment was also conducted at Areka Agricultural Research Center (ArARC) to determine sowing date for haricot bean in *belg* season when majorities (56%) of farmers grow the crop. The treatments included two varieties and seven sowing dates starting from February 17 at an interval of two weeks for three consecutive years. Sowing date and its interaction with variety had significant effect on grain yield of bean (Table 2). Variety Roba-1 was best favored when sown in mid-February, and the variety Red Wolaita gave the highest yield when sown between early- and mid-March. The overall mean yield showed that the optimum sowing date for haricot bean was between mid-February and mid-March. The yield differences between the two varieties were not significant.

Table 2. Effect of sowing date on seed yield (kg/ha) haricot bean varieties (1995-1997), Areka.

Sowing date	Variety: Roba 1	Variety: Red Wolaita	Mean
Feb. 17	1480 a	1000 c	1240 a
Mar. 3	1040 c	1350 ab	1195 ab
Mar. 18	1320 ab	1340 ab	1330 a
April 2	1240 bc	950 e	1090 b
April 17	1220 bc	430 e	830 c
May 2	561 e	540 e	550 d
May 17	429 e	590 cd	510 d
Mean	1040	890	
	Sowing date (SD)	Varieties (V)	SD X V
LSD(5%)	140	NS	211
CV(%)		25.3	

NS=Non-significant. Source: Unpublished research results from Areka Agricultural Research Center (ArARC).

Population density study for climbing bean: A plant population study was conducted for climbing bean at Kokate (Wollayita) for two years. The two factors in the experiment were row and plant spacing with three levels each, and were laid out in an RCB design in a factorial arrangement. The climbing bean variety was G-190700. The combined analysis of variance revealed that row spacing and its interaction with plant space had highly significant effect on grain yield (Table 3). Row spacing at 30 cm gave consistently highest yield in both years. Grain yield decreased as the row spacing increased. Plant spacing wider than 30 cm considerably decreased yield. However, the yield variation due to plant spacing was not statistically significant. The interaction between row spacing at 30 cm and plant spacing at 30 cm gave the highest yield in both years indicating that it was the optimum spacing for climbing bean for Kokate and similar areas. Plant population at this spacing was 111,111/ha.

Table 3. Effect of plant population (spacing) on grain (kg/ha) yield of climbing bean, Kokate, 2002 and 2003.

Row spacing	Plant spacing (cm)			
(cm)	20	30	40	Mean
30	2997abc	3375a	3138ab	3037a
60	2398bc	2325bc	2069cd	2264b
90	1416de	1088e	1087e	1196c
Mean	2137	2263	2098	

Source: Unpublished research results from Areka Agricultural Research Center ArARC).

Soil Fertility Management

Nitrogen and P fertilizer study for haricot bean: A study to determine nitrogen and phosphorus fertilizer rate for haricot bean was conducted at Awassa for three consecutive years. Five N and P fertilizer rates were laid out in RCBD, in a factorial arrangement. The bean variety used in the experiment was Mexican-142. The combined analysis over three years showed that grain yield was significantly ($P<0.05$) affected by the application of P fertilizer and by N x P interaction (Table 4). The highest grain yield was obtained at 46 kg/ha P_2O_5. There was no significant yield difference due to N fertilizer application. Although the interaction between N and P fertilizers was significant, reasonable yield was obtained at 23 kg/ha P_2O_5 without applying N implying that applying 23 kg/ha P_2O_5 was an optimum rate for haricot bean production at Awassa and similar areas. The crop season significantly ($P<0.01$) affected the crop in response to both N and P fertilizer rates and their interaction (Table 4). Bean yield was highest in 1994 when the total rainfall in the 4-month growing season starting from June was also maximum (600 mm).

Nitrogen and P fertilizer rate study for haricot bean intercropped with maize: An experiment was also conducted to determine N and P fertilizer rate for maize/bean intercropping at Awassa. Four levels of each N and P fertilizer were applied between rows of maize and haricot bean which were sown simultaneously. P fertilizer was applied at sowing, whereas N fertilizer was applied at knee-high stage of the maize crop. Recommended fertilizer rates were applied for sole maize (46 kg N/ha) and haricot bean (46 kg P_2O_5/ha). The varieties used were BH-140 and BH-660 for maize, and Roba 1 for haricot bean. Combinations of the two maize varieties with bean were treated as different experiment. Statistical analyses were done for intercropped maize and bean. Sole crops were used to calculate land equivalent ratio (LER).

Response of haricot bean to the levels of fertilizer was not statistically different in both experiments, i.e., with the two maize varieties (Table 5). However, better yield was obtained from application of 46/10 kg/ha N/P when bean was intercropped both with BH-660 and BH-140. N fertilizer application had significant ($P<0.05$) effect on both maize varieties and application of 46 kg N/ha was optimum for these varieties. The response of the two varieties for P fertilizer application was variable. BH-140 responded significantly for P and the highest grain yield (5192 kg/ha) was obtained from application of 10 kg P/ha. Although the highest yield was obtained from the application of 30 kg P/ha, BH-660 did not respond significantly. LER was highest at the fertilizer rate of 46/10 kg N/P/ha for the variety BH-660 and at rate of 92/10 kg N/P/ha, which was a little bit higher than 46/10 kg N/P/ha for BH-140. In general, bean grain yield was better when it was intercropped with BH-140 than with BH-660, and the optimum fertilizer rate for maize/bean intercropping was 46/10 kg N/P/ha.

Table 4. Effect of N and P rates on grain yield (kg/ha) of haricot bean over years, Awassa.

		P_2O_5 rates (kg/ha)					
Year	N rates (kg/ha)	0	23	46	69	92	Mean
1993	0	1052	1086	1302	1023	981	1089
	23	914	1061	1333	1163	1394	1174
	46	1354	1136	1119	1037	1333	1204
	69	1026	1264	1329	1248	1233	1228
	92	1269	1450	1277	1377	1264	1328
	Mean	1131	1199	1273	1178	1242	1204 *
1994	0	2244	2273	2569	2411	2269	2353
	23	2319	2098	2294	1986	1796	2098
	46	1561	2000	2508	2275	2179	2104
	69	1811	1817	2239	2281	2419	2113
	92	2056	1996	1800	2011	1631	1899
	Mean	1998	2037	2282	2193	2059	2114 **
1995	0	1313	1875	1531	2125	2281	1813
	23	1375	2156	2219	1656	1844	1850
	46	1500	2000	2000	2281	1500	1856
	69	1406	2313	2250	1656	2313	1988
	92	1656	2000	1394	2219	2313	1956
	Mean	1450	2069	1919	1988	2050	1895 **
Grand mean over P levels		1526 *	1768 **	1824 **	1786 **	1784 **	
Grand mean over N levels		1756	1708	1722	1776	1728	
	Cropping system	fertilizer	Interaction				
LSD (5%)	NS	1653	NS				
CV (%)	27.22						

NS= Non-significant; *, **= Significant at 5% and 1% level of significance, respectively. Source: Unpublished research results from Awassa Agricultural Research Center (AwARC).

Table 5. Effect of N and P rates on grain yield (kg/ha) of maize and haricot bean in intercrop situation, Awassa, 2002.

Treatment		BH-660 / H. bean			BH-140 / H. bean		
N rate (kg/ha)	P rate (kg/ha)	BH-660	Haricot bean	LER	BH-140	Haricot bean	LER
0	0	2628	893	1.21	4392 abcd	917	1.30
	10	4531	729	1.38	5227 ab	958	1.46
	20	3594	789	1.28	5026 abc	917	1.41
	30	5153	1128	1.82	5075 abc	1399	1.72
46	0	5729	1080	1.87	5023 abc	961	1.43
	10	5521	1156	1.91	5464 ab	1406	1.79
	20	4375	1104	1.67	5224 ab	1198	1.62
	30	5208	659	1.43	5395 ab	961	1.49
92	0	4236	920	1.49	4853 abcd	1297	1.62
	10	5597	865	1.67	5672 a	1414	1.83
	20	4688	878	1.53	4162 bcd	1170	1.43
	30	4896	872	1.55	4484 abcd	1292	1.56
138	0	3549	976	1.43	3445 d	1250	1.36
	10	3177	628	1.07	4106 bcd	1000	1.31
	20	3653	1195	1.63	4506 abcd	1493	1.69
	30	4520	1211	1.80	3685 cd	1677	1.67
	LSD,5%	NS	NS		1491	NS	
Mean against N rates	0	3976bc	900	1.43	5005 a	1048	1.49
	46	5208a	1000	1.72	5276 a	1132	1.58
	92	4854ab	883	1.56	4793 a	1293	1.61
	138	3725c	1003	1.49	3937 b	1355	1.51
	LSD,5%	942	NS		745	NS	
Mean against P rates	0	4035	967	1.50	4429 b	1106	1.43
	10	4706	860	1.52	5192 a	1195	1.61
	20	4077	992	1.53	4729 ab	1195	1.53
	30	4945	968	1.69	4660 ab	1332	1.61
	LSD 5%	NS	NS		1491	NS	
CV (%)		25.44	39.94		18.78	32.61	
Sole H.b		----	1146			1563	
Sole Mz		6146	---	---	6146	---	---

Source: Unpublished research results from Awassa Agricultural Research Center (AwARC).

Role of forage legumes in improving soil fertility and seed yield of haricot bean: Two forage legumes were relay-cropped with maize to see their effect in improving soil fertility and grain yield of haricot bean grown in the following season . The forage legumes were cowpea (*Vigna unguiculata*) and lablab bean (*Lablab purpureus*). Sole maize with and without fertilizer was added as treatment. The forage legumes were relay-cropped after detasseling at the end of August. The test sites were Awassa and Tula. Soil samples were taken before planting the haricot bean.

The treatments had no significant effect on grain yield of haricot bean in both years at Awassa (Table 6). However, highest bean yield was obtained from lablab bean grown plots followed by sole maize plots without fertilizer in 2001. But in 2002, the highest grain yield was obtained from non-fertilized sole maize plots. The mean over the two years also showed a better grain yield from sole maize plot without fertilizer and lablab bean.

The treatments also had no significant effect on bean grain yield at Tula (Table 7). However, the highest yield was obtained from sole maize plots, which were fertilized with 50/65 kg/ha P/N followed by sole maize plots, which did not receive any fertilizer. This result was consistent for 2001 and 2002. Relatively higher soil N was also recorded from these plots. Lower yield was recorded from cowpea and lablab bean plots.

Table 6. Effect of relay cropped forage legumes on seed yield of haricot bean, Awassa.

Treatment	Grain yield (kg/ha) 2001	Grain yield (kg/ha) 2002	Mean
Cowpea	1188	2539	1864
Lablab	3122	2539	2831
Sole maize without fertilizer	2983	2773	2878
Sole maize with fertilizer (100 kg/ha urea)	2879	2539	2709
LSD	NS	NS	
CV (%)	18.41	9.55	

In general, the forage legumes had different effect at the two locations. Relatively better grain yields were obtained from forage legume treatments at Awassa but also from non-forage legume treatments - sole maize fertilized with 50/65 kg/ha P/N. Plots with relatively higher initial soil N gave better grain yields. Thus, forage legumes could be used in relay-cropping or rotation, however, incorporating their biomass into the soil might bring considerable improvement.

Fertilizer rate study for soybean: A nitrogen rate study was conducted at Awassa on two soybean varieties (OC-793 and V1) of intermediate maturity group in 1995. Five N levels (0, 23, 46, 69 and 92 kg N/ha) laid out in RCBD, and all of them were applied at the sowing time. Soybean responded significantly ($P<0.05$) for N application. Grain yield of the two varieties increased linearly with increased rates of N up to 69 kg N/ha. The highest mean yield of the two varieties of 1840 kg/ha was obtained from the application of 69 kg N/ha, although it was not significantly different from the yield obtained with the application of 23 and 46 kg N/ha. The yield variation due to varieties and the interaction between N levels and varieties was not significant. Thus, for intermediate maturity group of soybean, application of 23 kg N/ha is enough under Awassa conditions, which is characterized by soil with loam texture, high level of P and medium level of N content.

Cropping System

Crop sequence: A cropping sequence study including maize, *tef*, potato, sweet potato and haricot bean was conducted for four years (1993-1996) at Areka, where double-cropping is a common practice. The treatment was composed of five crops, fallow and two fertilizer levels that were arranged in a split-plot design. Fertilizer was the main plot while crops and fallow were sub-plots. The fertilizer levels were recommended rates for each crop (46/46 kg N/ P_2O_5 /ha for maize and 46 kg P_2O_5/ha for each of the other crops), and a check (without fertilizer). The varieties used were two maize varieties (A-511 and Katumani), and one variety of the remaining crops - Dz-cross-37 for *tef*, Koka-6 for sweet potato, and local varieties for potato and haricot bean. The test crop, i.e., haricot bean (Red Woalaita) was sown after harvesting the preceding crops in the same season.

The preceding crops had no statistically significant effect on grain yield of haricot bean (Table 8). However, there were considerable grain yield differences in haricot bean in response to the preceding crops. Results over fertilizer levels and years revealed that better mean bean yield was obtained by sowing haricot bean following *tef* and maize (Katumani and A-511 in order), respectively, than other crops. The grain yields of bean succeeding the two root crops, potato and sweet potato, were poor. The grain yield advantage of haricot bean following *tef* over the yield obtained following sweet potato was 256 kg/ha, which is about 65%. The highest grain yield was from fallow plots with grain yield advantage of 32% and 129% over the yields obtained after *tef* and sweet potato, respectively. Bean responded significantly ($P<0.05$) for fertilizer application. Fertilizer application had 72% yield advantage over the untreated plots. The interaction between cropping sequence and fertilizer application had no significant effect on bean yield. Generally, the results revealed that cereals were good precursors for beans.

Table 7. Effect of relay-cropped forage legumes on grain yield of haricot bean and soil characteristics, Tulla.

Treatment	Soil characteristics, 2001				Grain yield (kg/ha)		
	PH H_2O	Nitrogen (%)	Organic matter	CEC (Meq/100g)	2001	2002	Mean
Lablab	5.8	0.175	3.29	10.86	3304	2049	2677
Cowpea	5.9	0.160	3.14	10.44	2947	2014	2481
Sole maize without fertilizer	6.0	0.197	3.23	10.65	3572	2362	2967
Sole maize with fertilizer (50/65 kg/ha DAP/Urea)	6.1	0.189	3.22	8.35	3751	2987	3369
Sole maize with 65 kg/ha urea	6.0	0.189	3.08	9.24	3485	1771	2628
LSD (5%)					NS	NS	
CV (%)					20.48	46.61	

Source: Unpublished research results from Awassa Agricultural Research Center (AwARC).

Table 8. Effect of preceding crops on succeeding haricot bean yield (kg/ha) in a double cropping system, Areka.

Preceding crop	Year 1993 F0	1993 F1	1994 F0	1994 F1	1995 F0	1995 F1	1996 F0	1996 F1	Mean F0	Mean F1	Grand Mean
Maize (A511)	450	520	440	650	340	660	100	310	332	535	434
Maize (Katumani)	360	610	340	590	480	770	140	300	330	568	449
Tef	450	410	660	670	500	1010	370	770	495	715	605
Potato	206	410	270	750	190	520	110	710	194	598	396
Sweet potato	202	380	200	760	200	540	90	420	173	525	349
Fallow	590	720	1120	1170	400	790	–	--	703	893	798
Mean	376	508	505	765	352	715	162	502	371	639	
CV(%)		29									

LSD (5%) for crop sequence (CS) was not significant, for fertilizer (F0 application was significant and for CSxF was not significant

F0 = No fertilizer applied to the precursor crop; F1 = Fertilizer applied. Source: Unpublished research results from Areka Agricultural Research Center (ArARC).

A crop rotation study conducted at Melkassa from 1992 to 1994 involving crop mixtures and sole crop sequences in maize system indicated that maize preceded by sole haricot bean was found productive whenever supplemented by mineral fertilizer (Habtamu et al., 1996). The contribution of haricot bean in the rotation with cereals on soil fertility and consequent cereal grain yields and their fertilizer requirement was underway at Melkassa. The results of an experiment in 2003 crop season on tef showed that the highest grain yield (555 kg/ha) and straw yield (1789 kg/ha) was obtained from *tef* planted after haricot bean rotation fertilized with 69 kg N/ha, while 326 kg/ha of grain and 1392 kg/ha of straw yield was obtained from continuous tef fertilized with the same rate of nitrogen.

Intercropping: An experiment was conducted to determine plant population for maize/bean intercropping at Areka for three years (between 1993 and 1997). The plant spacing for maize included, 20 cm (88,888 plants/ha), 25 cm (53,333 plants/ha) and 30 cm (44,444 plants/ha); and for bean included, 5 cm (325,925 plants/ha), 10 cm (177,777 plants/ha) and 15cm (118,518 plants/ha). The spacing for the two crops was laid out in RCBD in a factorial arrangement. Haricot bean was planted alternating between the rows of maize. The row spacing was constant at 75 cm and both crops were sown simultaneously. The varieties were A-511 and Awash-1 for maize and haricot bean, respectively. Sole crops were sown at their recommended spacing to calculate LER. Data were available only for three years because of failure encountered for two years (1994-1995).

The grain yield of bean was affected by its plant spacing. However, it was not significantly affected by the maize spacing (Table 9). The highest bean grain yield was from 5 cm spacing, which was significantly different from 15 cm. However, it was not significantly different from 10 cm spacing, which is the recommended space for sole haricot bean. The different spacings for maize had no significant effect on bean although better yield was obtained with wider maize spacing. Maize grain yield, on the other hand, was not significantly affected by both spacings, but was favored by lower maize spacing and higher bean spacing. The highest LER was from 25 cm maize spacing and 10 cm bean spacing, with a yield advantage of about 47% over the sole- cropping. LER also revealed that the recommended plant spacing for maize and bean in their sole cropping was also optimum for their association under Areka conditions.

An on-farm study was conducted at Melkassa to determine the effect of inter-cropping of beans with cereals, sorghum and maize. Planting pattern and schedule for maize-haricot bean intercropping system was tested during the 1992/1993 cropping season. The results revealed that planting both crops in row or broadcast simultaneously or bean relayed at shilshalo stage of maize was the appropriate system (Habtamu *et al.*, 1996). However, the highest LER of 1.57 was obtained from 2 rows of maize intercropped with 1 row of haricot bean simultaneously with maize (Table 10). This combination also gave the highest net benefit of 1887 Birr/ha.

Table 9. Effect of plant population on grain yield (kg/ha) of maize and haricot bean in intercropping over years, Areka.

Spacing (cm)		1993		1996		1997		Mean		
Maize	Bean	Maize	Bean	Maize	Bean	Maize	Bean	Maize	Bean	LER**
20	5	1867	222	2632	321	1691	221	2063	255	1.27
20	10	1928	190	3090	410	2091	181	2370	260	1.39
20	15	2622	105	3274	253	2198	207	2698	188	1.36
25	5	1563	284	2052	433	2217	315	1944	344	1.42
25	10	1983	259	3484	330	2024	242	2497	277	1.47
25	15	1607	124	3210	269	2642	203	2486	197	1.30
30	5	1173	253	2531	378	2284	325	1996	319	1.38
30	10	1743	161	1995	361	1844	179	1861	234	1.15
30	15	1847	135	3187	410	2345	167	2476	238	1.38
Mean		1820	193*a*	2828	352*ab*	2148	227*b*			
Sole*		1753	586	3407	561	3296	275	2819	474	
Mean (spacing)		Maize spacing				Bean spacing				
		20cm		2378	237	5cm		2000	305*a*	
		25cm		2311	274	10cm		2244	257*ab*	
		30cm		2104	267	15cm		2548	208*b*	
		Maize space	Bean space	Year	Interaction (all)					
LSD	Maize	NS	NS	**	NS					
	Bean	NS	**	**	NS					
CV (%)	Maize	35.3								
	Bean	35.4								

NS= Non-significant; * and **= Significant at 5% and 1% level of significance, respectively. Source: Unpublished research results from Areka Agricultural Research Center (ArARC).

Similar experiments were conducted at MARC and AwARC in 1992 crop season. At Melkassa, bean varieties intercropped in 2-row maize/1-row bean pattern gave significantly higher bean and maize yield. While, at Awassa, Awash-1 planted in maize/bean mixed in the same row pattern produced higher maize grain yield, whereas higher bean grain yield was obtained from M-142 planted in the same pattern. Besides, regardless of bean varieties, higher total LER and net return were obtained in 2-row of maize/1-row bean at Melkassa (Table 11). The two bean varieties gave higher grain yield when intercropped simultaneously with maize than when relayed (Table 12) (Nigussie and Reddy, 1995). Generally, the results obtained from these separate experiments were similar. In sorghum crop, it was also seen that alternate sowing of two rows of sorghum with a row of beans at a population density of 89,000 and 375,000 plants/ha was beneficial (Kidane et al., 1990).

A study was conducted to assess the possibility of intercropping pigeonpea with maize to improve soil fertility and crop yield on acid soil of Areka. Pigeonpea was intercropped between the rows (80cm spacing) of maize. Cropping system (sole and intercrop) combined with four levels of N and P fertilizer were laid out in a split-plot design. Cropping system was the main plot and NP interactions were sub-plots. Pigeonpea intercropping considerably decreased the grain yield of maize (Table 13).

The over all mean yield difference between sole- and intercropped maize was 1302 kg. However, this difference was higher (1980 kg) when fertilizer was not applied in both cropping systems. Percentage of yield loss due to intercropping decreased with increased rates of fertilizer application. Both N and P fertilizers had significant ($P<0.05$) effect on maize grain yield. The highest yield was obtained from the application of 46/69 kgN/P_2O_5/ha of sole-cropping. It has been concluded that compatible way of integrating pigeonpea in the cropping system or transferring its biomass should be further studied to utilize the crop in improving soil fertility beside its other uses.

Table 10. Different planting pattern and time of planting for intercropped maize haricot bean at Melkassa (1992-1993).

Pattren/time of intercropping	Grain yield (kg/ha) Mz	Hb	LER	Net income (Birr/ha)
Sole maize		-	1.00	1355
Sole haricot bean	-	1367	1.00	1440
Mz/Hb mixed broadcast and planted simul.	1258	884	1.49	1851
Mz in row and Hb broadcast and planted simul.	1026	866	1.25	1607
Mz/Hb mixed in the same row and planted simul	1227	715	1.19	1576
2Mz and 1 Hb rows planted simul	1623	660	1.57	1887
Mz/Hb mixed broadcast but planted at *shilshalo*	1821	174	1.18	1441
Mz in row and Hb planted in b/n rows at *shilshalo*	1728	319	1.25	1454
P<0.05	2.06	0.91	0.12	-

Note: Mz, maize; Hb, haricot bean; and Simul, simultaneous. Source: Habtamu et al. (1996).

Table 11. Effect of planting pattern and bean varieties on component grain yield, land use efficiency and net returns at Melkassa and Awassa.

	Bean variety							
	Awash-1				M-142			
Treatment	BY	MY	LER	NR	BY	MY	LER	NR
Melkassa								
2 maize/bean intercrop	1216	3570	1.40	3625	1119	3549	1.43	3428
Both mixed in same row	1201	3279	1.31	3351	1103	3280	1.35	3194
Maize row/bean broadcast	1141	3183	1.26	3016	1247	2704	1.26	2863
Maize/bean both broadcast	1008	2461	1.03	2286	1101	2753	1.22	2628
Mean	1142	3123	1.25	3070	1143	3072	1.31	3028
LSD(0.05)					37.2	87.3	0.04	141.34
Awassa								
2 maize/bean intercrop	1147	3149	1.25		1109	3237	1.28	3137
Both mixed in same row	1145	3250	1.29		1191	2874	1.20	2914
Maize row/bean broadcast	847	3175	1.18		837	2345	0.94	1983
Maize/bean both broadcast	834	2930	1.10		780	2423	0.89	1657
Mean	994	3126	1.21		977	2720	1.08	2410
LSD(0.05)					49.99	82.89	0.04	126.74

Note: BY= bean grain yield (kg/ha); MY= maize grain yield (kg/ha); LER=total land equivalent ratio; NR=net returns (Birr/ha).

Table 12. Effect of planting schedule and bean varieties on component grain yield, land use efficiency and net returns at Melkassa and Awassa.

	Planting schedule							
	Simultaneous				Relay			
Treatment	BY	MY	LER	NR	BY	MY	LER	NR
Melkassa								
Intercropped with Awash-1	1411	2927	1.31	3267	872	3319	1.20	2872
Intercropped with M-142	1352	2898	1.36	3183	932	3245	1.26	2873
Mean	1382	2913	1.34	3225	902	3277	1.23	2873
LSD(0.05)					26.27	61.71	0.03	NS
Awassa								
Intercropped with Awash-1	1114	3104	1.23	2989	983	3148	1.17	2711
Intercropped with M-142	1098	2553	1.08	2496	783	2887	1.07	2324
Mean	1106	2828	1.15	2748	828	3018	1.12	2518
LSD(0.05)					35.35	58.61	0.03	93.16

Note: BY= bean grain yield (kg/ha); MY= maize grain yield (kg/ha); LER= total land equivalent ratio; NR=net return (Birr/ha).

Table 13. Effect of pigeon pea intercropping on grain yield (kg/ha) of maize, Areka, 1997.

Fertilizer rate (kg/ha)		Cropping system		Mean	Yield reduction due to
N	P_2O_5	Sole-cropping	Intercropping	(NP interaction)	intercropping (%)
0	0	4063	2083	3073	48.7
0	23	3958	2500	3224	36.8
0	46	4688	4063	4373	13.3
0	69	5208	5313	5260	-
23	0	6042	3646	4844	39.6
23	23	4063	3229	3646	20.5
23	46	5417	5521	5469	-
23	69	5729	4479	5104	21.8
46	0	6146	3646	4896	40.6
46	23	7396	5000	6198	32.3
46	46	6250	5521	5885	16.5
46	69	6458	4791	5664	25.8
Mean		5451	4149		23.9
	Cropping system	fertilizer	Interaction		
LSD (5%)	NS	1653	NS		
CV (%)	27.22				

Source: Unpublished research results from Areka Agricultural Research Center (ArARC).

Integrated Crop Management

***Residual effect of applied fertilizer for maize on fertilizer requirement of haricot bean*:** An experiment was carried out to see the effect of fertilizer applied on maize on the subsequent fertilizer requirement of haricot bean grown immediately after maize in a double cropping system at Areka for three years (1998, 1999 and 2001). The fertilizer rate applied for maize was 46/46 N/P_2O_5 kg/ha, and the levels for haricot bean were 0, 11.5/4.5, 23/9, 34.5/13.5 and 46/18 P_2O_5/N kg/ha. Wolaita variety for haricot bean and variety BH-140 for maize were used.

Mean yield of haricot bean in each year and combined mean yields of three years showed that the levels of N/P had significant effect on yield (Table 14). The response of haricot bean was, however, different in both cases. Better yields were obtained from 9/23 to 13.5/34.5 kg/ha N/P_2O_5 in 1998 and 1999, but from 4.5/11.5 kg/ha N/P_2O_5 in 2001. In all the years, the least yield was obtained from the untreated plots. The overall mean of the three years showed that the application of 13.5/34.5 kg/ha N/P_2O_5 resulted in better yield than other levels. Yield was not significantly affected by season and interaction between N/P and season. Phosphate fertilizer had significant effect also on plant population and plant height (data not shown). Plant population was highest with application of 4.5/11.5 kg N/P_2O_5/ha and, in general, fertilizer application increased plant height. In conclusion, application of 9/23 to 13.5/34.5 kg/ha N/P_2O_5 is enough for bean following fertilized maize in double cropping system.

Table 14. Effect of DAP on grain yield (kg/ha) of succeeding haricot bean over years, Areka.

N/P_2O_5 rate	Year		
kg/ha	1998	1999	2001
0	386d	392c	300b
4.5/11.5	541cd	504bc	616a
9/23	797bc	728ab	664a
13.5/34.5	914ab	672ab	672a
46/46	877a	858a	645a
LSD	183.8**	246.6*	288.4**
CV(%)	24.9	25.3	23.1
	DAP	Year	Year x
DAP			
LSD	144**	NS	NS

NS= Non-significant; * and **= Significant at 5% and 1% level of significance, respectively. Source: Unpublished research results from Areka Agricultural Research Center (ArARC).

***Impact of eucalyptus trees on nearby sown haricot bean*:** An effort was made to see the impact of eucalyptus trees on the nearby-sown haricot bean (var. Red *Wolaita*). The experiment was conducted at Areka for four years. The treatments were root pruning (pruned and unpruned), and sowing distance from eucalyptus tree (ranging between 2 and 17 m). The experimental design was split-plot in which root pruning was the main plot. A trench was dug one meter away from established eucalyptus trees to prune or cut the roots. It was 0.5m wide and 1m deep. Haricot bean was sown from 2m to 17m away from the base of the eucalyptus stems. The crop was harvested at 3-m interval.

Distance from the trees had significant (P<0.05) effect on haricot grain yield (Table 15), which increased as the distance from the trees increased. The mean yield obtained from bean plots 5-8 m or more away from was significantly higher than the nearest plots. The yield obtained at 11 to 14 m was 60 % higher than the yield obtained from plots 2 to 5 m away from the trees. Root pruning and its interaction with distance had no significant effect on grain yield of bean. However, there was a considerable yield advantage with root pruning and the interaction. A yield advantage of 186 kg/ha was obtained with pruning, which was about 16% over unpruned roots. The highest yield from the interaction was obtained from pruned roots at a distance of 8 to 11 m. The highest yield obtained with root pruning was from plots relatively nearer (by at least 3 m) to the trees than with unpruned roots. This showed that root pruning could be used to decrease the effect of eucalyptus trees on bean yields, which continuously expanded for its fast growth habit and multiple uses.

RESULTS OF PHYSIOLOGIC STUDIES

Abuhay and McDavid (1996) conducted pot experiment under greenhouse conditions in the Rift Valley to compare stomatal behavior, water relations and leaf area development of pigeonpea and cowpea under variable moisture stress. Three treatments included, seriously stressed (SS), i.e., soil water content maintained at 30% field capacity (FC); moderately stressed (MS), i.e., soil water content maintained at 50% FC; well-watered (WW), i.e., soil water content maintained at 85% FC. The results showed that moisture stress in pigeonpea increased the stomatal resistance (SR) of only abaxial surface, whereas in cowpea it increased SR of both leaf surfaces (abaxial and adaxial surfaces). This difference suggested that the threshold for stomatal closure in cowpea was much higher than for pigeonpea.

Leaf water potential was also affected by increased moisture stress, and water potential in the SS plants was significantly lower than that of MS and WW plants. Leaf water potential values in pigeon pea were lower than in cowpea in all the treatments over time. Differences also occurred in leaf relative water content (LRWC) between the moisture stress treatments and between the two crops. The LRWC of SS plants was significantly lower in both pigeon pea and cowpea throughout the study. LRWC in stressed plants declined more rapidly in pigeonpea than in cowpea. Differences in both leaf water potential and LWRC were attributed to the differences in the stomatal behavior of pigeon pea and cowpea. Leaf area developments were adversely affected by increasing the levels of moisture stress in both crops.

FUTURE RESEARCH DIRECTIONS

In future, moisture conservation should be the major component of soil fertility management.

Long-term organic and inorganic fertilizer study will need to be carried out for specific agro-ecologies and soil types. Study on long-term crop rotation system involving legumes will need to be carried out to determine fertilizer schedules and place of legumes in the rotation, and their role in sustaining soil fertility and crop production. Further studies are required on long-term cropping systems with special emphasis on sustenance of soil fertility and crop productivity, and fertilizer management in the system.

Table 15. Effect of sowing distance, eucalyptus root pruning and season on grain yield (kg/ha) of haricot bean, Areka.

Treatment		Year				
Root pruning	Distance from the tree (m)	1997	1998	1999	2000	Mean
Unpruned	2-5	891	1104	1228	302	881
Unpruned	5-8	747	916	750	979	848
Unpruned	8-11	926	1343	1084	1750	1276
Unpruned	11-14	885	1115	1959	1896	1464
Unpruned	14-17	827	1219	875	1896	1204
Pruned	2-5	1037	479	1750	490	939
Pruned	5-8	1102	1396	1916	937	1338
Pruned	8-11	1212	1687	1916	1594	1602
Pruned	11-14	1110	1666	1166	1854	1449
Pruned	14-17	937	1166	1375	1635	1278
Year mean		967	1209	1402	1333	

	Pruning(p)	Distance(d)	Year(y)	pd	py	dy	pdy
LSD (5%)	NS	265.8	*	NS	NS	**	*
CV (%)	28.16						

Note: NS= Non-significant; * and **= Significant at 5% and 1% level of significance, respectively. Source: Unpublished research results from Areka Agricultural Research Center (ArARC).

REFERENCES

Abdissa Gemeda, and Setegn Gebeyehu. 1994. Bean production and constraints: Implications for future strategies with major emphasis to climbing beans. Paper presented at the Second Beans Planning Workshop, CIAT/IAR, Oct. 26-30, 1994, Nazareth, Ethiopia.

Abuhay Takele, and C.R. McDavid. 1996. Stomatal behavior, water relation and leaf area development of cowpea grown under moisture stress. *In* Woldeyesus Sinebo et al. (Eds.) *Increasing Food Production through Improved Crop Management.* Proc. First and Inaugural Conference of Agronomy and Crop Physiology Society of Ethiopia (ACSPSE), 30-31 May 1995, Addis Ababa, Ethiopia.

Asnakew Woldeab. 1991. Development of Technologies for the Dry Land Farming Areas of Ethiopia. *In* M.S. Reddy and Kidane Giorgis (Eds.) Proc. First National Workshop on the Dry Land Farming Research in Ethiopia, 26-28 Nov. 1991, Nazareth, Ethiopia.

AwARC.1993-2003. Research progress report for the years 1993 to 2002. Awassa Agricultural Research Center (AwARC), Awassa, Ethiopia.

Belay Semane, C.W.S. Wortman, and G. Hoogenboom. 1998. Haricot bean agro-ecology in Ethiopia: definition using agro-climatic and crop growth simulation models. *African Crop Science Journal* 6: 9-18.

CACC. 2002. Ethiopian agricultural sample enumeration, 2001/2002: Report on the primary results of area, production and yield of temporary crops (*Meher* season private peasant holding). Part I. Oct. 2002. Central Agricultural Census Commission (CACC), Addis Ababa, Ethiopia.

CSA. 2002. Time series data on area, production and yield of major crops, 2001/2002, Statistical Bulletin. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

FAO. 1979. Bean yield response to water p. 77-78. *In* J. Doorenbos and A.H. Hassam (Eds.). *Irrigation and Drainage* Paper 33. FAO, Rome.

Gemechu Gedeno. 1990. Haricot bean (*Phaseolus vulgaris* L.) agronomic research at Bako. p. 63-67. In Research on Haricot Bean in Ethiopia: An Assessment of Status, Progress, Priorities and Strategies. Proc. National Workshop Held in Addis Ababa, 1-3 Oct. 1990.

Habtamu Admasu, M.S. Reddy, Teshale Alemu, and Jibril Mohammed. 1996. Maize based cropping system for sustainable agriculture in semi-arid areas of Ethiopia. p.74-82 *In* Proc. First Agronomy and Crop Physiology Society of Ethiopia, Addis Ababa. Ethiopia.

Jasdanwala, R.T., A.G. Chege. 1993. The effect of season on grain yield and soil N contribution of four cultivars of beans. p. 44-51 *In* J.B. Smithson (Ed.) Proc. Third Multidisciplinary Workshop on Bean Research in Eastern Africa, Thika, Kenya, 19-22 April 1993. Network on Bean Research in Africa, Workshop Series No. 28. CIAT, Kampala, Uganda.

Kidane Georgis, Amare Abebe, Adhanom Negasi, Legesse Dadi, and WoldeYesus Sinebo. 1990. Cereal/legume inter-cropping research in Ethiopia. p. 167-175. *In* Proc. Workshop on Research Methods for Cereal/Legume Inter-cropping in Eastern and Southern Africa, Lilongwe, 21-28 Jan. 1989, Mexico, CIMMYT.

Lynch, J., and M. Piha. 1988. Adaptation of beans to infertile soils p. 89-95. *In* C.S. Wortman (Ed.) Proc. Workshop on Soil Fertility Research on Bean Cropping System in Africa, Addis Ababa, Ethiopia, 5-9 Sept., 1988. CIAT African Working Series No. 3.

Nigusse Tesfamicheal and M.S. Reddy. 1995. Maize/bean intercropping effect on component yield, land use efficiency and returns at Awassa and Melkassa. p. 51-55. *In* Woldeyesus Sinebo et al. (Eds.) *Increasing Food Production through Improved Crop Management.* Proc. First Inaugural Conference of the Agronomy/Crop Physiology Society of Ethiopia. Addis Ababa, Ethiopia.

Raya Abdagodu. 1988. Sidama mixed farming zone diagnostic survey report, Sidamo region. Research Report No 3/88. Institute of Agricultural Research (IAR), Ethiopia.

Rice, R.P., L.W. Rice, and H.D. Tindal. 1986. Fruit and Vegetable Production in Africa. Edition Hong-Kong.

Tsedeke Abate. 1990. Bean entomology. Paper presented at the National Planning Workshop on Haricot Bean, 1-3 Oct. 1990, Addis Ababa, Ethiopia.

Tsedeke Abate. 1995. Effect of seeding date and plant density on yield components and yield of common bean in south-central Ethiopia. Paper presented at the Sixth Annual Conference of Crop Science Society of Ethiopia, Addis Ababa, Ethiopia.

Cropping Systems and Soil Fertility Research on Haricot Bean (*Phaseolus Vulgaris* L.) in Eastern Ethiopia: A Review

Tamado Tana and Chemeda Fininsa

Department of Plant Sciences
Alemaya University, P. O. Box 138, Dire Dawa

ABSTRACT

Haricot bean (*Phaseolus vulgaris* L.) is one of the major food legumes in eastern Ethiopia, accounting for about 3% of the total cultivated area. About 95% of haricot bean is grown in intercropping mainly with sorghum and/or maize. The sole cropped bean is often grown on marginal soils, where nutrients and water are limiting. Several experiments were conducted on bean, maize and/or sorghum cropping systems in eastern Ethiopia with the objective of identifying appropriate density, planting pattern, planting date, fertilizer response and compatible bean genotypes for intercropping. However, limited studies were done on soil fertility on beans. This paper reviews recent research conducted on haricot bean cropping systems and soil fertility in eastern Ethiopia. The productivity of bean, intercropped with maize and sorghum, as measured by Land Equivalent Ratio (LER) was in most cases higher than sole cropping of the component crops. The LER was generally higher at marginal locations. However, higher agronomic advantage did not always give higher monetary advantage. Application of nitrogen and phosphorus fertilizers generally increased grain yield of bean, but the nodulation was decreased with increased rate of nitrogen. Systematic research is suggested to develop management options that could be tested and modified by farmers.

INTRODUCTION

Haricot bean (*Phaseolus vulgaris* L.) is one of the major food legumes in Hararge, eastern Ethiopia accounting for about 3% (11007 ha) of the total cultivated area (CSA, 2002). It is used as a cheap source of protein, a cash crop, an emergency crop in times of crop failure, and a supplementary animal feed. Bean is grown in crop rotations and intercropping mainly with sorghum and/or maize (Shemelis et al. 1990). It was estimated that about 95% of haricot bean is grown in an intercropping pattern involving two or more crops in eastern Ethiopia, the most common being sorghum and/or maize (Storck et al., 1991). Farmers attribute several advantages to intercropping as compared to the sole cropping of the component crops. These include: diversification of crop products, provision of balanced food, and supply of feed over longer periods of time, minimization of risk against poor crop harvests and crop failures, higher productivity and maintenance, and improvement of soil fertility. Depending on the environmental requirements of pathogens and insect-pests, intercropping could also help in the management of diseases and insect-pests.

In eastern Ethiopia, a sole crop of bean is often grown on marginal soils, where nutrients are limiting (Mitiku, 1990), and the crop is mainly produced by smallholder farmers who have limited access to inputs. However, farmers' practice whenever possible is to apply chemical fertilizer to associated cereal crops, causing beans to compete for the nutrients. Thus, yield potentials of haricot bean are not fully realized by farmers due to lack of recommendations on optimum cropping systems and soil fertility management. This paper reviews recent research conducted on these aspects in eastern Ethiopia, mainly at eastern Hararge, western Hararge and Dire Dawa.

The productivity of the intercrop systems as compared to sole crops was assessed by total Land Equivalent Ratio (LER), i. e., the relative land area required as sole crop to produce the same yield as an intercrop (Willey, 1979). The LER values of >1.00 indicate an agronomic advantage of intercropping over sole cropping. Gross Monetary Value (GMV) was also calculated to give some economic evaluation of the intercropping as compared to sole cropping.

CROPPING SYSTEMS

Component Crop Density

The overall mixture densities and the relative proportion of component crops are important factors in determining yield and production efficiency of bean/maize and bean/sorghum intercrop systems. Demissew (2002) conducted an intercropping study involving 25, 50 and 75% of sole bean variety Gofta population densities (250, 000 plants/ha) with optimum population (44,444 plants/ha) of maize variety Raare-1 at Alemaya. The highest LER of 1.06 was obtained from intercropping of 25% sole bean population (62500 plants/ha) with the recommended sole population of maize (Table 1). The LER showed a decreasing trend when the population of bean was increased from 25 to 100%. However, the highest GMV of 5100 Birr/ha was obtained from sole maize at the prevailing prices of that year. This was because of high yield potential of maize under sole cropping at Alemaya. Thus, GMVs were not always consistent with total LER values, indicating the need for economic evaluation of intercrop systems, over seasons and years. Tamado & Eshetu (2000) also reported the highest GMV value from sole cropped maize than intercropping with bean at Alemaya.

Table 1. Effect of population of haricot bean on performance of bean intercropped with optimum (100%) population of maize or sorghum in eastern Ethiopia.

Source of data/ parameters	Proportion of bean 25%	50%	75%	100%	Sole crop
Demissew (2002)					
Bean yield (kg/ha)	264	340	325	321	1709
Maize yield (kg/ha)	6171	5735	5295	5110	6800
LER	1.06	1.04	0.97	0.94	1.00
GMV (Birr/ha)	4971	4744	4394	4249	2222(5100)*
Yoseph et al. (2003)					
Bean yield (kg/ha)	479	649	857	-	3157
Maize yield (kg/ha)	7213	8312	7422	-	7561
LER	1.09	1.29	1.33		1.00
GMV (Birr/ha)	12032	13991	12887		3789 (12071)*
Bean yield (kg/ha)	362	595	556	-	799
Sorghum yield (kg/ha)	1473	1215	1193	-	1673
LER	1.34	1.48	1.41		1.00
GMV (Birr/ha)	3384	3227	3144		1209 (3203)*
Yesuf (2003)					
Bean yield (kg/ha)	567	576	506	-	910
Sorghum yield (kg/ha)	1661	1397	1235	-	1856
LER	1.52	1.39	1.22		1.00
GMV (Birr/ha)	3766	3391	2989		2047 (2784)*

*Gross monetary valuesnot between brackets are that of bean while those between brackets are of maize or sorghum.

On the other hand, Yoseph et al. (2003) reported the highest LER of 1.33 when 75% of bean var. Ayenew population (187,500 plants/ha) was intercropped with recommended population (44,444 plants/ha) of maize var. Raare-1 population. But the highest GMV of 13991 Birr/ha was obtained from intercropping of 50% of bean population (125,000 plants/ha) with recommended population of maize. In a similar study involving bean var. Ayenew and sorghum var.76 T1 # 23, they obtained the highest land use efficiency (LER = 1.48) from 50% bean population (125,000 plants/ha) and recommended sole population (53, 333 plants/ha) of sorghum at Babile (Table 1). However, the highest GMV of 3384 Birr/ha was obtained from intercropping of 25% of bean population (62,500 plants/ha) with recommended plant population of sorghum, which shows a greater yield contribution of sorghum to mixture yield. Like wise, Yesuf (2003) obtained the highest land equivalent ratio (LER) of 1.52 and Gross Monetary Value (GMV) of 3766 Birr/ha from intercropping of 25% of sole bean 'var. Mexican-142' population with an optimum sole population of local sorghum cv. Amajigita at Dire Dawa. He obtained a decreasing trend both in LER and GMV when the proportion of bean was increased from 25% to 75%. This could be due to an increase in competition for soil moisture with an increase in total population in such moisture deficit areas.

Although the yields of component crops were generally lower at Babile and Dire Dawa due to their marginal growing conditions, the average efficiency of intercropping as measured by total LER was higher than that at Alemaya (Table 1). This might indicate a more efficient utilization of growth resources by intercropping system under stress environmental conditions, which could contribute towards more yield stability. Tamado (1994) and Tamado & Eshetu (2000) also reported similarly higher LERs from groundnut/sorghum and bean/sorghum intercropping studies, respectively, at Babile than at Alemaya. The former site is moisture stress area, whereby there is enough moisture at certain parts of the season, but the growing season is short to the support late-maturing intercropping components.

Planting Pattern

Row arrangements, in contrast to arrangements of component crops within rows, could improve the amount of light received by the lower legume canopy. Some degree of grouping of the crops may provide greater advantages from intercropping by ensuring that the lower component crop receives a reasonable amount of light. Widening inter-row spacing of cereal component to accommodate more rows of the legume component improves legume seed yield and efficiency of the intercrop system. In bean/maize variety Alemaya Composite intercrop study, Chemeda (1997) obtained the highest LER of 1.30 from row intercropping than mixed intercropping at Alemaya (Table 2). Row intercropping gave relatively higher bean and maize yield than mixed intercropping. Similarly, Tamado & Eshetu (2000) reported the highest LER of 1.43 from bean variety GLPX-92 and sorghum variety IS-9302 intercropping as compared with mixed intercropping (LER = 1.13). In contrast to these, Dechassa (1996) did not observe a marked LER difference when bean and sorghum were row-intercropped or mixed intercropped (Table 2).

The use of double rather than single alternate row arrangements of component crops improved the yield and light penetration to the canopy of the legume component. In this regard, Kassu (1993) from bean/sorghum intercropping study obtained the highest LER of 1.22 when sorghum was grown in two paired rows spaced 140 cm with 4 rows of bean in between.

Relative Planting Date of Component Crops

The relative planting date of component crops is an important management variable manipulated in cereal-legume intercrop systems. The differential sowing improves productivity and minimizes competition for growth-limiting factors in intercropping by creating temporal and spatial complementarity between the component crops. Chemeda (1997) from bean cultivar. Red Wolaita relative planting date study with maize variety Alemaya Composite reported that simultaneous planting and planting of bean 10 days before maize improved bean grain yields (Table 3). The possible reason for this is that greater competitiveness of early-sown bean than the late-sown bean. Similarly, delayed bean planting generally increased maize grain yields. However, the highest LER of 1.18 was obtained when bean was planted 10 or 20 days after maize, and the lowest LER of 0.98 when bean was planted 10 days before maize showing more competitiveness of the cereal component. However, planting dates of intercrops should consider farmers' practices and choices in terms of labor availability, *shishalo* and other socio-economic factors.

Response to Nutrients

The response of component crops to applied nutrients differs in different cereal-legume intercropping systems. The cereal component with a faster-growing or more extensive lateral root system generally has a competitive advantage over the associated legume. There is a long-standing belief that advantages may occur only in low-fertility situations and this probably arises from the fact that intercropping could maximize resource-use efficiency under stress environments. In contrast to this traditional belief, Kassu (1993) from bean/sorghum and Demissew (2002) from bean/maize intercropping study, obtained a slightly increasing trend in LER with an increase in rate of application of nutrients (Table 4).

Genotype Identification

There is a need for identification of suitable genotypes for intercropping components, as the behavior of mixed stands is not predictable from the behavior of pure stands. In agreement with this, Dechassa (1996) from bean and sorghum cropping systems study, obtained significant genotype by cropping systems interaction (Table 5) and concluded that bean genotypes selected for high yield in sole crops to be not necessarily suitable for intercropping. Among five varieties of bean (GLPX-92, G-2816, BAT-338-1c, A-82, Mexican-142) evaluated under sole cropping, row and mix intercropping, with sorghum (varieties ETS-2752 & IS-9323), on the average variety G-2816 performed best under sole cropping, while variety A-82 gave the highest agronomic advantage from intercropping as measured by LER (Table 5).

SOIL FERTILITY MANAGEMENT

Generally, beans have high nitrogen requirement for expressing their genetic potential. However, as beans have the ability to fix and use atmospheric nitrogen, phosphorus is considered as the first and nitrogen as the second limiting plant nutrient for bean yield in the tropical zone of cultivation (CIAT, 1998). However, limited research has been done in eastern Ethiopian on soil fertility aspect of bean production.

Table 2. Effect of planting pattern of component crops on productivity and efficiency of bean/maize or bean/sorghum intercropping in Hararghe, eastern Ethiopia.

Crop combination and treatment	Bean grain yield (kg/ha)	Cereal grain yield (kg/ha)	LER	Reference
With maize at Alemaya				
Mix intercrop	510	3636	1.00	Chemeda (1997)
Row intercrop	771	4938	1.30	
Sole crop	1942	5673	1.00	
With maize at Babile				
Mix intercrop	398	3437	1.15	Tamado and
Row intercrop	206	4085	1.13	Eshetu (2000)
Sole crop	930	4724	1.00	
With sorghum at Babile				
Mix intercrop	289	2800	1.13	Tamado and
Row intercrop	415	3175	1.43	Eshetu (2000)
Sole crop	930	3476	1.00	
With sorghum at Alemaya				
Mix intercrop	301	5138	0.97	Dechassa (1996)
Row intercrop	178	5620	1.00	
Sole crop	2230	5942	1.00	
With Sorghum at Babile				
Mix intercrop	401	4271	1.05	Dechassa (1996)
Row intercrop	328	4288	0.99	
Sole crop	1637	4948	1.00	

Mitiku (1990) conducted field experiments on the effect of nitrogen levels on bean grain yields in Vertisols at Alemaya and in Alfisols at Hamaressa, in eastern Hararge. The application of nitrogen fertilizer to bean on both soil types suppressed nodulation but resulted in grain yield increase. (Table 6). The reduction in nodulation could be due to the preference by plants for the readily available applied mineral nitrogen than nodulation and nitrogen fixation, which is an expensive energy demanding process. The highest grain yield of 2749 kg/ha was obtained from 46 kg N/ha on Vertisols at Alemaya, whereas 23 kg N/ha gave the highest grain yield of 1407 kg/ha on Alfisols at Hamaressa. The highest N rate (69 kg/ha) was not superior at both the sites. This implies a need for application of nitrogen to haricot bean at both the sites. On the contrary, Eden (2002) reported an increase both in total and effective number of nodules with increasing rates of phosphorus on Entisols at Alemaya (Table 6). This is probably because phosphorus plays an important role in biological nitrogen fixation. Seed yield was also increased with increase in the rate of phosphorus up to 30 kg/ha, but the yield at 40 kg P/ha was lower. The highest seed yield was obtained at the phosphorus rate of 20-30 kg/ha, which may be economical at 20 kg/ha.

FUTURE RESEACH DIRECTIONS

Considerable efforts have been devoted to agronomic factors affecting the efficiencies of haricot bean/sorghum and bean/maize cropping systems. However, there is no conclusive recommendation for maximizing the production efficiencies of different systems. Thus, a more systematic study is required. Some suggestions for future research directions are:

1. There is a need to formulate a package of practices on bean cropping systems that can be tested and recommended to farmers.
2. Need for basic study on the possible effects of availability of various nutrients and soil moisture (including moisture conservation practices) on yield advantage from intercropping, and need for determining optimum fertilizer rate for bean/sorghum and bean/maize intercropping systems and soil types.

Table 3. Effect of planting date of bean on yields and Land Equivalent Ratio (LER) of bean/maize intercropping in Hararghe highland, eastern Ethiopia.

Bean relative planting date	Bean grain yield (kg/ha)	Maize grain yield (kg/ha)	LER
10 days before maize	877	3899	0.98
Simultaneous with maize	965	4357	1.09
10 days after maize	740	5341	1.18
20 days after maize	672	5604	1.18
30 days after maize	653	4981	1.08
Sole bean	2678	-	1.00
Sole maize	-	5971	1.00

Source: Chemeda (1997).

Table 4. Effect of fertilizer application on performance of bean intercropped with maize or sorghum.

	N rate (kg/ha)				
Parameter	0	29	58	87	Sole crop
Demissew (2002)					
Bean yield (kg/ha)	300	324	314	312	1709
Maize yield (kg/ha)	5058	5476	6091	5687	6800
LER	0.92	0.99	1.08	1.02	1.00
GMV (Birr/ha)	4184	4528	4976	4670	2222(5100)*
	Fertilizer rate (kg/ha)				
	Without fertilizer		With fertilizer (150 DAP + 100 urea)		
Kassu (1993), Alemaya					
Bean yield (kg/ha)	377		511		
LER	0.99		1.10		

Table 5. Grain yield (kg/ha) of bean varieties and LER of the intercropped bean/sorghum as affected by cropping systems in Hararghe, eastern Ethiopia.

	Sole crop	Row intercrop		Mix intercrop	
Site & varieties	Grain yield	Grain yield	LER	Grain yield	LER
Alemaya					
GLPX-92	2917	209	0.91	305	0.83
G-2816	2611	247	0.87	387	0.98
BAT-338-1c	1917	123	0.85	210	1.15
A-82	1994	163	1.15	273	0.89
M-142	1711	146	1.23	329	0.97
Mean	2230	177.6	1.00	300.8	0.96
Babile					
GLPX-92	1600	351	0.96	356	0.95
G-2816	2317	347	1.06	433	1.14
BAT-338-1c	1450	335	0.95	332	0.99
A-82	1478	300	1.03	477	1.16
M-142	1339	307	0.97	409	0.98
Mean	1636.8	328	0.99	401.4	1.04

Table 6. Effect of levels of nitrogen and phosphorus on nodulation and grain yield (kg/ha) of haricot bean grown on Vertisols, Alfisols and Entisols in Hararghe, eastern Ethiopia.

Source of data &parameters	Nitrogen rate (kg/ha)				
	0	23	46	69	Mean
Mitiku (1990)					
Nodule number per plant					
Vertisols	238	228	272	134	218
Alfisols	69	47	27	12	39
Volume of nodules per plant (ml)					
Vertisols	5.9	4.8	4.1	3.0	4.45
Alfisols	0.57	0.33	0.21	0.15	0.32
Grain yield (kg/ha)					
Vertisols	2107	2266	2749	2509	2408
Alfisols	1056	1407	1334	1210	1252
	Phosphorus rate (kg/ha)				
	0	10	20	30	40
Eden (2002), Entisols					
Total number of nodules*	22.4	25.1	33.2	38.6	51.8
Number of effective (ml)*	15.4	17.1	20.9	24.6	33.5
Grain yield (kg/ha)	2265.5	2383.7	2465.3	2496.9	2306.5

* Number of nodules is counted on per plant basis.

REFERENCES

Chemeda Fininsa. 1997. Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop. *African Crop Science Journal* 5: 15-22.

CIAT. 1998. Bean Project Annual Report 1997. CIAT Working Document No. 177. CIAT (Centro Internacional de Agricultura Tropical), Cali, Colombia.

CSA. 2002. Report on area and production for major crops in 2001/2002. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Dechassa Olani. 1996. Relative performance of haricot bean genotypes in sole and sorghum intercropped system. M. Sc. Thesis. Alemaya University of Agriculture, Ethiopia.

Demesew Mengesha. 2002. Effects of planting density of haricot bean and nitrogen fertilization on productivity of maize/haricot bean intercropping system in eastern Hararghe. M. Sc. Thesis. Alemaya University, Ethiopia.

Eden Tesfaye. 2002. Uptake and response of haricot bean (*Phaseolus vulgaris* L.) varieties to different levels of phosphorus application on Entisol of Alemaya. M. Sc. Thesis. Alemaya University, Ethiopia.

Kassu Kebede. 1993. Studies on plant population, and spatial arrangements of sorghum (*Sorghum bicolor*) and bean (*Phaseolus vulgaris*) intercropping as influenced by NP application in eastern Ethiopia. M. Sc. Thesis. Alemaya University of Agriculture, Ethiopia.

Mitiku Haile. 1990. Preliminary studies of biological nitrogen fixation by haricot bean on two soil types in Hararghe, Ethiopia. p. 97-109. *In* Proc. Second Regional Workshop on Bean Research in Eastern Africa. March 5-8, 1990. Nairobi, Kenya.

Shemelis W/Hawariat, Mitiku Haile, and Wogayehu Bekele. 1990. Haricot bean production systems in Hararghe highlands, p. 14-18. *In* Proc. Research on Haricot Bean in Ethiopia, 1-3 October 1990. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Storck, H., Bezabih Emana, Mulat Demeke, and Berhanu Adenew. 1991. Studies on the smallholder agriculture in the Hararghe Highlands, eastern Ethiopia. Working Paper No. 66, Hannover University, Germany.

Tamado Tana. 1994. Intercropping of groundnut (*Arachis hypogaea* L.) and sorghum (*Sorghum bicolor* L. Moench) with emphasis on spatial arrangements. M. Sc. Thesis. Alemaya University of Agriculture, Ethiopia.

Tamado Tana, and Eshetu Mulatu. 2000. Evaluation of sorghum, maize and haricot bean cropping systems in East Hararghe, eastern Ethiopia. *Ethiopian J. Agricultural Sciences* 17: 33-45.

Willey, R.W. 1979. Intercropping, its importance and research needs. Part 1. Competition and yield advantages. *Field Crop Abstracts* 32: 1-10.

Yesuf Mohammed. 2003. Effects of planting arrangement and population densities of haricot bean on productivity of sorghum/haricot bean additive mixtures. M. Sc. Thesis. Alemaya University of Agriculture, Ethiopia.

Yoseph Beyene, Habtamu Zelleke, and U. R. Pal. 2003. Effect of component densities on the productivity of maize/bean and sorghum/bean intercropping systems in eastern Hararghe. Paper presented at the 20th Annual Research and Extension Review Meeting, Alemaya University of Agriculture, Ethiopia.

Biological Nitrogen Fixation Research on Food Legumes in Ethiopia

Asfaw Hailemariam[1] and Angaw Tsigie[2]

[1]National Soil Research Center, (EARO) P.O. Box 147, Addis Ababa, [2]Holetta Agricultural Research Center, (EARO) P.O. Box 2003, Addis Ababa

ABSTRACT

The management of nitrogen is crucial for agricultural sustainability. Few agro-technologies meet the criteria for sustainable agricultural development as neatly as legume biological nitrogen fixation (BNF), which may not be a panacea, but it is often the most feasible and economical N input for resource-poor farmers of Ethiopia. Most farmers spare fertile soils for the production of cereal crops, while food legumes are grown in marginal soils, usually for crop rotation purposes. As a result, the average grain yield of most food legumes in Ethiopia is low, and ranges between 500-900 kg/ha, which is much below potential yields of about 1760 kg/ha. In an attempt to overcome this situation, in recent years research on *Rhizobium leguminosarum* revealed 10-50% yield increase on faba bean, field pea and lentil, and appropriate *Rhizobium sp.* strain for chick pea gave up to 38% yield increase. It is encouraging that the research work on BNF has been initiated on all food and some forage legumes of the country, and there is an effort to locally produce inoculants for some food legumes on a pilot-scale. In future, these have to be strengthened, and distribution system for the farmers has to be in place. In this article, the progress made in the area of BNF in food legumes in the recent years in the country is assessed, and the future direction is indicated.

INTRODUCTION

Nitrogen is a nutrient that most frequently limits crop production. Global agriculture now relies heavily on large-scale industrial nitrogen fixation - the N fertilizers that fueled the Green Revolution. The global increase in the use of N fertilizer parallels the population growth, and agriculture now annually consumes nearly 80 million metric tons of N from fertilizer (World Bank, 1990). By conservative estimates, the world's population will double in the next half century, with most population growth rate occurring in the developing nations of the tropics, such as Ethiopia. Consequently, further increases in N inputs will be necessary and inevitable.

Nitrogen fertilizers are petroleum-based products, vulnerable to political and economic fluctuations in the oil markets. They are expensive inputs, costing agriculture more than US$ 45 billion per year. At the farm level in Ethiopia, fertilizers are often so costly that the government is forced to provide fertilizer on credit terms or it is unavailable due to lack of infrastructure. Environmental costs are also high. Crops use fertilizer-N inefficiently and generally plants do not assimilate more than 50% of the N fertilizer applied. The remainder is a potential source of environmental pollution. Furthermore, many cropping systems have reached the point of diminishing returns to fertilizer-N applications, and there is a decline in global cereal production per unit of N fertilizer application (World Bank, 1990). This trend is not sustainable, and points towards higher economic and environmental costs for each unit of food produced.

The concept of "sustainability" recently has catalyzed a re-evaluation of agricultural development in the past decade. Agricultural systems are assessed not only in terms of inputs and outputs, but also in the context of their environmental and social impacts. Food grain legumes are very important crops in Ethiopia (Desta and Angaw, 1986; Balesh and Asnakew, 1993; Aynabeba et al., 2001). They are exclusively important source of dietary protein.

In Ethiopia, pulse crops rank second as food after cereals and occupy about 17.7% of the total cultivated areas, and contribute about 12% of the total production. The major food legumes in the country are faba bean, chickpea, field pea, haricot bean, fenugreek, groundnut, cowpea, pigeon pea, grass pea, lupine and soybean. Most farmers spare fertile soils for the production of cereal crops, while pulses are grown in marginal soils, usually as rotation crops (Asfaw and Solh, 1993). As a result, the yield for most pulse crops in Ethiopia is low and ranges between 500 – 900 kg ha^{-1}, whereas the average yield potential of these crops is about 1760 kg/ha (Desta, 1988). The use of nitrogen fertilizers is not practiced for these crops.

Increasing the yields of these crops is important for improving the nutritional quality of food of the population. If different effective Rhizobia are identified to be used for inoculant production of these crops, these crops could get sufficient N they require, and, thus, will supply significant amount of residual N to the succeeding crops (Aynabeba et al., 2001). In attempts to overcoming the constraints, BNF research in Ethiopia started in the early 1980s (Amare, 1982). However, attention given was not sufficient or was not well coordinated vis-a-vis its importance in agro-economic sector. In recent years, many BNF researches were initiated for most food legume crops, however most of these research findings are found either in the form of reports or within the researchers hands as unpublished data. Thus, such information has also been included in this review.

RESPONSE TO FERTILIZER APPLICATION

Although the tendency of farmers to use fertilizers on food legume crops is non-existent or scanty, there are some researches on fertilizer trials still being conducted. However, results from Denbi and Ginchi did not show any significant differences from non-fertilized control plots in lentil (Table 1), While at Holetta, application of 120 kg N/ha +20 kg P/ha in faba bean provided three times higher grain yields (Angaw et al., 1990) (Table 2).

The objectives of some of these studies may not be to find out fertilizer recommendation rates but to see the fertilizer effects on Rhizobial strains performance, nodulation and nitrogen fixation (Table 3). According to Angaw et al. (1990), the indigenous *Rhizobium* in the non-inoculated and non-fertilized control plants had performed better than the inoculated and 120 kg N/ha fertilized plants (Table 3). This indicates that 120 kg N/ha may have suppressed the indigenous *Rhizobium* sp. and might not have given equal required N to the plant whenever it was needed.

Table 1. Effect of NP fertilizers on grain yield of lentil at Denbi and Ginchi, 1989 cropping season.

	Yield (kg/ha)			
	Denbi		Ginchi	
Treatment	Dry matter	Seed	Dry matter	Seed
Control (0,0)	3180	1460	3070	1810
23 kg N /ha	3710	1730	3170	1870
46 Kg N /ha	3840	1730	3340	2040
20 kg P /ha	3680	2640	3220	1980
23 N + 20 P (kg/ha)	3990	1770	3440	2110
46 N + 20 P (kg/ha)	4350	1780	3520	2390
L.S.D. (5 %)	NS	NS	NS	NS
C.V. %	10.7	14.1	15.0	13.2

Source: Angaw et al. (1990).

RHIZOBIAL CULTURE COLLECTIONS AND CHARACTERIZATION

There have been a large number of collections of Rhizobia from time to time in the two main BNF study laboratories of the country, viz., Holetta Agricultural Research Center (HRC) and National Soil Research Center (NSRC) (Desta and Angaw, 1986; Asfaw, 1993). The collection from most known pulses growing areas showed good nodulation with enough number of nodules per plants (Table 4). However, some of these nodules were found to be less effective in the effectivity tests. Effective isolates were later coded (in the parentheses) with the strain numbers as shown in Table 4 (Asfaw, 1993; Aynabeba et al., 2001).

NEED FOR INOCULATION

In the past, a number of studies were conducted at different places to assess the need for inoculation indirectly using application of chemical fertilizers. Desta and Angaw (1988) found the highest nodulation at Holetta on two soils types in which the lowest scores were recorded from Bekoji and Goha Tsion areas. Studies conducted by the same authors in 1989 at Holetta showed that higher number of nodules per plant was recorded when faba bean was fertilized with P-K fertilizers. Both grain and dry matter yields were significantly increased by the applications of N-P-K. Since a positive response was achieved with N fertilizer application, they concluded that rhizobial inoculation might be justified for increased faba bean yield on Nitosols of Holetta. However, these types of studies do not have a direct indication of the *Rhizobium* status, but is believed to be a useful indicator for more fertilizer requirement that could be through chemical or biological agents.

Table 2. Effect of *Rhizobium* strains and NP fertilizers on nodulation, plant height and yield of faba bean at Holetta.

		Nodule score				Yield (kg/ha)	
Treatment	Plant ht (cm)	No.	Size	Position	Color	Dry matter	Grain
Control	83.5	0.5	1.6	2.5	2.2	1340	440
20 kg P/ha	103	1.6	2.2	1.7	2.9	3140	740
120 kg N /ha	31.4	0.7	1.3	1.5	1.8	2940	670
120 N+20P (kg/ha)	128.1	1.5	1.8	0.9	2.4	6120	1400
R. Strain #18	94.1	3.8	1.2	1.0	4.0	2850	640
R. Strain #51	87.4	3.8	1.0	1.0	4.0	2240	540
R. Strain #64	98.6	3.8	1.6	1.0	4.0	2590	610
Multi strains of ICARDA	89.8	3.9	1.4	1.0	4.0	2350	580
L.S.D. 5 %	8.7	_	_	_	_	14.8	2.0
C.V. %	6.2	_	_	_	_	9.9	19.5

Source: IAR (1990).

Table 3. The effect of *Rhizobium* strains and NPK fertilizers on nodulation and seed yield of chickpea (K850 3/27 Fx378) at Ginchi.

	Nodule Score				Yield (kg/ ha)	
Treatment	No.	Size	Position	Color	Dry matter	Seed
Control	3.6	2.8	1*	4Ψ	5070	3350
120 N+35.2 P+48 K (kg/ha)	3.8	3.0	1	4	5710	3710
35.2 P+48 K (kg/ha)	3.3	2.8	1	4	4940	3380
Strain 31+35.2 P+48 K (kg/ha)	3.0	3.1	1	4	5500	2980
Strain 36+35.2 P+48 K (kg/ha)	3.3	2.0	1	4	5800	3230
Strain 39+35.2 P+48 K (kg/ha)	3.3	2.5	1	4	5470	3070
120 N (kg/ha)	1.5	1.1	1	2.8	5620	3270
L.S.D. 5 %					NS	NS
C.V. %					3.7	15.7

*: Position of nodule at main root (crown); Ψ: dissected nodule's inside color; 1, whitish; 2, very light pinkish; 3, pink; and 4, deep dark pink color, indicating oxygenated leghaemoglobin during nitrogen fixation. Source: IAR (1990).

Table 4. Culture collection and isolation and assessment of potential nitrogen fixation capability in laboratory and greenhouse experiments.

		Nodule score on authentication tests				
Collection site	Crop	No. nodules/ plant	Weight g/plant	Position[a]	Internal color[b]	Remark
Andit tsid	Faba bean	> 30	>2	4	4	Excellent (EAL 120)
Ankober	Faba bean	>30	2	4	4	Excellent (EAL 121)
Alemaya	Faba bean	>30	2	4	4	Excellent (EAL 110)
Debre-Zeit	Faba bean	>30	2	4	4	Excellent (EAL 101)
Mojo	Chickpea	>30	>2	4	4	Excellent (EAL 001)
DebreZeit	Chickpea	>30	2	4	4	Excellent (EAL 004)
Tillili	Chickpea	>30	2	4	4	Excellent (EAL 010)
Asebeteferi	Field pea	>30	2	3	3	Very good (EAL 300)
Melkasa (Ay)	Haricot bean	>30	2	3	4	Excellent (Ayenew)
Kerssa	Lentil	>30	1.2	3	3	Good
Babille	Groundnut	>30	1.0	2	4	Good
Debre-work	Grass pea	>30	1.5	2	3	Good

[a] Nodulation position on 1= on root hairs; 2= lateral roots; 3= main roots; 4= crown root. [b]Dissected nodule internal color 1= white; 2=light pink; 3= pink; 4= deep reddish pink/greenish.

RESPONSE TO INOCULATION

In recent years, many studies were conducted to evaluate effective rhizobial isolates and to find most effective strains for different agro-ecologies of the country. The results of these studies showed different results at different places. Angaw (1995) found that strains # 18, # 51, and # 64 in combination with 20 kg P/ha fertilizer increased grain yields (44% and 13% for #18 and #51, respectively) but did not show significant differences to uninoculated treatments at Goha Tsion (Table 5). However, the same stains revealed highly significant yield differences in Holetta Nitosols (Table 6). Also, strains collected and some exotic strains from NIFTAL Project, Ohio University, USA, showed positive effects on faba bean (Asfaw, 2000).

Table 5. Effect of *Rhizobium* inoculation on some characters of faba bean at Goha Tsion.

Treatment	Plant height (cm)	Grain yield (kg/ha)
Control	84.75	889.0
Strain # 18 +20kg P/ha	81.50	1283.0
Strain # 51+20kg P/ha	84.00	1006.0
Strain # 64+20kg P/ha	84.25	808.0
20kg N/ha +20kg P/ha	90.50	1090.0
20kg P/ha	84.50	975.0
C. V. %	9.32	24.45
L.S.D. (0.05)	NS	NS

MULTI-LOCATION INOCULATION STUDIES

NSRC in collaboration with some regional agricultural bureaus had conducted various adaptive and demonstration trials on faba bean and chickpea response to inoculation and found mixed results (Table 7).

FACTORS AFFECTING RHIZOBIUM

It is well understood from literature that the population and establishment of *Rhizobium* in soils are affected by many factors. However, studies in Ethiopia focus mainly on applied aspects of BNF, and not on the basic research. There are only few studies in these areas. Wassie et al. (1999) and Yifru (2003) found that rhizobia when inoculated along with phosphate solubilizing microorganisms performed better than when they were inoculated alone on faba bean and field pea, indicating that *Rhizobium* required phosphorus for nitrogen fixation.

DEVELOPMENT OF RHIZOBIA INOCULANT PRODUCTION

The Microbiology Section of NSRC in collaboration with National Fertilizer Industry Agency (NFIA), with World Bank assistance, made the necessary studies in developing pilot-scale *Rhizobium* inoculants production in Ethiopia (NSRC, 2000, 2002). Among these studies, inocula-carrier production and alternate materials for *Rhizobium* mass production were identified. In selection of carriers, Asfaw (2002) found that local lignite, found around Bedele and provided by the Coal and Phosphate Project, was the best followed by filter press mud and charcoal (Table 8). In an attempt to replace imported mannitol sugar for mass production of *Rhizobium*, Molasses-D, a sugar industry byproduct, gave good result for *Rhizobium* growth in broth culture. Thus, in the future use of Molasses-D has been recommended in place of mannitol sugar.

FACTORS AFFECTING INOCULANT PRODUCTION

In the above study, it was also tried to look at the problems of inoculants production in the country. It was found that inoculants production was not a quick profit making enterprise, but a far-sighted low profit making public enterprise. Thus, the initial production has to be carried out by a government organization.

FUTURE DIRECTION AND CHALLENGES TO RHIZOBIUM RESEARCH

As it has been indicated above, the progress in this sector is very slow, whereas the crops to be addressed are many. The main actors in these research efforts are the HARC and NSRC. These centers were carrying out similar activities until recent past. Now, in order to save time and money, they have agreed upon to share and delineate responsibilities. Research can continue at every center but the cultures have to be preserved at one culture collection center, may be at the Institute of Biodiversity Conservation Research (IBCR) as a microbial genetic conservation. Inoculants production has to be started at NSRC as it has all the necessary equipment, and needs labor and few regular employees as assistants. This Center could be given proper attention to develop it as a Center for Inoculant Production on large-scale for distribution/sale to farmers. In future, it is recommended that whenever a pulse crop variety is released and is being introduced to the farmer, its symbionant, the *Rhizobium*, should also be introduced along with the seeds of the released variety. Now, the Kulumsa Agricultural Research Center in collaboration with NSRC is doing research on some released varieties of faba bean, which is a good start and needs further encouragement.

A future direction and challenge in research should be on other organisms of nitrogen fixation such as *Azotobacter*, *Azospirillium*, *Anabaena* etc. as *Rhizobium* is not the only nitrogen-fixing organism. These organisms are useful for crops of diversified nature; from vegetables to cereals.

Table 6. Faba bean dry matter and grain yield, plant height and nodulation as affected by *Rhizobium* inoculation.

Treatment	Nodulation score (0-4 scale)				Plant height (cm)	Grain yield (kg/ha)
	Number	Size	Position	Color		
N_0 P_0	0	-	-	-	42.55	680
N_0 + 20 kg P/ha	0	-	-	-	51.00	1540
Strain #18 + 20 kg P/ha	4	4	1	4	88.62	3980
Strain #64 + 20 kg P/ha	1	1	3	3	56.50	2320
Strain #51 + 20 kg P/ha	3	4	1	4	57.50	2740
23 kg N/ha + 20 kg P/ha	0	-	-	-	61.75	2050
120 kg N/ha + 20 kg P/ha	0	-	-	-	66.87	2240
C.V. %					12.06	55.40
L.S.D (0.05)					10.82	2980
L.S.D (0.01)					14.75	4.10

Table 7. Summary results of multi-location adaptive and demonstration trials.

Region	Location	Crop	Response	Region	Location	Crop	Response
Amhara (N. Shoa)	Inewari	FB	Some strains	Oromia (Bale)	Sinana	FB	High
						FP	High
Amhara (E.Gojam)	Feres-bet	FB	High (all strains)	Oromia (Arsi)	Kulumsa	FB,Fp	Some
					Bekoji	FB,FP	High
					Assassa	FB,FP	Non
Amhara(E.Gojam)	Hulet –eji anesie	FB	High(all strains)	Oromia (E. Shoa)	Akaki	CP	High
					Addaa	CP	Some
Amhara(W.Gojam)	Adet	FB	Non	SNNPR (Guragei)	Goro	CP	high
South Gondar	Fartta	FB	High	SNNP (Hadya)	Hosaana	FB	High
	Libokemekem	CP	high	(Kambatta)	Angacha	FB	High
North Gondar	Dabat	FB	High				
	Kola Diba	CP	High				
North Wollo	Waddla	FB	High				

Source: NSRC (2002).

Table 8. Survival of *Rhizobium leguminosarum* population (log. no.) on different carrier materials for 90 days at room temperature.

Carrier	Log. no. of population Rhizobia cells at respective days of incubation at room temperature						
	Initial population	At 15 days	At 30 days	At 45 days	At 60 days	At 75 days	At 90 days
Lignite	10.041	9.869	9.903	9.806	9.531	9.322	9.255
Charcoal	10.041	7.079	7.477	6.301	6.699	4.477	4
Filter press mud	10.041	9.579	9.903	7.663	7.602	7.707	7.672
Bagasse	10.041	Nil	Nil	Nil	Nil	Nil	Nil
Farm yard manure	10.041	7.176	7.302	7.079	5.301	5.079	5.699
Coffee hall	10.041	Nil	Nil	Nil	Nil	Nil	Nil

REFERENCES

Amare, A. 1982. M. Sc. Thesis, Department of Biology, Addis Ababa University, Addis Ababa, Ethiopia.

Angaw, T. 1995. Needs for chickpea inoculation trial. *In* Soil Science and Water Management Research Report. Holetta Agriculture Research Center Progress Report, Institute of Agricultural Research (IAR), Holetta.

Angaw, T., B. Desta , D. Getnet, and B. Haile. 1990. Effect of *Rhizobium* strains inoculation on nodulation and yield of faba bean. *In* Soil Science and Water Management Research Report. Holetta Agriculture Research Center Progress Report, IAR, Holetta.

Asfaw, H. 1993. Culture collection of *Rhizobium* strains of some important pulses of Ethiopia at the National Soil Laboratory. Improvement of Soil Service for Agricultural Development, (Eth./87/010) Document No. 71, NSSP, MoA. 9 pp.

Asfaw, H. 2000. Soil biology and microbiology research report. In Annual Report of National Soil Research Center Ethiopian Agricultural Research Organization (EARO), Addis Ababa.

Asfaw, H. 2002. Comparison of carriers and alternate propagation material for rhizobial inocula production. Proc. Sixth Annual Conference of Ethiopian Society of Soil Science (ESSS), April 21-22, 2002 Addis Ababa, Ethiopia.

Asfaw, T., and M.B. Solh. 1994. Overview of achievements in cool-season food legume research in Ethiopia. p. 404-415. *In* Asfaw et al. (Eds.) *Coo-Season Food Legumes of Ethiopia.* Proc. First National Cool Season Food Legumes Review Conference, 16-20 December 1993. Addis Ababa, Ethiopia.

Aynabeba, A., A. Fassil, H. Asfaw, and B. Endashaw. 2001. Studies of *Rhizobium* inoculation and fertilizer treatments on growth and production of faba bean *(Vicia faba)* in some yield-depleted and yield sustained regions of Semien Shewa. *Ethiopian J. Agric. Science* 24: 197-211.

Balesh, T., and W. Asnakew. 1993. Evaluation of faba bean *Rhizobium* strains on Vertisols. p. 46-47. *In* Nile Valley Regional Programme on Cool-season Food Legumes. Annual Report 1991/92. ICARDA/ NVRP-DOC-024, Ethiopia.

Desta, B. 1988. Biological nitrogen fixation research on grain legumes in Ethiopia: An overview. p. 73-78. *In* D.P. Beck and L.A. Materon (Eds.) Proc. Workshop on Biological Nitrogen Fixation on Mediterranean-type Agriculture, April 14-17, 1986, ICARDA, Syria.

Desta, B., and T. Angaw. 1986. Exhaustion trial on cereals, pulses and oil crops. p. 226-228. *In* Holetta Progress Report, IAR, Addis Ababa.

Desta, B., and T. Angaw. 1988. Evaluation of root nodules collected from faba bean. *In* Faba bean Research in Ethiopia under IAR/IFAD/ICARDA Nile Valley Project on Faba Bean, 1985-1987 Crop Season. IAR, Addis Abeba.

IAR. 1990. Holetta Agricultural Research Center progress report. Institute of Agricultural Research (IAR), Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

NSRC. 2000. Annual progress report. National Soil Research Center (NSRC), Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.

NSRC. 2002. Annual progress report. National Soil Research Center (NSRC), Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.

Wassie, H., H. Asfaw, and A. Fasil. 1999. Studies on phosphate solubilizing ability of bacteria isolated from some Ethiopian soils. *In* Proc. 9th Annual Conference of the Biological Society of Ethiopia, Feb.3-5, Addis Ababa, Ethiopia.

World Bank. 1990. World Bank Technical Paper No. 174.

Yifru, A. 2003. Effect of dual inoculation of *Rhizobium* and phosphate solubilizing bacteria on nodulation, yield and nitrogen and phosphorus nutrition of fieldpea (*Pisum sativum* L.) in Sinana area. MSc Thesis, Alemaya University, Ethiopia.

Role of Food Legumes in the Cropping Systems in Ethiopia

Amanuel Gorfu [1] and Daba Feyisa[2]

[1]*Kulumsa Agricultural Research Center, P.O. Box 489, Asela,* [2]*Bako Agricultural Research Center. P.O. Box 03, Bako,West Shoa, Ethiopia*

ABSTRACT

Food legumes have dual benefits in Ethiopian agriculture. They ameliorate soil fertility through atmospheric nitrogen fixation and also contribute to the protein diet of the population. Food legumes are either grown in sole stand as a precursor crop to particularly cereals or as a companion crop intercropped with various crops. Experiments conducted at Melkassa and Awassa revealed that intercropping of beans with maize resulted in higher land equivalent ratio (LER) of 46% and 31%, and net returns of 3869 and 3405 Birr ha^{-1}. Growing faba bean and field pea together resulted in higher production per unit area compared with a pure stand of each crop. A double cropping trial conducted for two years at Sinana in Bale showed that field pea grown during the *belg* season followed by bread wheat in the *meher* season was the best sequence both in agronomic and economic terms. A faba bean precursor crop increased soil nitrogen content in wheat-based cropping system in Arsi. In an experiment conducted at different locations in Arsi, the soil N balance after faba bean production was found to be equal or better than the optimum N rates required for wheat production. Faba bean-based rotation also showed a marked reduction in weed density and biomass compared with continuous wheat or rotation with other cereals like barley. Thus, due to improved soil fertility and other rotation advantages grain yield of wheat after faba bean production was increased by more than one t/ha as compared to continuous wheat production.

INTRODUCTION

In the cereal-based cropping systems in Ethiopia, food legumes and oil crops are the major rotational crops. Allocation of crop species in rotation with cereals varies with altitude, rainfall and soil type (Tanner et al., 1999). Certain food legumes are grown in pure stand as preceding crops to cereal production particularly in high- and mid-lands of the country. Some of the food legumes are grown as intercrops with cereals such as sorghum and maize in lower areas. Among the major food legumes, faba bean, field pea, chickpea, lentil, grass pea (rough pea) and haricot bean are widely cultivated in Ethiopia. Although food legumes rank second to cereals in area of production (CSA, 2002) their productivity is rather low due to shortage of high yielding, disease-tolerant adaptable varieties, and weed problem. On the contrary, continuous cereal production is a common practice in most highlands of Ethiopia. In high potential areas such as the highlands of Arsi and Bale, rotation of wheat with dissimilar species is uncommon because of the high yields obtained from improved varieties of wheat and attractive wheat grain prices in local markets. But, continuous cereal production can result in yield decline, particularly where soil fertility and weed control practices are sub-optimal or where soil-borne diseases are common (Amanuel et al., 2000b; Berhanu, 1985; Kefyalew et al., 1999; Tezera et al., 1996).

Sustainability of agricultural production is adversely affected by soil erosion, declining soil fertility, diseases and problematic weeds. Legumes in general and food legumes in particular have a big role in minimizing these adverse effects and contribute much to the productivity of the system when included in a cropping system (Bohlool et al., 1992; Wilson and Hamblin, 1990). Food legumes also play an important role in a cropping system since their seeds are the major source of protein diet for resource poor population, and the residues also play a vital role in improving soil fertility. Some food legumes, such as faba bean are good atmospheric N_2 fixers and enhance the soil N balance relative to cereals (Amanuel et al., 2000a.; Jensen, 1986; Maidl et al., 1996).

Growing N_2 fixing leguminous crops in association with dissimilar crop species as intercrops, particularly with cereals, would result in more remunerative values. As precursor crops to cereals, food legumes have several benefits such as maintenance or improvement of soil fertility and soil structure, enhance water infiltration and reduce run off, and minimize the build-up of weeds, pests and soil-borne diseases. A number of experiments were conducted in different parts of Ethiopia to identify suitable intercrops, and cropping sequences in the cereal-based cropping system to make it more sustainable (Amanuel and Tanner, 1991; Amanuel et al., 2000b; Asefa et al., 1992; Hailu et al., 1989).

INTERCROPPING

Maize/bean Intercropping Effects on Yield Components, Land Use Efficiency and Net Returns

An experiment was carried out at Melkassa and Awassa during 1993 crop season to evaluate the relationship between maize and bean different planting patterns and planting schedules of bean varieties and to identify intercropping systems that can give sustainable yields and economic returns. An early maize variety, Katumani composite, and two bean varieties with different growth habits, Awash-1 (erect type) and M-142 (semi-prostrate), were planted simultaneously with maize and relay planted one month after maize planting. The planting patterns used were sole maize, sole beans, 2 rows of maize/1 row of beans, maize/bean mixed in the same row, maize in rows/beans broadcast, and maize/bean both broadcast.

The results showed that maize yields were significantly higher in relay intercrops, whereas bean yields were higher in simultaneous intercrops at both locations (Nigusse and Reddy, 1996). However, higher land equivalent ratio (LER) of 46% and 31% and net returns of 3869 and 3405 Birr/ha were obtained from beans planted simultaneously with maize in 2 rows maize/1 row bean patterns at Melkassa and Awassa, respectively. Thus, bean varieties planted simultaneously with maize in 2 maize/1 bean intercrop pattern can give sustainable yield and income advantage in addition to reducing risk of total crop failure due to unreliable rainfall in the Rift Valley of Ethiopia.

Mixed Cropping of Faba Bean and Field Pea in Ethiopia

Field experiments carried out on Nitosols of Holetta Agricultural Research Center (HARC) from 1991-93 to investigate the merits of different combinations of faba bean and field pea. Five mixtures of faba bean (cv. CS-20-DK) and field pea (cv. G22763-2C), 0:100-M1; 25:75-M2; 50:50-M3; 75:25-M4; and 100:0-M5, were factorially combined with two levels of weeding (no weeding and hand-weeding once). Results exhibited that faba bean and field pea as mixed crops resulted in higher production per unit area than monoculture of the either crop (Amare, 1996). The highest seed yield of 1.979 t/ha was obtained in M4 of weeded compared with the pure crop of each species (1.316 t/ha for faba bean and 1.368 t/ha for field pea). The next highest seed yields were from M3 (1.54 t/ha) and M2 (1.526 t/ha) weeded treatments. In unweeded treatments, the highest yield was produced in M3 (1.492 t/ha) that is by far higher compared to pure crop of each species (1.029 t/ha faba bean and 1.189 t/ha field pea). Therefore, producing crops in mixture resulted in substantial bonus yields. The explanation for this could be the mixtures could have utilized environmental resources more efficiently than pure stands by complementing each other, and field pea in mixture performed better as it was supported by faba bean.

The land equivalent ratio (LER) values calculated for individual crop component indicated that mixed cropping affected faba bean more than it did field pea in both weeded and unweeded conditions (Amare, 1996). The LERs for faba bean ranged from 0.19 (M2) to 0.65 (M4) for weeded and 0.15 (M2) to 0.59 (M4) for unweeded conditions. In contrast, LERs for field pea were quite high, with values from 0.82 (M4) to 0.94 (M2) in weeded and 0.71 (M4) to 1.00 (M2) for unweeded conditions. The total LERs for mixed cropping were always greater than unit ranging from 1.12 (M2) to 1.47 (M4) in weeded and 1.15 (M2) to 1.30 (M3 and M4) in unweeded treatments indicating yield advantage from mixing faba bean and field pea. The greater LER values for field pea than faba bean indicated the dominance of field pea over faba bean in all mix proportions.

Mixing faba bean and field pea in a ratio of 75:25 and 50:50 gave considerably greater monetary advantages over 25:75 proportions. All mixing proportions resulted in substantial monetary advantage over each of the monoculture crops.

Determination of the Optimum Proportion of Faba bean and Field pea in Mixed Cropping in Baku Area

Another mixed cropping experiment was executed by Bako Agricultural Research Center (BARC) on farmers' fields around Shambu area from 1997 to 1999 cropping seasons to determine the optimum proportion of faba bean and field pea in a mixed croppind sytem (Tolera and Daba; 2001). Five different proportions of faba bean (cv. CS-20-DK) and field pea (cv. G22763-2C) and one farmers' local practice (0:100; 25:75; 50:50; 75:25; 100:0 and 82:18 of faba bean and field pea proportions) were laid in RCBD with four replications. The combined data analysis for the three years revealed that higher yield of faba bean and field pea in mixed cropping was obtained from higher proportion of faba bean than field pea. Increasing the seed rate proportion of field pea in mixed cropping gave greater yield advantage of field pea with adverse effects on faba bean grain yields. Reducing field pea proportion in the mixture and increasing faba bean proportion showed better grain yield of both crops (Table 1). A proportion of 75:25 faba bean and field pea was the most suitable for mixing both crops resulting in higher seed yield and total land equivalent ratio (LER) of 55%, and was found agronomically compatible and economically profitable for the area.

Table 1. Effect of seed rate proportion on faba bean (Fb) and field pea (Fp) mean grain yield, land equivalent ratio (LER) and net benefit (NB) in mixed cropping at Shambu.

Treatment	Grain yield (kg/ha)		LER			
Fb: Fp	Fb	Fp	Fb	Fp	Total	NB
100: 0	1063	-	1.00	-	1.00	886.04
0: 100	-	533	-	1.00	1.00	508.05
50: 50	389	478	0.37	0.90	1.27	828.67
25: 75	324	537	0.30	1.01	1.31	850.74
75: 25	708	470	0.67	0.88	1.55	1149.76
82: 18	842	354	0.79	0.66	1.45	1133.00
Mean	665	474				
LSD (5%)	80.28	53.39				
CV (%)	13.73	13.85				

Source: Tolera and Daba (2001).

Maize-based Cropping Systems for Sustainable Agriculture in Semi-arid Areas of Ethiopia

An experiment was conducted during 1992 to 1993 to examine the relative benefits of mixed and intercropping systems under farmer's field conditions at four on-farm locations: Boffa, Wonji, Welenchiti, and Melkassa. The experiment was laid out in a randomized complete block design (RCBD) with four replications. The treatments examined were: i) sole maize, ii) sole bean, iii) maize/bean mixed broadcast both planted together, iv) maize in row, bean broadcast between maize rows both planted together, v) maize/bean mixed in the same row both planted together, vi) maize 2- rows/1- row bean planted together, vii) maize/bean mixed broadcast, but bean relay planted at "Shilshalo", and viii) maize in row/bean relay planted between maize rows at "Shilshalo" (Habtamu et al., 1996).

Averaged over four locations and two years, intercropping beans in a row pattern of 2 maize: 1 bean gave the highest land equivalent ratio (LER 1.57). The intercropping advantage expressed in terms of LER from different combinations ranged from 18-57%. As an average of all locations and years, the intercropping benefits were quite promising indicating that improved biological productivity is possible from improved maize based intercropping systems.

The results illustrated that maize showed good compatibility with beans, while maintaining almost 80-100% of the sole maize yields. Considerable bonus yields were obtained from beans by maintaining 100% of maize population and 50% of bean population in all intercropping systems. Incidence of weeds was generally low in intercropped treatments as opposed to sole crops. It was also observed in intercropping treatments, where both crops were planted simultaneously, that weed incidence was relatively lower than in relay planted treatments. Economic analysis indicated that highest net benefit of 1887 Birr ha^{-1} was obtained when one row of bean was intercropped with two rows of maize. The sole maize crop gave the lowest net benefit followed by sole bean treatment.

Evaluation of Soybean Genotypes for Intercropping with Maize at Bako

A field experiment was conducted at Bako Agricultural Research Center during 1999 and 2000 cropping seasons to evaluate cropping system and genotype interaction for soybean and to identify genotype(s) suitable for multiple cropping systems (Negash et al., unpublished data). The results showed that cropping system and genotype x cropping system interaction affected the measurable agronomic parameters differently (Tables 2 and 3). It was concluded that those parameters which were significantly affected by cropping system x genotype interaction included seed yield, selection for genotype should be under both systems (i.e., sole and intercropping) so as to identify best genotype(s) performing in each system. For non-significant parameters, selection could be done either in sole or intercropping system. Thus, considering seed yield and other agronomic traits genotypes that were selected for sole cropping in descending order were TGX-13-3-2644, AGS-65, and PR-149-66 for sole cropping, whereas Scott, AGS-65 and TGX-13-3-2644 were selected for intercropping.

Relay Cropping of Different Crops in Short Cycle Maize Guto at Bako

An experiment was carried out between 1990 and 1992 to investigate the advantage of relay cropping of maize with haricot bean, *tef* and sweet potato to identify the appropriate time of relay planting (Tolessa et al., 1995). Results showed that relay cropping had no significant effect on the grain yield of maize. However, all the relay cropping treatments showed higher overall benefits than the sole maize. The advantage of relay cropping was 71.9% when maize was harvested green and 45.9% when maize was harvested at maturity. Relay planting of haricot bean starting from 50% to 15 days after 50% flowering of maize was an attractive alternative for maize farmers.

Table 2. Grain yield and other agronomic traits as affected by soybean genotypes x cropping system interactions at Bako, 1999-2000.

Genotype	Days to mature		Plant height (cm)		Number of pods per plant		Grain yield (kg/ha)	
	Sole	Inter	Sole	Inter	Sole	Inter	Sole	Inter
ALAMO	123	125	56j-q	53m-r	23	11	1748f-j	244 l
N-80-50232	124	124	47p-r	51n-r	23	9	1549i-k	278 l
RILITTO	119	119	44qr	43q-r	29	11	1107k	180 l
KWANKYO	123	122	47o-r	55k-q	23	11	1690h-j	355 l
OC-793	122	122	48o-r	41r	29	9	1945d-j	243 l
UFV-1	122	120	52n-r	55 l-q	29	7	1458jk	209 l
AGS-217	123	123	64f-n	69d-g	22	7	2243a-f	285 l
SABLE	124	124	68e-l	60i-p	23	8	1613h-j	217 l
AGS-65	129	129	68e-l	65e-n	26	14	2547ab	464 l
SCOTT	128	128	65e-n	69d-g	27	15	1972d-i	509 l
G-9945	130	129	66e-n	67e-l	22	15	1790ij	365 l
DAVIS	128	128	54 l-r	58j-p	28	10	1667h-j	294 l
DB-1601	130	128	65e-n	63j-n	28	12	2037c-i	384 l
CLARK-63K	130	127	53m-r	67e-l	24	12	1733g-j	266 l
V-1	130	130	61h-o	64g-n	24	12	2062b-h	357 l
TUNIA	128	130	67e-n	74b-h	20	15	2238a-g	393 l
TGX-13-3-2644	131	132	58j-p	62h-n	25	11	2565a	454 l
PR-149-66	132	133	92a	81a-d	32	14	2529a-c	425 l
42-S-2	132	141	58j-p	65e-n	22	11	1736g-j	343 l
IMPROVED PELICAN	133	131	82a-c	74b-h	24	16	1880d-j	314 l
ISRA-44-A/73	133	133	69d-k	57j-p	25	10	2042c-i	279 l
IPM-81-EP7	135	135	78b-e	78b-f	28	11	2284a-e	393 l
JANCK BACKONG	135	134	85ab	86ab	28	12	2075a-h	211 l
IPB-142-81-EP7	136	135	72c-i	76b-g	24	12	2328a-d	233 l
Standard Error of mean	1.30		3.08		2.38		117.6	
LSD(0.01)	NS		11.35		NS		432.90	

NS = Non-significant; Means in the column followed by different letters vary significantly at P=0.01. Source: Negash et al. (unpublished).

Table 3. Variance ratios and levels of significance for days to flowering (DF), days to maturity (DM), plant height (PH), pod height (POH), number of pods per plant (NPP), grain yield (GY) and 100-seed weight (HSW) as affected by cropping system, genotype and cropping system x genotype interaction at Baku 1999-2000.

Parameter	Cropping system (CRS)	Genotype (Gen)	CRS x Gen
Df	0.0081NS	113***	2*
DM	0.0091NS	29***	1 NS
PH	0.2097NS	28***	2***
POH	26***	7***	1 NS
NPP	47***	1NS	1 NS
SY	231.64***	6.59***	3.67***
HSW	79***	21***	2***

Note: *, **, *** and NS means significant at 5%, 1%, 0.1% and non-significant (NS), respectively. Source: Negash et al. (unpublished).

Selection of haricot bean genotypes to phosphorus stress under intercropped condition in eastern Ethiopia

Two studies were conducted at Amaressa and Alemaya, eastern Ethiopia to investigate the nodulation and grain yield capacity of agronomicaly promising bean genotypes under intercropped conditions on Pelluderts, Rhodustalfs and Ustorthents. In the first study during 1992 and 1993 cropping seasons at Amaressa, 89 bean varieties were evaluated under sole conditions on low fertility soil (Eylachew, 2001). Forty-two genotypes performed better, with and without phosphorus, than the local check, M-142. Of these, 25 entries with 50% grain yield advantage over the check were advanced and tested under intercropped conditions during 1994 and 1995 cropping seasons. Genotypes G-3585, G-6113, and G-6342 provided better grain yields on Pelluderts, and genotypes G-5162 and G-4379 on Ustorthents. In the second study, of the 21 high yielding candidate varieties obtained from the Ethiopian Bean Breeding Program tested, only genotypes G-11060 and Guanjuato showed stable plant stands on both the soil types.

CROP ROTATION

A long-term crop rotation experiment was initiated during 1992 at Asassa and Kulumsa in Arsi zone of southeasten Ethiopia to evaluate interactions among wheat-based cropping sequences and annual application of inorganic nitrogen and phosphorus fertilizers (Tanner et al., 1994). The soils of the Asassa station are classified as Calcic Chernozem and that of Kulumsa as intergrade between an Eutric Nitosol and a luvic Phaeozem. The experiment was laid out in a split-plot design with crop rotation as main plots and fertilizer levels as subplots. Precursor crops used were faba bean (*Vicia faba*), rapeseed (*Brassica carinata*) and barley (*Hordeum vulgare*). Two levels each of N fertilizer (30 and 60 kg/ha) and phosphorus (0 and 20 P kg/ha) was used in a factorial combination. A treatment with continuous planting of wheat was included as a check.

Rotation Effect on Wheat Yield

Results of the experiment in different years indicated that wheat grain yield and crop parameters were enhanced by dicot-rotations than cereal rotations at Asassa and Kulumsa locations (Amanuel et al., 1996a; Tanner et al., 1999; Amanuel et al., 2000b). Wheat following faba bean gave higher grain yields. A long-term effect indicated that faba bean as a precursor crop increased mean grain yield of wheat by 660 to 1210 kg/ha at Kulumsa, and by 350 to 970 kg/ha at Asassa as compared to the continuous wheat (Table 4). Highest grain yield was recorded in wheat grown after faba bean in two-course rotation (FbW) and in first wheat after faba bean in three-course rotation (FbWW). From an economic point of view, a three-course rotation with either faba bean (FbWW) or rapeseed (RpWW) was found as an appropriate cropping sequence in a wheat-based cropping system.

Table 4. Mean yield increment of wheat (kg/ha) due to rotation and higher level of N and P as affected by crop rotation at Kulumsa and Asassa, 1995-1999.

Cropping sequence	Grain yield increment due to rotation over continuous wheat		Yield increase due to higher N and P rates			
			N		P	
	Kulumsa	Asassa	Kulumsa	Asassa	Kulumsa	Asassa
FbW	1370	860	40	-60	380	580
FbWW	1300	1050	250	0	140	360
FbWW	620	380	310	260	160	420
RpW	670	600	730	240	650	320
RpWW	640	470	850	420	550	280
RpWW	310	80	780	390	-30	610
BaW	200	230	850	140	270	460
BaWW	120	220	660	390	0	330
BaWW	100	10	550	610	110	250
Cont. wheat	3130	2400	620	450	150	230

FbW = Wheat after faba bean in two-year rotation; FbWW = First wheat after faba bean in three-year rotation; FbWW = Second wheat after faba bean in three-year rotation; RpW = Wheat after rapeseed in two-year rotation; RpWW = First wheat after rapeseed in three-year rotation; RpWW = Second wheat after rapeseed in three-year rotation; BaW = Wheat after barley in two-year rotation; BaWW = First wheat after barley in three-year rotation; BaWW = Second wheat after barley in three-year rotation. Source: Amanuel et al. (2000).

Thereafter, a three-year rotation of wheat with faba bean (FbWW), rapeseed (RpWW), barley (BaWW) and continuous wheat was conducted on farmers' fields in Asassa, Bekoji and Etheya areas from 1999-2001. Experiments conducted at Asassa and Etheya showed that precursor crops significantly affected most wheat parameters, which in order of importance, were faba bean > rapeseed > barley ≥ wheat. At Bekoji, the performance of wheat was superior after rapeseed (KARS, unpublished data).

An experiment was conducted starting 1992 at Bekoji sub-centre (2780m asl) to evaluate the interactions among barley-based cropping sequences and annual applications of inorganic nitrogen and phosphorus fertilizer. The experiment was laid out in a split-plot design with crop rotation as main plots and fertilizer levels as subplots. The rotation crops included were faba bean, rapeseed, wheat, and continuous barley. The fertilizer levels used were 0 and 41 kg N/ha and 0 and 20 kg P/ha, and were applied in factorial combination. In this experiment, each phase of specific rotation was included in the experiment every year to avoid assessing the effects of the rotational crops under differing seasonal conditions. A 3-year cycle required three plots in each replication to include all three phases of the rotation, while a 2-year cycle occurred in two phases each year. The analysis of data from 1992-94 showed that barley grain yield was significantly affected by crop rotation, fertilizer P, and rotation by P- interaction (Asefa et al., 1997). Barley grown after dicotyledonous crops resulted in grain yield increment of 62 and 46% as against barley after cereals in 1993 and 1994, respectively. A two-course rotation resulted in 31% higher grain yield of barley than a three-course rotation. Within a three-course rotation, first barley after break crop exceeded second barley crop by 57%.

The effect of precursor crops and nitrogen rates on durum wheat and *tef* was tested by Debre Zeit Research Center (DZARC) under improved drainage on Vertsols at Cheffe Donsa in the central highlands of Ethiopia (DZARC, 2000). In the experiment, wheat and *tef* crops were grown under enhanced surface drainage condition (BBF) with four rates of nitrogen (0, 30, 60 and 120 kg/ha) superimposed on plots, which had been planted to *tef*, wheat, chickpea, lentil and rough (grass) pea in the previous season. Although yield was affected by heavy rains obtained in July and August, durum wheat gave better yields when grown after rough pea and chickpea than wheat following wheat. *Tef* grown after *tef* also resulted in the lowest grain yield as compared with *tef* following other precursor crops. A crop rotation experiment was conducted on bread wheat at Sinana Station during *bona* (*meher*) season (August to December) of 1995-98 and *genna* (*belg*) season (April to August) of 1996 and 1997 on two separate fields for each season. Precursor crops were grown during *genna* 1996 and *bona* 1995 and 1997 seasons, while the principal crop was grown in alternate years, i.e., *genna* 1997 and *bona* 1996 and 1998 seasons. Six precursor crops, viz., wheat, barley, emmer wheat, faba bean, field pea and linseed, and two rates of fertilizer (9-23 and 41-46 N/P_2O_5 kg/ha) were used. The results indicated that there was no significant effect of precursor crops on grain yield of the subsequent wheat in all the seasons. However, wheat after legumes resulted in yield advantage of 8-14% as against the wheat after cereals (Tilahun et al., 2000).

Results of an experiment conducted at Jimma Agricultural Research Center (JARC) to determine the effect of preceding crops on succeeding maize crop under conventional and minimum tillage practices showed that maize grown in conventional tillage after preceding crops performed better than the continuous maize (Tesfa et al., 2003). In minimum tillage practice, continuous maize resulted in yields similar to maize following preceding legumes.

Rotation Effect on Soil N

Food legumes in crop rotation are known to enhance the nitrogen content of the soils. In an experiment conducted at three sites (Asassa, Bekoji and Kulumsa) in Arsi highlands to determine N_2 fixation, the amount fixed by faba bean ranged from 139-210 kg N/ha. This in turn resulted in substantial mean soil N balance that ranged from 12 to 58 kg N/ha after the seed had been removed and all faba bean residue components were incorporated with the soil (Table 5). In contrast, the mean soil N balance in wheat after wheat was at deficit (- 9 to –44 kg N/ha) indicating the need for high rate of fertilizer N application in a continuous wheat production system (Amanuel et al., 2000a).

In the crop rotation experiment, it was observed that yield response of wheat to fertilizer N after faba bean production was very low as compared with wheat following rapeseed and continuous wheat due to the adequately available N as a result of atmospheric N_2 fixation by faba bean (Table 5). In the crop rotation experiment initiated in 1992 at KARC, soil NO_3 analysis subsequent to 1994 harvest showed higher soil NO_3 in wheat-faba bean rotations (10.43 mg) relative to wheat-rapeseed rotations (7.30 mg), attributable to N contributed by the faba bean precursor crop as a result of N_2 fixation. First year wheat after faba bean exhibited a higher soil NO_3 level compared to the second year wheat after the same break crop (11.5 vs. 9.31 mg). Annual application of 41 kg N/ha increased the soil NO_3 content from 5.60 to 8.74 mg/kg soil (Amanuel et al., 1996b).

Table 5. N_2 fixation by faba bean and soil N balance (kg/ha) after faba bean and wheat production at different locations.

	Kulumsa	Asassa	Bekoji
N_2 fixed (Faba bean)	139 – 184	147 – 174	169 – 210
N balance after Faba bean	36 – 92	(-9) – (28)	20 – 43
Wheat	(-35) – (-56)	(-19) – (-44)	8 – (-32)

Source: Amanuel et al. (2000a).

In order to determine the N requirement of wheat after faba bean and field pea, an experiment was carried out on farmers' fields in Bekoji and Gonde-Etheya areas of Arsi zone from 2000-2002 (Yesuf, 2002 - unpublished data). Soil sample analysis showed that the organic matter and available nitrogen contents of faba bean field were superior to that of field pea precursor plots. Wheat grain data across years indicated that greater grain yields were obtained in wheat after faba bean than wheat following field pea (Table 6). Contrarily, wheat grain yield response to fertilizer N was better in wheat following field pea precursor. This showed that more N was contributed to the subsequent wheat crop from the faba bean than field pea plots due to the large amount of organic matter present in the faba bean field through decomposition and mineralization. However, the grain yield increases in wheat after either faba bean or field pea were not significantly different at both locations.

Rotation Effect on Weeds

Crop rotation system is one of the most effective and inexpensive practices for maintaining weed species equilibrium and avoiding competition in subsequent cereal crops. In a crop rotation trial at Kulumsa experiment site, faba bean as a break crop decreased *Andropogon* and total grass weed density more than rapeseed precursor crop (Amanuel et al., 1996a). Analysis of the total weed biomass indicated that dicot rotation generally reduced the total biomass produced by different weed species (Kefyalew et al., 1999). Another aspect of cropping system studied in wheat growing areas, double cropping using dicot crops in the bimodal rainfall area of Bale was found promising in reducing the density and infestation level of some problem weeds (Tanner et al., 1994). The effect of cropping sequence on weeds varied with location and weed species. Crop rotation with dicots, particularly faba bean, decreased the density of some broadleaf weed species by enhancing hand weeding, thus reducing weed density in the subsequent wheat crops (Kefyalew et al., 1996). Rotation had a highly significant effect ($P<0.001$) on eyespot incidence at Asassa. It was observed that the presence of wheat in the rotation once in two years greatly influenced eyespot infection. However, the rotation effect was non-significant on eyespot at Kulumsa. Nevertheless, wheat in dicot rotations receiving fertilizer N had a reduced incidence of eyespot, whereas wheat in continuous cereal rotations receiving N manifested an increased incidence of eyespot. At Asassa, all rotation phases receiving P fertilizer showed increased eyespot incidence.

DOUBLE CROPPING

Potential for Double Cropping in the Cereal-based Farming System in Sinana

A double-cropping trial was conducted for two years at Sinana Agricultural Research Center (SnARC) in Bale region during 1990 and 1991. Five precursor crops, viz., emmer wheat, bread wheat, barley, linseed, and field pea were planted in the 1990 *belg* season. In 1991, the trial was repeated and duplicated with one set of treatments on exactly the same subplots established in 1990, while a second set was initiated on a new location (Zewdu et al., 1995). Compared to the traditional farmers' practice of fallowing land during one of the two annual cropping seasons, double cropping increased total farm grain output and net income. The best crop combination both in agronomic and economic terms consisted of field pea grown during the *belg* season followed by bread wheat in the *meher* season.

GREEN MANURING

A trial conducted at Adet Agricultural Research Center (AdARC)in 1992 and 1993 revealed that wheat after green manure incorporation resulted in significantly higher grain yields (Yeshanew and Asgelil, 1999). A 2-year mean grain yield showed that lupin as green manure increased grain yield of wheat than that of green manure with vetch.

CONCLUSIONS AND FUTURE DIRECTION

Food legumes play a vital role in keeping cropping systems sustainable. Inclusion of food legumes in a cropping system also enhances the quality of human nutrition with protein diet. This is more conspicuous in Ethiopia, where the majority of the population cannot afford animal protein. Food legumes, as preceding crops, contribute much to the productivity of other crop species, particularly cereals, by improving the fertility of the soil through N_2 fixation, breaking disease cycle, and minimizing weed infestation. They are also good source of income for the small-scale and resource-poor farmers. Some food legumes fit into inter-copping system and complement with cereals and enhance economic returns of small-scale farmers. The benefit of crop rotation with leguminous crops is more useful if all the under- and above-ground residues are incorporated into the soil after seed harvesting.

Table 6. The effect of different levels of N fertilizer on grain yield (kg/ha) of bread wheat at different locations, 2000-2002.

	Etheya-Gonde		Bekoji	
% N applied of the recommended rate*	After Faba Bean	After Field Pea	After Faba Bean	After Field Pea
0	3722	3179	3148	2235
20	3843	3424	3228	2431
40	3730	3644	3265	2682
60	3980	3660	3241	2775
80	3950	3748	3453	3111
100	4046	3822	3263	2793
Mean (kg/ha)	3879	3580	3266	2671

*The recommended rate based on wheat after wheat is 123 and 82 kg N/ha for Etheya-Gonde and Bekoji, respectively. Source: Yesuf (unpublished data).

Although food legumes have important place in sustaining cereal-based cropping system in Ethiopia, their production and productivity is limited due to shortage of high yielding, disease resistant varieties, and weed problem. To solve these problems, research efforts should be directed to develop desirable technologies to induce farmers to include more food legumes in their cropping systems either as precursors or intercrops. Therefore, the future studies should be focused on the following areas:

1. Study contributions of food legumes to soil fertility and reduction in external N fertilizer use in the subsequent cereal production in different agro-ecologies and different soil types and crops.
2. In depth study on the effect of precursor/intercrop food legumes on weed dynamics, diseases and other factors on the subsequent cereal production for different soil types and crops in different agro-ecologies.
3. Develop sustainable cropping system for different cereal-based cropping systems in collaboration with specialists in different fields, namely, agronomist, breeder, pathologist, soil microbiologist, socio-economist and extensionists.

REFERENCES

Amanuel Gorfu, and D.G. Tanner. 1991. The effect of crop rotation in two wheat production zones of southeastern Ethiopia. p. 486-490. *In* D.A. Saunders (Ed.) *Wheat for the Non-traditional Warm Areas.* CIMMYT, Mexico.

Amanuel Gorfu, D.G. Tanner, Kefyalew Girma, and Asefa Taa. 1996a. The influence of crop rotation and fertilizer level on weed density in bread wheat in southeastern Ethiopia. p. 71-76. *In* D.G. Tanner et al. (Eds.) *The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa.* Addis Ababa, Ethiopia: CIMMYT.

Amanuel Gorfu, D.G. Tanner, Kefyalew Girma, Asefa Taa, and Duga Debele. 1996b. Soil nitrate and compaction as affected by cropping sequence and fertilizer level in southeastern Ethiopia. p. 175-176. *In* D.G. Tanner et al. (Eds.) *The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa.* Addis Ababa, Ethiopia: CIMMYT.

Amanuel Gorfu, R.F. Kuehne, D.G. Tanner, and P.L.G. Vlek. 2000a. Biological nitrogen fixation in faba bean (*Vicia faba* L.) in the Ethiopian highlands as affected by P fertilization and inoculation. *Biol. Fertil. Soils* 32: 353-359.

Amanuel Gorfu, Kefyalew Girma, D.G. Tanner, Asefa Taa, and Shambel Maru. 2000b. Effect of crop rotation and fertilizer application on wheat yield performance across five years at two locations in southeastern Ethiopia. p. 264-271. *In* The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Amare Ghizaw. 1996. Mixed cropping of faba bean and field pea in Ethiopia. p. 56-63. *In* Proc. First and Inaugural Conference of Agronomy and Crop Physiology Society of Ethiopia (ACPSE), 30-31 May 1995, Addis Ababa, Ethiopia.

Asefa Taa, D.G. Tanner, and Amanuel Gorfu. 1992. The effect of tillage practice on bread wheat in three different cropping sequences in Ethiopia. p. 376-386. *In* D.G. Tanner et al. (Eds.) *The Seventh Regional Wheat Workshop for Eastern, Central and Southern Africa.* CIMMYT, Nakuru, Kenya.

Asefa Taa, D.G. Tanner, Kefyalew Girma, and Amanuel Gorfu. 1997. Grain yield of barley as affected by cropping sequence and fertilizer application in southeastern Ethiopia. *African Crop Science Journal* 5: 135-146.

Berhanu Kinfe. 1985. Progress on weed management in wheat production in Ethiopia. p. 92-102. *In* Proc. Fourth Regional Wheat Workshop for Eastern, Central and Southern Africa, and Indian Ocean. CIMMYT, Njoro, Kenya.

Bohlool, B.B., Landha, J.K., Garrity, D.P., and T. George. 1992. Biological nitrogen fixation for sustainable agriculture. *Plant Soil* 14: 1-11.

CSA 2002. Federal Democratic Republic of Ethiopia. Federal Statistical Authority. 271. Addis Ababa, Ethiopia.

DZARC. 2000. Annual Research Report 1998/99. EARO, Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

Eylachew Zewdie. 2001. Selection of haricot bean (*Phaseolus vulgaris* L.) genotypes to phosphorus stress under intercropped condition in eastern Ethiopia. p. 53-62. *In* Proc. Fifth Conference of the Ethiopian Society of Soil Science, March 30-31, 2000, Addis Ababa, Ethiopia.

Habtamu Admassu, M.S. Reddy, Teshale Alemu, and Jibril Mohammed. 1996. Maize based cropping systems for sustainable agriculture in semi-arid areas of Ethiopia. p. 74-82. *In* Proc. First and Inaugural Conference of Agronomy and Crop Physiology Society of Ethiopia (ACPSE). 30-31 May 1995, Addis Ababa, Ethiopia.

Hailu Gebre, Amsal Tarekegne, and Endale Asmare. 1989. Beneficial break crops for wheat production. *Eth. J. Agic. Sci.* 11: 15-24.

Jensen, E.S. 1986. Symbiotic N_2 fixation in pea and field bean estimated by ^{15}N fertilizer dilution in field experiments with barley as a reference crop. *Plant Soil* 92: 3-13.

Kefyalew Girma, Asefa Taa, Amanuel Gorfu, and D.G. Tanner. 1996. Effects of crop management practices on the population dynamics of different weed species in bread wheat in Arsi region of Ethiopia. p. 96-103. *In* D.G. Tanner et al. (Eds.). *The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa.* Addis Ababa, Ethiopia: CIMMYT.

Kefyalew Girma, Amanuel Gorfu, D.G. Tanner, Shambel Maru, and Asefa Taa. 1999. Weed population dynamics under different rotations in wheat based cropping systems in the southeastern highlands. p. 405-411. *In* Proc. Fourth African Crop Science Conference. Casablanca, Morocco.

Maidl, F. X., F. Haunz, A. Panse, and G. Fischbeck. 1996. Transfer of grain legume nitrogen within a crop rotation combining winter wheat and winter barley. *J. Agron. Crop Sci.* 176: 47-57.

Negash Geleta, Chemeda Daba and Setegn Gebeyehu. Evaluation of soybean genotypes for intercropping with maize at Bako (Unpublished).

Nigusse Tesfamichael, and M.S. Reddy. 1996. Maize/bean intercropping effects on component yield, land use efficiency and net returns at Awassa and Melkassa. p. 51-55. *In* Proc. First and Inaugural Conference of Agronomy and Crop Physiology Society of Ethiopia (ACPSE). 30-31 May 1995, Addis Ababa, Ethiopia.

Tanner, D.G., Amanuel Gorfu, P. Maina Murage, and Negussie Tadesse. 1994. A collaborative research agenda to develop sustainable wheat production technologies for East Africa. p. 229-240. *In* D.G. Tanner (Ed.) *Developing Sustainable Wheat Production Systems.* The Eighth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Tanner, D.G., H. Verkuijl, Asefa Taa, and Regassa Ensermu. 1999. An agronomic and economic analysis of a long-term wheat-based crop rotation trial in Ethiopia. p. 213-248. *In* The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Tesfa Bogale, Leta Tullu, and Tadesse Eshetu. 2003. Effect of preceding crops on succeeding maize crop in conventional and minimum tilled fields. p. 14-15. *In* Proc. Workshop on Conservation Tillage. SG 2000, Ethiopia.

Tezera Wolabu, Kefyalew Girma, Ayele Badebo, and D.G. Tanner. 1996. The effect of alternate crop management practices on Take-all and eyespot disease of bread wheat in southeastern Ethipia. p. 432-439. *In* D.G. Tanner et al. (Eds.) The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Tilahun Geleto, Kedir Nefo, and Feyissa Tadesse. 2000. Crop rotation effects on grain yield and yield components of bread wheat in the Bale highlands of southeastern Ethiopia. p. 316- 324. *In* The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Tolera Abera, and Daba Feyisa. 2001. Determination of the optimum proportion of faba bean and field pea in mixed cropping at Shambo. Paper presented at 10th Biannual Conference of Crop Science Society of Ethiopia. (In press).

Tolessa Debele, Gemechu Gedeno, and Melakeselam Leul. 1995. Relay cropping of different crops in short cycle maize Guto at Bako. p. 75-79. *In* Sebil. Vol. 6. Proc. Sixth Annual Conference. 3-4 May 1994, Addis Abeba, Ethiopia.

Wilson, J. M., and J. Hamblin. 1990. The effect of fumigation, rotation with lupins, and nitrogen application on plant growth and common root rot of wheat at Geraldton, western Australia. *Aust. J. Agric. Res.* 41: 619-631.

Yeshanew Ashagrie, and Asgelil Dibabe. 1999. The effect of green manuring and application of fertilizer on the yield of bread wheat at Adet in northwestern Ethiopia p. 182-185. *In* The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Yesuf Assen. 2002. N fertilizer requirement of bread wheat after legume precursor crops. (Unpublished data).

Zewdu Yilma, D.G.Tanner, Lemma Zewdie, and Girmay Gebru. 1995. The potential for double cropping in the cereal-based farming system in Sinana woreda of Bale region. pp. 64-74, Crop Science Society of Ethiopia (CSSE). In Sebil. Vol. 6. Proc. Sixth Annual Conference, 3-4 May 1994, Addis Abeba, Ethiopia.

Improving Drought Resistance of Grain Legumes in Ethiopia: A Physiological Approach

Tilahun Amede

Tropical Soils Biology and Fertility Institute of CIAT/ African Highlands Ecoregional Programme (AHI)
P.O.Box 5689, Addis Ababa, Ethiopia

ABSTRACT

Drought is one of the most limiting factors to grain legume production on a global scale; the situation in Ethiopia is expected to deteriorate unless the current trend of land degradation and climatic variability get reversed. Despite the alarming demand for drought-resistant cultivars, breeders are slow in achieving this goal due to the challenge of identifying traits that reflect true drought resistance. Four different scenarios of drought are apparent in Ethiopia, which may call for grain legume varieties with distinct physiological and agronomic traits. This paper discusses the current available knowledge on synchronizing traits of drought resistance in various grain legume germplasm with the phenological stage where plant water stress is most apparent.

UNDERSTANDING DROUGHT

Grain legumes are the major sources of protein for humans and animals, and also major soil fertility restorers. The cereal-based system of Ethiopia could have been out of production if it was not for grain legumes (faba bean, pea, chickpea, lentil, haricot bean and others) that have partly restored the fertility status of the soil and broken crop-pest cycles. However, productivity of food legumes in the region is limited by frequent droughts. While drought is yet one of the most limiting factors to crop production on a global scale, the situation in Ethiopia is expected to deteriorate unless the current trend of land degradation and climatic variability get reversed.

Drought denotes a prolonged period without considerable precipitation that may cause a reduction in soil water content, thereby causing plant water deficit. It is mainly caused by variable supply of rainfall across seasons, poor water holding capacity of soils and improper management of water resources. It has been happening at least once in three years in Ethiopia for the last 30 years, causing human and environmental disasters. Despite the alarming demand for drought-resistant cultivars, breeders are slow in achieving this goal due to the challenge in identifying traits that reflect true drought resistance.

Physiological drought could be defined either by the external water status at the boundaries of the plant (soil, air) or by the internal plant water status within the tissues (Tardieu, 1996). The first approach defines water stress as an imbalance between supply and demand, linked to the atmospheric saturation deficit following water potential gradient and leaf area (Tilahun, 1998). The second definition associates water stress with the control mechanisms of the plant, where plant water status is regulated within the plant accompanied by changes in water flux with or without changes in plant water potential under low soil water potential. The effect of drought could be appreciated through decreased plant productivity, growth inhibition and/or metabolic disturbance at various levels of plant organization. Decreasing water content may lead to loss of turgor and wilting, cessation of cell enlargement, reduction in photosynthesis and interference with many other physiological processes, including the production of toxic super oxides and hydroxyl radicals. At the whole plant level, drought tolerance of legumes depends primarily on matching of phenology to soil water availability, water acquisition potential by the roots, and efficient use and conservation by the plant system.

Four different drought scenarios have been identified by Tilahun et al. (2003). These include:

a) Scenario I representing terminal drought. In this case, there could be enough water for early establishment and growth, but later phenological stages are exposed to soil water deficit. This is typically the case in relay cropped beans in the Rift Valley, or chickpea after tef or wheat crop in the mid-highlands of Ethiopia. It is also a common phenomenon in regions that fully depend on irrigation for producing the major cash and food crops, and grow food legumes on the residual moisture. Thus, the crop is exposed to terminal drought starting from the early pod-filling stages.

b) Scenario II representing intermittent drought. This is typical of regions with relatively good rainfall amount but poor distribution during the growing period. There could be enough water for the crop throughout the life cycle except for some short dry spells that may happen at any time of the season. This is very common in regions with extended growing period (e.g., Areka and Awassa in southern Ethiopia).

c) Scenario III representing relatively predictable drought. In this case, the total amount of precipitation could be comparable to good years, but most of the rain falls within a short time of the growing season. The grain legume plants could be exposed to stress at early stage of growth but could receive enough water at later stages if the planting date is adjusted accordingly. This is a common phenomenon in most parts of the Rift Valley.

d) Scenario IV representing dry semi-arid climates. In this case, the amount of rainfall is relatively low to cover the physiological demand of the crop at any stage of growth despite its fair distribution throughout the growing period.

YIELD COMPONENTS OF GRAIN LEGUMES AND DROUGHT

Seed yield formation in legumes is a more intricate process than in cereals in that the development of generative organs is relatively gradual and could be prolonged if the external conditions, like water and nutrients, are not readily available. Seed yield is the product of number of plants (or fruitful axes) per unit area, number of pods per plant, number of seeds per pod and 100-seed weight. These yield factors are determinant for producing economic yield, and vary in time scale. The number of plants per unit area depends on the number of plants emerged and/or survived till maturity. For this yield factor, drought at the beginning of the growing season is very detrimental. Number of pods per plant or seeds per pod depends on the number of branches produced and the number of well-developed pods/seeds. In this case, intermittent and terminal drought could dictate pod formation, seed setting and seed filling by altering the source-sink relationship through affecting assimilate production, translocation and partitioning. Number of pods per plant is the most variable trait to affect seed yield in grain legumes, and is the reason why drought at or after flowering could reduce grain yield significantly. Drought at flowering is also known to cause abortion of flowers/pods, through assimilate shortage resulting in yield reduction.

REACTIONS OF LEGUMES TO DROUGHT

Legumes could respond to drought stress differently, depending on the species, stage of plant growth and intensity of drought. Whenever legumes experience a rapid water deficit, most leaves are known to orient themselves parallel to the incident light, and also alarm the biochemical systems. If the time of stress is extended to hours or days then physiological activities will be diverted from functions of cell expansion and growth to mechanism of restitution of the physiological integrity. For example, bean plants may react to the stress or through short-term strategies, like changes in hydraulic signals or stomatal adjustment. At this stage, photosynthetic rate could be comparable to the non-stressed plants but assimilates could be invested to develop long-term stress tolerance mechanisms at the expense of growth. Crops exposed to water stress for days to weeks may develop long term physiological strategies like altering the leaf area, modifying root to shoot ratios and alike. When available soil water is reduced, plants usually undergo three progressive stages of dehydration (Sinclair and Ludlow, 1986). At the initial stage of mild drought, assimilation and transpiration are comparable to that of well-watered plants as long as soil water uptake meets evapo-transpiration requirements. In the second stress period, the photosynthetic capacity of the plant is reduced below the maximum potential level. This is considered to be the most dynamic stage for developing adjustment mechanisms and to regulate processes for the maintenance of metabolic activities (Tilahun, 1998). In the third phase, plants merely survive and delay death. Recovery after rain or irrigation depends on the duration of stress and type of species.

MECHANISMS OF DROUGHT RESISTANCE IN GRAIN LEGUMES

Drought resistance is polygenic and is commonly accompanied by negative impacts on seed yield. For example, decreasing leaf area or shortening the maturity period of a genotype may improve water availability for the plant by decreasing cumulative transpiration but also ultimately decreasing economic yield. Selection for drought resistance based on yield alone may not bring about the required genetic shift in specific physiological attributes, as the component of genetic variance is low compared with environmental or genotypic-environment-interaction variance under stress conditions (Rosielle and Hamblin, 1981). Adaptation to non-drought factors, such as pests, diseases, nutritional status, etc. may have also an overriding effect on the physiological integrity of the plant, thus the genetic component of drought resistance of a given genotype could be masked. Despite previous disappointments, drought resistance of legumes could be still improved by manipulating the genetic make-up for efficient water use and effective assimilate partitioning leading to increases in economical yield. Many physiological traits have been associated with drought resistance (Ludlow and Muchow, 1990). The major drought resistance mechanisms in beans could be classified as drought avoidance (drought resistance with high plant water potential) and drought tolerance (drought resistance with low water potential) (Subbaro et al., 1995). To date, however, no traits are known that confer global drought tolerance (Passioura, 1996). Moreover, short-term responses to water stress at the cellular and sub-cellular level alone may not contribute to yield under conditions of water deficit (Passioura, 1996).

Traits of Varieties Fitting to Scenario I

Reduced plant size: Seed yield is a converted function of biomass accumulation, which is linearly related to cumulative transpiration (Tanner and Sinclair, 1983). Higher grain yield in legumes is positively correlated with higher plant biomass but negatively with drought resistance (Slim and Saxena, 1993). In faba bean, Tilahun et al. (1999) showed that drought sensitivity increases with increasing plant height and the correlation was very high (r=+ 0.93). Thus, high yielding genotypes were drought sensitive and vice versa. However, it is not yet known whether combining high-yielding and drought resistance traits within a single genotype is possible. Since genotypes that are water-saving are commonly low-yielding, growing these genotypes in favorable years would lead to a considerable yield loss (Slim and Saxena, 1993).

***Drought escape*:** The most effective strategy of a drought-resistant crop should be to match the most sensitive phenological growth stage to the peak soil water availability (Richards, 1996), and drought escape could be one of the most reliable strategies of drought resistance for specific environments. However, drought escape in beans is strongly associated with low yield. A yield trial from CIAT on 42 bean genotypes with varying maturity period from 52 to 83 days showed that differences in maturity were strongly associated with a yield difference of 2000 kg ha-1 (White, 1988). In chickpea, drought escape was a major contributor to yield differences under drought conditions, although few cultivars exhibited real drought tolerance (Slim and Saxena, 1993). Low yield in early-maturing genotypes could be not only due to reduced periods of photo-assimilation but also due to shortened remobilization/translocation times. Despite this, it is not known whether drought-escaping genotypes have alternative tolerance mechanisms or not.

Traits of Varieties Fitting to Scenario II and III

Developmental plasticity: In comparison to drought-escaping types, genotypes with a potential developmental plasticity would be much preferable. Developmental plasticity means the ability of a genotype to adjust the duration of different growth phases and canopy development pattern to suit moisture availability during the growing season (Subbaro et al., 1995). For instance, peg initiation and elongation of groundnut plants cease when soil moisture is depleted to 80% of the plant-available water, and recommences when soil water is adequate (Chapman et al., 1993). Pod setting and filling at lower nodes during the early growth of some chick-pea genotypes ensured that at least some seed setting occurred in case of receding soil moisture (Saxena et al., 1993).

***Stomatal regulation*:** Water loss at the plant level largely depends not only on the size of the transpiring areas (mainly leaves) but also number and size of the stomata, and the conductivity of the cuticle. In crops, about 90% of total water loss is associated with stomatal transpiration (Monneveux and Belhassen, 1996) followed by water loss through the cuticle. The hydraulic conductivity of the cuticle depends upon thickness, and on the presence or absence, and the nature of cuticular wax embedded or deposited on it. Plant transpiration loss could also be modified by the presence or absence of leaf traits such as leaf rolling ability, the color of the transpirative organ or leaf reflectance. Moreover, early seedling establishment, early vigor, rapid canopy development in order to minimize evaporation, as well as leaf area maintenance have been suggested as potential drought resistance mechanisms in grain legumes (Subbaro et al., 1995).

An experiment conducted to evaluate the effect of drought on stomatal closure in bean in comparison to chickpea showed that in beans CO2-fixation decreased by about 75% after 3 days of mild stress, while in chickpea CO2-fixation was not affected by drought except for 25% reduction on the six days of stress (Tilahun, 1998). In other studies, O'Toole et al. (1977) showed that photosynthesis and transpiration rates in common bean were near zero at plant water potentials of -0.9 to 1.0 MPa, showing that stomatal closure is one of the first steps of defense against drought in beans since it is a more rapid and flexible process than other mechanisms like root growth or reduction in leaf area. However, stomatal closure caused a drastic decrease in biomass accumulation thereby grain yield through reduced photosynthesis (Tilahun, 1998). Thus, it could be considered as an effective survival strategy for intermittent stress but not important for terminal stress since production of economic yield is the major goal at this stage of growth.

***Efficient roots*:** Mild drought favors root growth at the expense of shoot growth in order that roots extend to the unexplored deeper part of the soil for available water. Adequate root density throughout the soil profile may increase the diffusion area, thereby improving water availability and uptake. Maintenance of water status under water limitation can be partially attributed to root depth and root length density (Subbaro et al., 1995). Slim and Saxena (1993) showed that root depth could be considered as an alternative trait to screen drought resistant lines. Sponchiado et al. (1989) compared two drought-tolerant and two drought-sensitive genotypes under drought-stress conditions at CIAT-Palmira to identify physiological differences of drought resistance. Their results showed differences in drought tolerance among genotypes were associated with root depth, but not root length density, as roots of drought-tolerant genotypes reached a depth of 1.3 m, while roots of drought-sensitive ones only reached 0.8 m. Similarly in chickpea, genotypes with deeper root systems exhibited higher leaf water potential than shallow-rooted genotypes under drought-stress conditions (Slim and Saxena, 1993). In some cases, crops with higher root length density were not necessarily drought-tolerant (Hamblin and Tennat, 1987). Plants often maintain higher root length density than is required by the surface area of the shoot, mainly to minimize effects of other stress factors such as pests, and nutrient deficiency (Passioura, 1983). In addition, it is not known what proportion of the roots is actively involved in water uptake. Extensive root growth at the early stage of plant development could be a disadvantage in semi-arid regions, as it may exhaust the available water prematurely and expose the plant to a critical and terminal drought later on (Passioura, 1996).

Traits of Varieties Fitting to Scenario IV

Mobilization of assimilate to grain: Screening many lines in the field based on root depth or density is laborious and normally impractical. The simplest method suggested for screening drought-resistant lines in the field is delayed sowing (Singh et al., 1994). Since legumes grown in semi-arid regions commonly encounter terminal drought, sowing a month later than normal in the spring has been effective in differentiating between drought-resistant and drought-sensitive lines (Singh et al., 1994). As translocation is less affected by drought than photosynthesis and respiration (Boyer, 1976), late sowing may help to evaluate the ability of the genotype to translocate reserves to the sink during the onset of terminal drought. The assimilates could act as buffer against the effects of water deficits on current assimilation (Ludlow and Muchow, 1990), and could originate from pre-anthesis or post-anthesis periods depending up on the time of stress and the amount of reserve available in the stem.

Osmotic adjustment: When legumes are exposed to drought, they may alter cell solute concentration by allocating resources so that the osmotic potential of the cell is reduced, and turgor is maintained (osmotic adjustment). It allows turgor-driven physiological processes, as stomatal movement and cell growth to continue despite low plant water potential. It also increases seed yield under stress conditions through modifying the soil-plant water gradient thereby increasing the amount of water transpired. Osmotic adjustment, through accumulation of effective osmotica, is thus an important mechanism of drought resistance in legumes (Tilahun, 1998). However, accumulation of solutes in the plant cell per se did not guarantee osmotic adjustment. Besides osmotic adjustment, solute deposition in plant cells under drought stress could have four principal causes (Tilahun, 1998). Firstly, plants may lose substantial amounts of water that may lead to a reduction in the expansion rate of the tissue (reduced cell volume), and thereby to an accumulation of solutes in the cell. Secondly, some primary metabolites (proteins, carbohydrates or lipids) may be degraded at higher stress intensities, and the by-products could accumulate as secondary metabolites in the cell. Thirdly, decrease in cell elongation (growth) may cause slowing down of assimilate biosynthesis but effective import of assimilates to the sink cells could be high enough to increase the concentration of solutes and ultimately cause a reduction in the osmotic potential of the cell (Kramer and Boyer, 1995). Fourthly, under moderate levels of stress, roots may still actively absorb inorganic ions (potassium, calcium, sodium, magnesium, chloride, and others) from the soil. Nutrients may not be utilised by the plant owing to drought-induced growth inhibition but instead, the translocated ions may accumulate in the cell and induce substantial reduction in osmotic potential (Munns, 1988). Therefore, differentiation between solute accumulation due to a concentration effect and true osmotica is a prerequisite before using solute accumulation synonym to osmotic adjustment (Tilahun and Schubert, 1997).

Comparative research on osmotic adjustment between common bean and chickpea genotypes showed that solute pool accumulation due to drought in bean was a concentration effect while the accumulation was a true osmotic adjustment in chickpea (Tilahun and Schubert, 1997, Tilahun, 1998). In other studies, Parsons and Howe (1984) compared common bean (*Phaseolus vulgaris*) with tepary bean (*Phaseolus acutifolius*) for their water relations, and concluded that tepary bean was more drought-tolerant than the common bean due to higher osmotic adjustment potential of tepary beans. They suggested a transfer of osmotic gene from tepary bean to common bean to improve drought resistance. In general, there is no convincing data to date, which suggests osmotic adjustment as a mechanism of drought resistance in common bean.

THE WAY FORWARD IN DROUGHT RESEARCH

There is a clear understanding among researchers that there are no drought resistance traits of global importance, especially when the expected outcome is beyond survival, but economic yield. Therefore, it is a necessity to characterise the target environment not only from the meteorological but also from the plant aspect. It should be characterised in terms of severity of water stress, rate of development of stress, duration of stress, spatial heterogeneity and alike. Detail characterisation of the environment may help to design and model genotypes with fitting traits.

The other common mistake in drought research is the medium used to identify candidate materials, which is commonly done under inappropriate environments. Testing materials under natural field conditions is a realistic but a challenging task for two possible reasons. Firstly, there is commonly a year-to-year variation in plant water availability; hence the experiment should be conducted for many years in many drought-prone environments before reaching to a decision on the fate of the tested materials. Secondly, besides water stress, many other factors, like variability in soil water holding capacity, complicate the results. Hence careful attention should be taken. A very close type of experimentation is using a rain-out shelter in the field. This could be done even under well-watered years by covering part of the plot with rain-out covers. The most reliable method could be line-source irrigation or pot experimentation. However the size of the pot should be big enough to allow free growth of roots (a pot with 15 kg soil is found to be appropriate). The drawback of pot experiments and line source irrigation is that only few treatments under few replications could be handled at a time.

Although challenging, there is an opportunity to improve drought resistance through conventional breeding using the existing genetic diversity. However, much of the genetic variation for improving drought tolerance has been lost during domestication, selection and modern breeding, leaving pleiotropic effects of the selected for development and adaptation (Foster et al., 2000), and hence searching for new gene pools from primitive land races and related wild species may require a different strategy. The use of molecular tools for elucidating control mechanisms of stress resistance could be done by engineering genes, which regulate osmoprotection, water and ion movement, availability of functional and structural stress-induced proteins and free radical scavenging systems (Wang et al., 2001). These techniques could be efficiently used to develop drought-resistant genotypes as long as polymorphism is observed in segregating populations, the molecular marker is tightly linked to the traits of interest, and the phenotypic information on the segregating population is available (Sharma and Lavanya, 2002).

REFERENCES

Boyer, J.S. 1976. Photosynthesis at low water potentials. Philos. Trans.R. Soc. London Ser. B. 21: 501-512.

Chapman, S.C., M.M. Ludlow, F.P. Blamey, and K.S. Fischer. 1993. Effect of drought during early reproductive development on growth of cultivars of groundnut (Arachis hypogaea L.) II. Biomass production, pod development and yield. Field Crops Res. 32: 211-225.

Foster, B.P., R.P. Ellis, W.T.R. Thomas, A.C. Newton, and R. Tuberosa, D. This, R.A. El-Enein, M. Bahri, and M. Ben Salem. 2000. The development and application of molecular markers for abiotic stress tolerance in barley. J. Exp. *Bot.* 51: 19-27.

Hamblin, A., and D. Tennat. 1987. Root length density and water uptake in cereals and grain legumes: How are they correlated? Aust. J. Agric. Res. 38: 513-27.

Kramer, P. J., and J. S. Boyer. 1995. Water Relations of Plants and Soils. Academic Press, UK. 480 pp.

Ludlow, M.M., and R.C. Muchow. 1990. A critical evaluation of traits for improving crop yields in water-limited environments. Advances in Agronomy 43: 107-153.

Monneveux, P., and E. Belhassen. 1996. The diversity of drought adaptation in the wide. Plant Growth Regulation 20: 85-92.

Munns, R. 1988. Why measure osmotic adjustment ? Aust. J. Plant Physiol. 15: 717-726.

Parsons, R.L., and Howe, P.K. 1984. Effects of water stress on the water relationship of Phaseolus vulgaris and the drought-resistant P. acutifolius. Physio. Plant. 60: 197-202.

Passioura, J.B. 1983. Roots and drought resistance. Agric. Water Manage. 7: 265-280.

Passioura, J. B. 1996. Drought and drought tolerance. Plant Growth Regulation 20: 79-83.

Richards, R.A. 1996. Defining selection criteria to improve yield under drought. Plant Growth Regulation 20: 157-166.

Rosielle, A.A., and J. Hamblin. 1981. Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci. 21: 943-946.

Saxena, N.P., C. Johanson, M.C. Saxena, and S.N. Slim. 1993. Selection for drought and salinity tolerance in cool season food legumes. p 45-270. *In* K.B. Singh and M.C. Saxena (Eds.) Breeding for stress tolerance in cool season food legumes. Wiley, UK.

Sharma, K.K., and M. Lavanya. 2002. Recent developments in transgenics for abiotic stress in legumes of the semi-arid tropics. JIRCAS Working Report 23: 61-73.

Sinclair, T.R., and M.M. Ludlow. 1986. Influence of soil water supply on the plant water balance of four tropical grain legumes. Aust. J. Plant Physiol. 13: 329-341.

Singh, K.B., R.S. Malhotra, M.H. Halila, E.J. Knights, and M.M. Verma. 1994. Current status and future strategy in breeding chickpea for resistance to biotic and abiotic stresses. Euphytica 73: 137-149.

Slim, S.N., and M.C. Saxena. 1993. Adaptation of spring-sown chickpea to the Mediterranean basin. II: Factors influencing yield under drought. Field Crops Res. 34: 137-146.

Sponchiado, B.N., J.W. White, J.A. Castillo, and P.G. Jones. 1989. Root growth of four common bean cultivars in relation to drought tolerance in environments with contrasting soil types. Expl. Agric. 25: 249-257.

Subbaro, G.V., C. Johansen, A.E. Slinkard, R.C. Nageswara, N.P. Saxena, and Y.S. Chauhan. 1995. Strategy for improving drought resistance in grain legumes. Critical Reviews Plant Sciences 14: 469-523.

Tanner, C.B., and T.R. Sinclair. 1983. Efficient water use in crop production: research or re-search. p. 1-28. In H. Taylor et al. (Eds.) Limitations to efficient water use in crop production. American Society of Agronomy, Madison.

Tardieu, F. 1996. Drought perception by plants. Do cells of droughted plants experience water stress. Plant Growth Regulation 20: 93-104.

Tilahun Amede. 1998. Analysis of drought resistance in grain legumes. The case of Vicia faba, Pisum sativum, Phaseolus vulgaris and Cicer arietinum. Ulrich E. Grauer Publishing, Stuttgart, Germany. 135 pp.

Tilahun Amede, and S. Schubert. 1997. Solute pool enlargement in drought sensitive or -tolerant grain legumes. Concentration effect or osmotic adjustment ? p. 165-166. In Plant Nutrition for Sustainable Environment. Kluwer Academic Publishers, Japan.

Tilahun Amede, E. von Kittlitz, and S. Schubert. 1999. Differential drought responses of faba bean (Vicia faba L.) inbred lines. J. Agron. & Crop Sci. 183: 35-45.

Tilahun Amede, P. Kimani, W. Ronno, L. Lunze, and N. Mbikayi. 2003. Coping with drought: strategies to improve genetic adaptation of common bean to drought prone regions of Africa. CIAT Occasional Publication Series 38.

Wang, W.X., B. Vinocur, O. Sheseyou, and Altman, A. 2001. Biotechnology of plant osmotic stress tolerance: Physiological and molecular considerations. Acta Horticultura 560: 285-292.

White, J.W.1988. Preliminary results of the bean international drought yield trial (BIDYT). p. 126-145. In J.W. White et al. (Eds.) Research on Drought Tolerance in Common Bean. Working Document No. 41. CIAT, Cali, Colombia.

The Role of Farm Implements in Bean Production

Seyoum W/senbet, Workneh Abebe, Laeke Kebede, Haji Sani and Friew Kelemu

Melkassa Agricultural Research Center, P.O.Box 436, Nazareth,Ethiopia

ABSTRACT

Agricultural production can be increased by using inputs (seeds and fertilizer) and/or by bringing in more land into production. These alone cannot effect increased agricultural production. For the direct inputs to perform to their optimum potential, the physical environment like proper seedbed and weed-free conditions are essential. Minimal harvesting losses and proper post-harvest handling techniques are required after the crop has reached physiological maturity and before it reaches the end-user. All these are attainable if proper agricultural mechanization technology is employed at the right time. Efforts have been made by the Agricultural Mechanization Research Program to develop agricultural equipment and technologies for land preparation, crop establishment inter culture and post-harvest handling and transportation. Plows, harrows, weeders, threshers, and water-lifting devices have been developed by the center. These implements will improve labor productivity and quality of work, which will have a tremendous effect on the productivity and production of haricot bean. Storage, packaging and handling are some of the areas, which still need the attention of the research system.

INTRODUCTION

The Ethiopian economy is mainly agrarian. It employs 85% of the population, contributes to 45% of the gross domestic product and 90% of the national export earning. The population of the country is increasing at an alarming rate of 3.3% annually and is expected to reach 117.2 million by the year 2030 (Dry Land Agriculture Strategic Plan, 1999, unpublished). Food deficit in the whole country is increasing as evidenced by chronic food insecurity mainly to drought, which led to frequent famines in different years. To meet the food demand of the ever-increasing population and finance the other sectors of the economy, it is not debatable that more efforts are required to increase productivity and productiion. This is attainable by the introduction of a wise mix of bio-chemical-, socio-economics- and physical science-based technologies to the agricultural production system. The latter is the role to be played by the agricultural engineering sector. The Agricultural Engineering Research Program (AERP) is expected to deliver technologies, which will help attain the country's agriculture development goals and objectives.

The country covers vast and diversified 18 major agro-ecology zones (Mengistu and Ermias, 1987). The diversified agro-ecology has resulted in varied vegetation, animal species and environmental condition, which need appropriate technology for the sustained use of the resources for a better life of the Ethiopian population at large. The particular agro-ecology condition dictates the kind of agricultural technology intervention needed to make the best use of the resources.

The major agro-ecological zones of the country include arid, semi-arid, sub-moist, moist, sub-humid, humid and per-humid zones. Among them, it is in the sub-moist and moist zones, where haricot bean is widely grown. Agricultural mechanization technologies, which create the environment for the crop to perform to its potential through the delivery of proper seedbed, land forming and crop establishment technologies, especially in a moisture-stress and fragile soil environment, need to be given a serious attention.

THE FARM POWER AND MACHINERY RESEARCH PROGRAM

According to the economic theory, it is the wise mix of production factors, which help increase productivity and production. In agriculture, production factors cannot be simplified as land, labor and capital and rely upon them to effect increased productivity and production. For the development of a country one has to go further and see which production factors are pivotal in increasing productivity, production and contribute to the over all economic development of the country.

Addressing the sub-sector in this respect, parallel to other disciplines would change the traditional farming system and the life style of the people. It would be unthinkable to bring a substantial change in the farming system of the country by concentrating only on the other components without addressing the farm power and machinery problem. Efforts have been made by the Agricultural Mechanization Research Program (AMRP) to develop agricultural equipment and technology for land preparation, crop establishment, inter culture and post-harvest handling and transportation.

Past Research and Achievements

The Agricultural Implements Research and Improvement Center (AIRIC) conducted a survey in 1986/87 (Pathak, 1987) in six administrative regions of the country to document agricultural implements related production constraints. The survey was conducted in the major crop production zones, and pulses were one of the major enterprises considered in the survey. In most of the bean growing regions, plowing for bean was conducted on the average two-three times compared to wheat or *tef*. Except in Arsi, there was no record on fertilizer use, and weeding was done once or twice in most of the surveyed areas (Pathak, 1987). According to a socioeconomic survey, farmers in haricot bean growing areas use twice the seed rate to suppress the weed growth in haricot bean.

Basic Studies on Draft Animal Power

As draft animals are an important component of seedbed preparation, a basic study on the draft performance of the indigenous oxen was carried out at Nazareth and Holetta. According to the study, the average working speed of the Ethiopian oxen was found to be only 0.4 to 0.5 m/s, while 1.1 m/s is a commonly reported speed for draft oxen. Under the conditions of the study, they performed best at a pull level of 15% of their body weight contrary to reports of 10% elsewhere. The oxen performed better at higher altitudes. Also, the v-yoke was found to be better than the neck-yoke as a single animal harness. Based on these results, it was recommended that wider implements than *maresha* (the local plow) be introduced for secondary tillage in order to alleviate timeliness problem through full utilization of the pulling capacity of a pair of indigenous oxen. It was also found that for the large number of farmers owning only one ox, the introduction of low draft tillage implement would be beneficial together with the single animal harness.

Pre-harvest technology: Several prototypes from abroad as well as from different places in the country were collected and tested both in the laboratory and field (Table 1). Then, the required modifications were made on the implements to make them both technically and economically acceptable by the small-scale farmers.

Table 1. Summary of field test results conducted on different plows at Melkassa Research Center.

Parameter	*Maresha*	Ardu plow	Nardi plow	Nazareth plow
Soil moisture(%)	17.5	19	17	-
Weeding efficiency(%)	92	94.3	89	97.3
Average depth (cm)	6.6	20.8	9.8	9.9
Draft (kgf)	102.5	98.4	92.1	76.1
Time hr/ha	20	23.3	24.6	22.7

Source: AIRIC Test Reports 1, 2, 3, 4 (unpublished).

After several field and laboratory tests, modifications were made on the most promising prototypes and finally a plow named after Nazareth was developed. The plow was given to the Center's Agronomy/Physiology Division for further testing. A 12% increase in maize grain yield was reported compared to *maresha* (Farm Power and Machinery Strategy 2001, unpublished). Despite this, there were complaints on the weight, handle and depth adjustment systems of the plow. Based on the feedbacks collected, a series of modifications were made on the plow and finally the *erf* (handle) and *mofer* (beam) attached moldboard plow was developed. The main components of this implement are; the moldboard plow bottom that was found to be superior to *maresha* in terms of field performance, light weight and cost, the *erf*, the *mofer* , *merget* (a rope used for attachment) and a portion of *deger* (the wooden wing of *maresha*), which is used to stabilize the plow.

Besides the plow, several other implements were developed by the center in the pre-harvest category. The winged plough is a land preparation implement, which does not invert the soil, is light in weight and can be pulled by single ox or donkey. As the plow does not invert the soil, it minimizes moisture loss through evaporation and is very useful for the moisture-stress areas.

Ridge tier: Tied ridges are small depressions made between rows especially in moisture-stress areas. Experiments conducted at Kobo and Mekele showed that yields of sorghum, maize and mungbean were significantly increased by using the tied ridges (Hailu and Kidane, 1988). However, limitation to this practice has been the backbreaking exercise of making the tied ridges by hand. Taking this into account, AIRIC developed the ridge-tier, which was four times faster than the manual practice. There was complaint on the original design, as it required both hands of the farmer for the operation leaving him no option to guide his oxen. This problem is now solved as the farmer only uses one hand for the operation of the modified version. Comparative tests made by farmers on the improved package, moldboard plow, winged-plow and ridge tier in combination showed increased grain yield of haricot bean (AIRIC Progress Report, 2000, unpublished). An observation conducted on farmers' field showed that improved package of implements moldboard plow with tie ridger gave higher yield compared to the conventional *maresha* (Table 2).

Planter: Most Ethiopian farmers have been using the method of broadcasting seeds and fertilizers and covering by *maresha* for a long time. Broadcasting is not a suitable method of planting row crops like maize, sorghum and pulses as it does not ensure desired plant population. The spacing will not be uniform and hinders the use of improved weeding practices, which contributes to lower yield. Hand dibbling is also a tedious and labor intensive, which affects productivity. Though plant spacing is not a problem in close growing crops like wheat and barley, row planting of these crops will increase weeding efficiency. At the Mechanization Research Center, research has been conducted on planting implement to obtain optimum plant population and spacing in non-tillering crops. Precision seed metering devices were also collected, tested and evaluated both in the laboratory and field. Based on these results, a prototype was developed and weaknesses were observed on this implement.

Table 2. Comparison of grain yield from improved implements as reported by farmers.

No.	Name of farmer	Plot size (ha)	Implement	Grain Yield (q/ha)	
				Improved	Maresha
1	Teshome Bose (Awash 1)	0.5	Mb, WP, TR	10	8
2	Teshome Bose (Mex 142)	0.01	WP	11	15
3	Birhanu Melka	0.5	Mb, WP,TR	14	10
4	Juke Bedada	0.5	Mb, WP, TR	12	10

Mb= Moldboard plow; WP= Winged plow; TR= Ridge tier.

Modifications were made on the seeding attachment and two ground wheels were added to drive an agitator, the covering device was replaced by a chain drag bar, and a device was fabricated to directly attach it to the *maresha*. This equipment was tested for maize, sorghum and haricot bean using different seeding plates prepared for these crops.

Three types of planters, viz., Earthway, Wheel hoe and Hassia planter were tested at AIRIC using haricot bean variety Mexican 142 in early August in 1986. Though not significant, the Earthway planter was found better in terms of time compared to the other two (Table 3). The performance of the crop was not conclusive since it was planted late. All were hand-pushed ground wheel-driven planters with exchangeable seed plates depending on the kind of crop to be planted.

Table 3. Planting test results of Earthway, Wheel hoe and Hassia planter on haricot bean at Melkassa, 1988.

Parameter	Earthway	Wheel hoe	Hassia
Plot size (m^2)	30	30	30
Row length (10m)	10	10	10
Row spacing (cm)	37.5	37.5	37.5
Seed rate (kg/ha)	61.2	111.2	44.4
Field capacity (ha/hr)	0.042	0.039	0.041
Seed spacing (cm)	16.2	12.8	15.5
Seeding depth (cm)	3.2	2.2	2.9
Plant population/ha	853,333	1,413,333	622,222
Yield (q/ha)	13.13	14.33	13.43

Source: AIRIC Test Report No. 35 (1989) (unpublished).

The plant population in all cases was higher than the recommended 500,000 plants. The draft required was felt to be higher in all cases especially when it was wet. Based on this, the improvement work continued on *maresha*-attached planter. The planter was mounted on *maresha* and provided with different plates for different crops including haricot bean. An Indian-type funnel planter and a hand-operated animal-drawn planter were fabricated in the workshop. Field tests were carried out to compare these implements together with dibbling seeds behind the plow and broadcasting (Tables 4 and 5).

Table 4. Field test results of different planting methods using two kinds of planters at Melkassa, 1991.

Parameter	Funnel-type planter	Animal-drawn planter
Spacing (cm)	28.5	14.8
Maximum gap (cm)	440	62
Seed rate (kg/ha)	16.7	32.5

Source: AIRIC Progress Report (1992) (unpublished).

Tests conducted on the planter showed that the draft requirement was found to be on the average 87.9 kgf (kilogram force) and the field capacity was 0.1 ha/hr, when used with a covering device, which is adjustable between 4 cm and 7 cm. The width of covering of a single pass was also dependent on the choice of the farmer ranging from 60-80 cm. Spacing between hills ranged from 50-60 cm while the number of hills ranged from 9-12 for haricot bean. The planter worked effectively in different types of soils; in muddy and cloddy fields as its metering mechanism did not depend on ground wheels (AIRIC Progress Report, 1996, unpublished).

In 1995, the raw planter as an attachment to the *maresha* was launched through a project on participatory research for improved agro-ecosystem management. This gave the researchers the opportunity to collaborate and support farmers to test and further improve the implement under farmers' field conditions and livelihood constraints (AIRIC Progress Report, 1996, unpublished). Based on the feedback, the planter was modified and taken back to the farmers. In 1998 *meher* season new distribution plates for multiple improved maize and bean seed varieties were fabricated. By using this improved implement the project farmers were able to substantially increase crop yields, which enabled them to buy additional oxen and inputs.

Weeder: Different types of animal-drawn weeders were tested at AIRIC in the early 1980s, but the work was not pursued further due to the higher mechanical damage observed on the crop (Table 6). A manual wheel-hoe weeding implement and a single animal-drawn (ox or donkey) inter-row weeder were also developed by the Center. The implements reduced the time and labor required by many folds, destroyed weeds between rows and buried them in the row. The exceptional advantage of the weeders is that they cut shallow and move little soil, so that the young seedlings are not buried unlike the *maresha*. Recently, an animal-drawn cultivator was tested on maize, which could be extended to be used on the haricot bean as well. This implement reduces the weeding time by 18-fold, and is a light and simple equipment having all the advantages described above.

Table 5. Field efficiency of different planting methods tested at Melkassa, 1991.

Category	Broadcasting and covering with *maresha*	Seeding with row-planter	Dibbling behind the plow
Field capacity (ha/hr)	0.029	0.134	0.023
Labor requirement	1	1	2
Man (hr/ha)	35	7.46	86.95
Seedling emergence	44.87	66.37	-

Table 6. Test results of mechanical weeders on haricot bean.

Name of implement	Depth of operation (cm)	Time (min)	Mechanical damage (%)	Weeding efficiency	Yield (q/ha)
Spring tine	4.68	15.3	10.63	72.85	21.8
Expanding hoe	4.47	26.3	7.26	79.75	23
Duck foot	4.24	27	5.09	58.67	20.3
Control	-	112.47			20.9

Source: AIRIC Progress Report (1984,85).

Harvesting

The mechanization of grain harvesting has been a long time objective of farmers. The cutting and manual threshing of small seeds are extremely tedious. Before recorded history, people learned to use reaping tools and animal treading to increase the productivity of small grain harvest. Evidence of the wheeled reaping cart in ancient Gaul has been found. Horse-drawn reaping machines and stationary threshers date from the early 1800s in the United States. An important early application of steam power was for stationary threshing, separating and cleaning of food grains. Attempt to develop a field machine to accomplish all the small grain harvest in one-operation dates back to the 1830s, and this effort was realized with the coming of the combine harvester. The modern combine is one of the most important machines in mechanized agriculture. It has been adapted to the harvesting of more than 100 food and feed, crops, and processing of grain crops.

Initially, all beans for canning were hand-picked. By the late 1950s, the costs and availability of labor for hand-picking became restrictive. The development of the mechanical harvester and new culture such as tender crop, which were especially suited to mechanical harvesting, changed the entire industry. The hand-picked types keep blooming and getting pods over a long period of time as mature pods are harvested two or three times over several weeks. Machine harvesting requires a concentrated maturity, where majority of the pods are ready at the same time for one-time harvest over destructive harvest. Moreover, the best machine-harvested types bear the pods in the mid- to upper part of a strong upright plant so that high proportion of the pods can be machine-harvested.

Harvesting of beans in Ethiopia is normally done when most of the pods have dried. The pods are then brownish and have a brittle texture. The plants are pulled up and left in rows or small stokes in the field for further drying. When dried they are transported, carried by humans or animal back or by trailer to the threshing ground, which is formed by consolidated earth. Threshing is done by trampling oxen or by running it over with tractor. Then the stalks are removed with forks and the seed winnowed by throwing it up to the wind. As the pods are getting brittle, when they dry out, late-harvesting may lead to seed shattering. These can be reduced if pulling of the pods is done early in the morning. Some attempts were made to thresh beans using the IAR threshing-shelling machine. Some observations were made at Endeber using haricot bean, but there was no follow up work, and the use of this machine has been limited to wheat, barley and maize.

Storage

Each kernel/grain of a crop is a small parcel comprising energy. Being biologically active, it continues to respire during storage giving off heat and moisture as waste products. Ideal storage conditions are those which reduce this activity to a minimum. By so doing, the accumulation of heat and water vapor, which would either reduce the storage life of the grain or even cause loss of the crop partly or wholly are prevented. Traditional methods of on-farm storage rely on controlling below the relevant critical level. These are oxygen availability, and water and temperature level. In addition to these factors, the stored crop can be at risk from fungal diseases, insect-pests, loss of germination and mite infestation. For crop harvested with low moisture content the main problem encountered is the development of insect infestation. Storage in hermetically sealed containers may eliminate the necessity of using chemical pesticides. Initial insect activity consumes the oxygen available in the gas tight structure, and when the oxygen level drops below a certain limit the insects cannot survive. To meet this objective, the division of stored products of the Volcani Center at Bet Dagan, Israel developed a gas tight P.V.C. silo that can be sealed to a degree of gas tightness to provide these conditions. The P.V.C. silos are transportable structures and can easily be erected. Gas tightness can be obtained to eliminate insect infestation and grain temperature can be monitored by aeration whenever necessary (Donahaye, 1992).

In Ethiopia, draft combined with post-harvest loss problems is important causes for the existing food deficit. The attempts to produce more grain alone cannot lead to food self-sufficiency. Reducing losses and increasing food availability through a sound storage and handling system, efficient marketing and appropriate processing technologies could contribute greatly to a country's poverty alleviation program. Research on bean storage equipment is scarce. The common impression is that storage losses are estimated to be in the range of 20%-50%, even the actual figures can vary considerably by altitude, type of commodity, design and construction of the storage structure.

Field observations conducted to determine food grain losses in traditional storage facilities in Akaki indicated that the physical grain damage for legumes stored for 13 months were 36% for faba bean, 26.1% for chickpea, 25% for vetch, and about 4% for field pea and lentil (Yemane and Yilma, 1986). They also stated that in addition to the quantity, losses due to physical damage, the infestation by beetles could cause nutrient loss of about 12% of the available protein in different grain legumes studied. In general, grain damage and weight losses in store are believed to be due to insect-pests, rodents and mould growth. Farmers store nearly all their grains in a variety of ways. According to Yemane and Yilma (1986), common storage systems used in Ethiopia are *debignet, slicha, akomoda,* bags and interwoven baskets which are meant for temporary storage of usually less than one quintal of seed. They also use bulk storage units called *gotera, gota,* underground pits jute bags or sacks in unoccupied rooms. *Gotera* is made of interwoven sticks or bamboo plastered with a mixture of cow dung or clay mud and *tef* straw. The roof is of detachable, conical-shaped thatch grass. *Gota* is made of a combination of cow dung, ash mud and *tef* straw and is kept indoors. The common problem with most of these storage structures is that insects and rodents can easily attack stored products. The material used for making grain store makes a difference in the extent of damage. Yemane and Yilma (1986) noted in their experiment that lentil seeds stored in *gottera* plastered with clay soil had a grain damage of only 4% compared to 11.4% for *gottera* plastered with cow dung. Alemaya University, Chilalo Agricultural Development Unit (CADU), Sasakwa Global 2000 (SG, 2000) and others have tried to introduce a number of improved storage structures to the farmers, but adoption have been minimal, which could be attributed to cost and other factors.

Water-lifting Devices

Two types of water-lifting devices have been developed. The manually operated pump has a capacity of 180 l/min from a 4m depth while the donkey-powered one lifts 300 l/min from a 7m depth. In a test conducted at Melkassa using the hand-operated pump a yield of 36.1 quintal was recorded in haricot bean (AIRIC Progress Report, 1984, unpublished).

Transport

Draft animals particularly donkeys are very useful to Ethiopian farmers. The performance of the draft animals is dependent on the harness, design of a cart, condition of the animal and other factors. Proper harnessing may increase the efficiency and comfort of the animal while working. Carting is a bit known in the southern part of the country where the terrain is convenient to do so. However, the conventional donkey-drawn cart is defective in many ways leading to operational deficiency. The cart is neither statically or dynamically balanced, hence the large part of the load has to be borne by the animal itself. Taking this into account an improved donkey cart with a transporting capacity of 500 kg was developed in AIRIC.

AGRICULTURAL AND INDUSTRIAL PRE-EXTENSION ACHIEVEMENT

AIRIC has batch produced and popularized its successful prototypes around Wolenchiti and Bofa in collaboration with the Research-Extension Department of the Center and the Ministry of Agriculture *woreda* offices. The *erfe-* and *mofer*-attached plow and planter have been distributed to the farmers around Bofa and Wolencheti, and favorable responses were received on the performance of these equipment. Besides, a substantial number of plows have been distributed to the farmers in the Merahabete area with the Menschen for Menchen Group. Every year threshing-shelling services are given to the local farmers using the threshing-shelling machine developed by the Center. A small number of donkey carts and an ox-cart were given to Wolencheti farmers, and feedback was collected accordingly.

As part of the pre-extension activity, trainings were given to the Rural Technology Promotion Centers of different Regional States on the manufacturing of plow, ridge-tiers, weeders, maize hand-shellers and carts at different times. Trainings were also provided to the rural technology centers and local artisans from different parts of the country

MULTIPLICATION OF AGRICULTURAL EQUIPMENT

Research generates the technology and once tested on station, the workshop produces the prototypes in batches for verification on farmers' fields. If the equipment is found satisfactory on farmers' field, they have to be multiplied in larger quantity for popularization work. This later stage work has been handled to a limited extent by the regional rural technology promotion centers. Once this work is done, the manufacturing sector, private or government, has to pick it up and commercialize the technology. Accordingly, AIRIC has previously given the drawings as well as prototypes of plow, ridge-tier, donkey cart and threshing and shelling machine to Tateke Engineering and Akakai Spare Parts and Hand Tools Factory as a result of the protocol agreement reached between the EARO (Ethiopian Agricultural Research Organization) and the Ministry of Industry.

The improvements made on the moldboard plow over the last 12 years by AIRIC have created a demand by the farmers, and now the Akaki Spare Parts and Hand Tools Factory has begun the large-scale manufacturing of the moldboard plow. The EARO has signed a contract on the transfer of the design of the moldboard plow to the factory. Other mature prototypes are also expected to enter a similar scheme very soon.

CONCLUSIONS AND FUTURE DIRECTIONS

Appropriate agricultural implements are necessary to rip the benefit of the genetic potential of a variety as they improve the physical growing environment of the crop and improve the harvesting and subsequent handling till the crop reaches the end-user and the market. The emphasis to-date has been mainly on cereal crops. Farm implements have a universal nature and can serve most crops especially for land preparation and intercultivation. The plows, planters and inter-row cultivators are successful implements and need to be popularized among the user community. There is no significant work in the harvesting and post-harvest category. When talking about market, quality is important and the post-harvest and handling aspects, including storage, needs a refined technological input to meet the market standard. A lot more needs to be done in these areas and a refined work in the other categories is expected from the AMRP.

REFERENCES

Donahaye, E.J. 1992. Seal and store bagged grain. PERI NEWS 4. Agricultural Research Organization. Israel.

Hailu Gebre, and Kidane Giorgis. 1988. Sustainable crop production in the semi-arid area of Ethiopia. Ethiopian *J. Agric. Sciences* 10: 99-107.

Mengistu Negash, and Ermias Bekele. 1987. Towards a comprehensive agro-ecological zonation of Ethiopia. P.13-27. *In* Proc. 10th National Crop Improvement Conference (NCIC), 28-30 March, 1987.

Pathak. B.S. 1987. Survey of agricultural implements and crop production techniques. Field Document No. 2. Agricultural Implements and Improvement Center. Institute of Agricultural Research (IAR), Ethiopia.

SG 2000. Post-harvest management and storage of cereal grains. Training Manual. Addis Ababa, Ethiopia.

Yemane Kidane, and Yilma Habteyes. 1986. Food grain losses in traditional storage facilities in three areas of Ethiopia. *In* Proc. National Workshop on Food Strategies for Ethiopia held at Alemaya University, 8-12 December 1986

GIS for Agro-climatic Analysis in the Production of Pulses in Ethiopia

Betre Alemu[1] and Friew Kelemu[2]

[1]Ethiopian Develoopment Research Inistitute, P.O.Box 2479, Addis Abeba, Ethiopia, [2]Melkassa Agricultural Research Center, Nazreth, Ethiopia

ABSTRACT

Geographic Information System (GIS) is seldom used in agricultural research in Ethiopia. Now, digital geographic information is available regarding elevation, rainfall, temperature, soil type and land cover with reasonable temporal and spatial resolution. Meteorological records and agricultural research results could also be geographically referred and interpolated to forecast agro-climatic conditions of similar areas and future trends. A digital elevation model for Ethiopia has been developed using 200 m elevation resolution digital contour map of Ethiopia. The average temperature during the growing period has been estimated using a linear regression equation, where temperature drops by 0.7 ^{0}C with every 100 m rise in elevation. The maximum and minimum temperature at 5 km by 5 km pixel resolution has been used to characterize the environments. The cumulative growing degree-days during the growing period with 8 ^{0}C base temperature, and 20 ^{0}C optimal temperatures for flowering of most pulses with 75% probability have been used. The available rainfall during the growing period has been estimated on decadal basis also with 75% probability when the rainfall is more than half of the potential evapo-transpiration. Potential areas for cultivation of pulses have been geographically indicated and their extent has been estimated. However, models that enable to estimate yield from climatic parameters are not precise especially for the diverse conditions of Ethiopia. Holistic breeding approach through targeting of environments and defining the light and temperature response of genotypes is essential, since most agronomic traits of pulses that control yield are influenced by light and temperature. There is an immediate need to institutionalize GIS in Ethiopian agricultural research system.

INTRODUCTION

Cool season food legumes (CSFLs) are of Mediterranean and West Asia derivation and domestication, with Turkey to Iran as major centers (Asfaw et al. 1994). Many of the CSFLs have been grown in Ethiopia since ancient times, which became a secondary center of diversity especially for *Cicer*. Ethiopian agriculture is decisively subsistent farming where all the field pea, lentil, chickpea, grass pea and faba bean are cultivated predominantly by the traditional farming community. As a result, the yields are extremely low: field pea, 0.6-0.9 t/ha; lentil, 0.88 t/ha; chickpea a little over 1 t/ha; and grass pea almost similar to chickpea (Asfaw et al. 1994).

The diverse climatic conditions and the variability from year to year have played a great role in instability in production of different field crops especially the pulses. Even if, meteorological records have been used to explain performance of crop genotypes, the spatial variability of agro-climatic conditions and their extent has not been adequately explained and used in agricultural research. Particularly, pulses are very sensitive to climatic change. Most of the agronomic traits of pulses that are significantly correlated with yield are influenced by light and temperature. Among the important traits that influence yield are days to flowering, harvest maturity, number of pods per plant that are directly affected by light and temperature. The limits of genotypes in their response to maximum and minimum temperature have also not been precisely indicated. The requirement of cumulative growing degree-days for flowering, maturity, and harvest index for improved genotypes of pulses is not available. However, the average temperature during the growing period is linearly correlated with altitude, which ranges from below zero in the Dallol depressions to over 4600 m in Semien Mountain. It has been generally indicated that optimum day/night mean temperature fluctuations during the growing season (June to late-December) for field pea and faba bean are 20/10 ^{0}C. For lentil, grass pea and chickpea, a temperature regime of 30/10 ^{0}C during the growing season is optimal. It has also been traditionally said for mid-altitude areas, highlands or indicating the location names of areas of adaptation.

Closer matching of phenology to rainfall regime appears to offer the best scope for improving and stabilizing crop yields in Ethiopia. Rainfall pattern and soil moisture characteristics together determine the timing and length of the growing season and thus dictate the choice of crops and cropping systems. It is, therefore, advisable to identify long-duration cultivars (120-140 days) for high rainfall areas, intermediate cultivars (90-110 days) for mid-altitude areas, and short-duration cultivars (60-70 days) that are tolerant to intermittent drought.

MAJOR AGROCLIMATIC FACTORS AND THEIR SPATIAL CHARACTERISTICS FOR PRODUCTION OF FOOD LEGUMES IN ETHIOPIA

Light and Temperature

Photoperiod and/or temperature are the major environmental modulators within each given environment of the cultivar's days to flowering, days to harvest maturity, harvest index, adaptation and yield. Photoperiod is an essential environmental condition to grow crops. At Debre Zeit, a mid-altitude location, sun-shine during the growing period goes as low as 4:55 hours in July and 4:40 hours in August, and it linearly increases to 9:45 hours in December due to cloud cover. Short sunshine hours are prevalent in the highlands that make photoperiod an essential parameter for the pulse research program. Plant responses to photoperiod have a large day length by temperature interaction. An increase of day length for beans, which are short day plants, or of temperature, and especially an increase of both, will curvilinearly intensify the photoperiod responses. These responses include delay of flowering and consequent delayed maturity, which results in longer duration of active photosynthesis and growth. These responses also include additional branching and consequent additional leaf area, and an attendant decrease in the proportion of the net biomass assimilated that will be partitioned to the seed. Thus, a photoperiod response gives altered levels of many of the physiological and also morphological components of the net biomass accumulation and it's partitioning.

In retrospect, there is lack of studies on the correlation between days to maturity and the harvest index. Yield trials lack to express the effects of days to maturity as they have narrow ranges of genotypes and environments. Early days to flowering and maturity suggest the possibility of the genotype to be photoperiod insensitive. Each higher temperature causes photoperiod insensitive genotypes to flower earlier under both short and long photoperiods. Short photoperiod prevents the photoperiod-gene activity of the photoperiod sensitive genotype. Hence, under shorter photoperiod the higher temperature will result in earlier days to flowering. On the contrary, under longer photoperiod, sensitive genotypes respond to higher temperature with delay in days to flowering and also pod filling. Studies on photoperiod sensitive and insensitive genotypes under controlled environments resulted in the following conclusions (Wallace and Yan, 1996):

1. Any delay of the days to flowering due to the photoperiod sensitive genotype of bean was exponentially elongated by each higher temperature.
2. On the contrary, the same higher temperature causes a smaller and opposite change toward earlier days to flowering of the photoperiod insensitive bean genotype.

In conclusion, activity of photoperiod sensitive gene causes partitioning of the photosynthate toward the vegetative organ, while the insensitive allele causes the partitioning to be toward the reproductive organ. Differential modulation by photoperiod and temperature of the days to flowering of photoperiod insensitive and sensitive genotypes caused the largest source within the total Genotype x Environment interaction control of the days to flowering. This interaction has been quantified for bean and pea. Therefore, the International Center for Research in the Semi-Arid Tropics (ICRISAT) and International Center for Agricultural Research in the Dry Areas (ICARDA) have recently designed holistic breeding approach considering genetic variability in photoperiodism and its interaction with temperature so as to optimize production of pulses in diversity. Fitted models have been developed to estimate the days to flowering of bean genotypes from sensitivity to photoperiod, sensitivity to temperature, base temperature that allows gene action, optimal temperature, optimal photoperiod, basic duration at optimal temperature and photoperiod (Wallace and Yan, 1996).

Asfaw et al. (1994) reported that faba bean and field pea were always vulnerable to frost damage in Ethiopian highlands. This usually occurs at the prime vegetation or early anthesis stage, and damages are often irreversible. High temperatures, particularly at altitudes of 1800 m or less, are deleterious to faba bean at the reproductive stage and can result in considerable flower and pod drop. In drought-affected areas, low-moisture stress results in considerable reduction in grain yield. Thus, yield of all the five food legumes are low and always variable from year to year compared with small-grain cereals. The reasons for such fluctuating low yields have not yet been determined through research.

In Ethiopia, yield of faba bean is inherently low and always variable from year to year compared with small-grain cereals. Biological constraints to high yield include factors such as ineffective pollination and seed set (autosterility) and flower and pod drops. Asfaw et al. (1994) reported that 67% of the flower drop was due to the lack of fertilization, which might result from either ineffective pollination or pollen fertility. The magnitude of fertilization was also reported to be significantly variable from season to season. Studies indicated that high temperature interfered with normal pollen tube growth and fertilization. However, genetic variation exists among cultivars in their tolerance to high temperature and flower bud drop, which could be due to zygotic abortion as well. Since days to flowering are an indirect measure of days to maturity, selection for earliness resulted in a wide range of variation for days to flowering in the advanced breeding lines. Days to flowering ranged from less than 45 to over 55 days (Asfaw et al., 1994).

For beans, photoperiod does not control days to initiation of the flower buds, but is controlled by both the days to flowering and the partitioning of the assimilates as measured by harvest index. Hence, day length can modify all stages of development of the flower and is often an important factor controlling the onset and development of vegetative reproduction. Continuous selection could raise harvest index, while reducing both the yield and the days to maturity. Similarly, continued selection for higher biomass will raise harvest index while lowering the yield potential and enlarging the days to maturity. These interconnections cause negative or positive correlations among the levels of the aerial biomass, harvest index and the days to maturity. Generally, genotypes with optimal days to maturity will have maximum yield.

In Ethiopia, the magnitude of variation in days to flowering has been studied (Asfaw et al. 1994). Ethiopian field pea lines can be classified into two types: suitable for mid-altitudes and for high altitudes. The late-flowering lines originated mostly from northern Europe and the USA, whereas the early-flowering group originated mostly from Ethiopia, India and ICARDA. Days to flowering and plant height characteristics had similar trends. Under Ethiopian growing condition, variations in short-day effect were observed in introductions from the UK, USA, Scandinavia and Germany. Thus, flower initiation in some lines was quite a prolonged phenomenon under local conditions. Hybridization and selection for improving agronomic traits and increasing seed size have generated a wide range of variability in days to flowering, maturity and 1000-seed weight. The Ethiopian origin field pea lines are tall and leafy with long internodes and are produced in mid-altitudes with rainfall of 600-700 mm.

In chickpea, Geletu and Yadeta (1994a) reported that the highest heritability trait was 100-seed weight. Number of seeds/pod and plant height also had high heritability, whereas the number of primary and secondary branches and number of pods/plant had low heritability. This indicates that the number of primary and secondary branches and number of pods/plant are highly influenced by the environment. Study of the relationship between grain yield and other characters revealed that days to maturity, plant height and number of pods/plant were highly associated with grain yield. Similarly, it was indicated that number of pods/plant and 100-seed weight had significant positive correlation coefficient with grain yield/plant. Generally, it was suggested that tall plant height, high number of primary and secondary branches and number of pods/plant would serve as useful selection criteria to develop high-yielding chickpea genotypes (Geletu and Yadeta, 1994a). It was also reported in lentil that the number of secondary branches had significant and negative associations with days to flowering, which suggested that the early-flowering lines would have less secondary branches than the late-flowering lines in lentil (Geletu and Yadeta, 1994b). The number of pods per plant, days to flowering, and number of primary and secondary branches were the major direct contributors towards seed yield in lentil (Geletu and Yadeta, 1994b).

The adaptation regions of haricot bean varieties have been defined based on temperature and main season rainfall. Mid-altitude areas like Awassa, Alemaya and Jimma have been found to be best adapted for most of the haricot bean varieties, while low-altitude areas like Ziway are marginally suitable (Table 1).

Table 1. Suitability of haricot bean variety Awash Melka based on average temperature and rainfall during the growing period.

Location	Suitability	Average temperature during the growing period (°C)	Rainfall during the growing period (mm)
Awassa	Best	19.28	407
Alemaya	Best	17.46	396
Jimma	Moderate	21	471
Ziway	Marginal	20.38	336

Source: Haricot Improvement Project, Melkassa Agricultural Research Center (MIARC).

Rainfall and Length of Growing Period

Growing season durations vary due to differences in moisture, and/or temperature as altered predominantly by elevation, latitude and longitude. Stress due to lack of moisture or low or high temperature establish the beginning and end of the growing season at a site. The yield will be maximized for a genotype having the optimal duration of growth and development to harvest maturity. A genotype that requires longer growth and development than the growing period will have much of any biomass that was partitioned to the yield wasted, because the yield organs cannot develop fully to harvest maturity.

In Ethiopia, one of the most important and sensitive issues in planning agricultural production is precise prediction of the start of the growing season. This will minimize the risk of crop failure due to false start of rainfall on the one hand and loss of rainfall before sowing on the other. Then, the criteria set to define the start of the growing season can be used with reasonable flexibility. Once decadal rainfall is above 30 mm and exceeds half of the potential evapo-transpiration, moisture is sufficiently available to plants until the end of the season (FAO, 1984). Therefore, this criterion could serve as a reliable threshold to start sowing. These sowing thresholds could be of considerable practical application, if more reliable weather forecasts are available and farmers are made aware of the forecasts.

In low rainfall regions, due to the rapid exhaustion of the soil water reserve, the grain filling period for most of the available crops extends beyond the period of moisture availability. Consequently, moisture stress during grain filling may result in premature drying of the leaves, with consequently reduced assimilatory capacity and lower grain yields, much below the potential yields of the improved cultivars.

In high rainfall regions, where water-logging may be a problem at seedling establishment, other agronomic practices like raised beds may be better than late-planting. Soil conservation measures are also imperative, where water loss through surface run-off and deep drainage, which may exceed 45% of the annual rainfall. Therefore, a well-defined approach is needed to help farmers to choose a planting schedule and to select the appropriate cultivars that fit their growing season.

In the context of current Ethiopian agriculture, selection of crop species and cultivars for drought-prone regions needs a very critical assessment, especially with respect to yield stability so that farmers are guaranteed reasonable yields even in dry areas. The use of mixture of varieties with different maturity groups will be useful to consider as a strategy to minimize the risk of crop failures due to unfavorable weather conditions. Therefore, improvement of cultivars should focus on developing materials that are drought-tolerant and with the capacity to adapt to the prevailing variability of weather.

AGROCLIMATIC DATABASE DEVELOPMENT

A contour digital map of Ethiopia with 200 m elevation resolution in ArcInfo Coverage format has been acquired from the University of Berne, Switzerland. The map has been exported to IDRISI 32 for raster-based analysis. Monthly maximum and minimum temperature, growing degree-days with 5 km by 5 km resolution have been obtained from Blackland Research Center, Texas Tech University, USA. The database has been developed based on meteorological records and satellite imagery (Corbet, 1997). From the same source, cumulative growing degree-days during the growing period with 8 ^{0}C base temperature, 20 ^{0}C optimal temperature for flowering of most pulses with 75% probability has been used. Besides, the available rainfall during the growing period has been estimated on decadal basis also with 75% probability when the rainfall is more than half of the potential-evapo-transpiration. Available rainfall has been one of the important agro-climatic variables to define the scope of growing pulses in Ethiopia. All the data have been imported to 500 m by 500 m pixel resolution using the flat UTM geographic co-ordinate system.

Each of the agro-climatic data has been classified using the suitability ranges of pulses (Table 2).

In addition, for haricot bean variety Awash-Melka suitable areas have been categorized into three classes based on the yield records (Table 1). Maps of average temperature during the growing period have been stretched in the range of zero to one taking 19.28 ^{0}C optimal temperature and 21^{0}C as maximum and 12.5 ^{0}C as minimum using Fuzzy Set Membership Function in IDRISI 32. Similarly, the average rainfall during the growing period has been stretched taking 401.5 mm as optimal rainfall and 336 mm as minimum and 471 mm as maximum. The two stretched images have been overlayed together by setting the rainfall to have three times more weight than temperature using Multicriteria Evaluation Module in IDRISI 32 to define suitable areas for growing the variety (Garlinge, 1998; and Asfaw et al. 1994).

The average temperature during the growing period has been very variable (Fig. 1). Most pulses are suitable in the range of 12.5 to 24 ^{0}C. Extremely highland tropical climates in the highlands cause frost damage on most pulses. Besides, average temperatures above 24 ^{0}C are very hazardous for most pulses.

Average maximum temperature during the growing period over 35 ^{0}C is not suitable for most pulses. In addition, more than 30 ^{0}C is deleterious for faba bean and field pea (Fig. 2). Average minimum temperature below 5 ^{0}C could cause frost damage and poor performance of physiological activities of most pulses (Fig. 3). Areas with minimum temperature in the range of 5-15 ^{0}C are conducive for most pulses (Fig. 3). Such temperature fluctuations have been caused due to the topographical diversity of Ethiopian landscape (Fig. 4). In addition, the average diurnal temperature fluctuation during the growing period is an essential parameter for crop production in Ethiopia. Fluctuations in the range of 10-20 ^{0}C are optimal for production of pulses (Asfaw et al., 1994). The average diurnal temperature fluctuation during the growing period was found to be above 20 ^{0}C in the northern part of the country, which is extreme condition for production of pulses (Fig. 5). The northern highlands, which have been covered with forests, have been degraded and hence get very cold in the night and relatively hot in the afternoon. Even if, the classification is based on general recommendation, most pulses have genotype by environment interaction caused by the variation in growing degree-days. Most pulse growing areas in Ethiopia have long duration of growing degree-days with optimum moisture to meet the temperature requirement for sufficient flowering and maturity.

The average amount of rainfall during the growing period is also significantly variable in Ethiopia (Fig. 6). Suitable areas for the haricot bean variety Awash Melka based on average temperature and rainfall during the growing period have been defined (Fig. 7).

Table 2. Suitability of pulses to climatic conditions.

Crop	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Growing degree-days (hrs)	Minimum rainfall (mm)
Faba bean	30	6	1300	400
Field pea	21	10	1600	350
Desi chickpea and lentil	30	10	1600	350
Kabuli chickpea	30	10	2000	425
Grass pea	35	10	Not Available	250

Adapted from Garlinge (1998) and Asfaw et al. (1994).

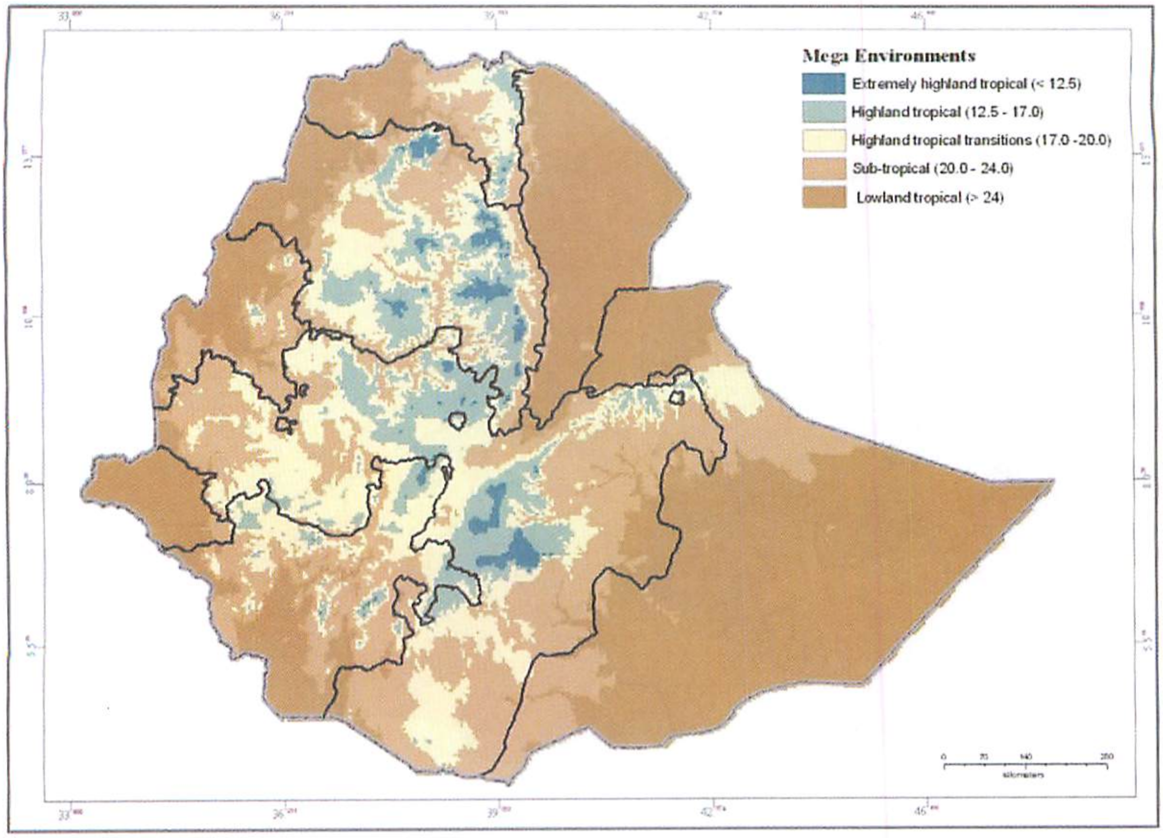


Fig. 1 Mega environments in Ethiopia due to average temperatures during the growing period in degree Celsius.

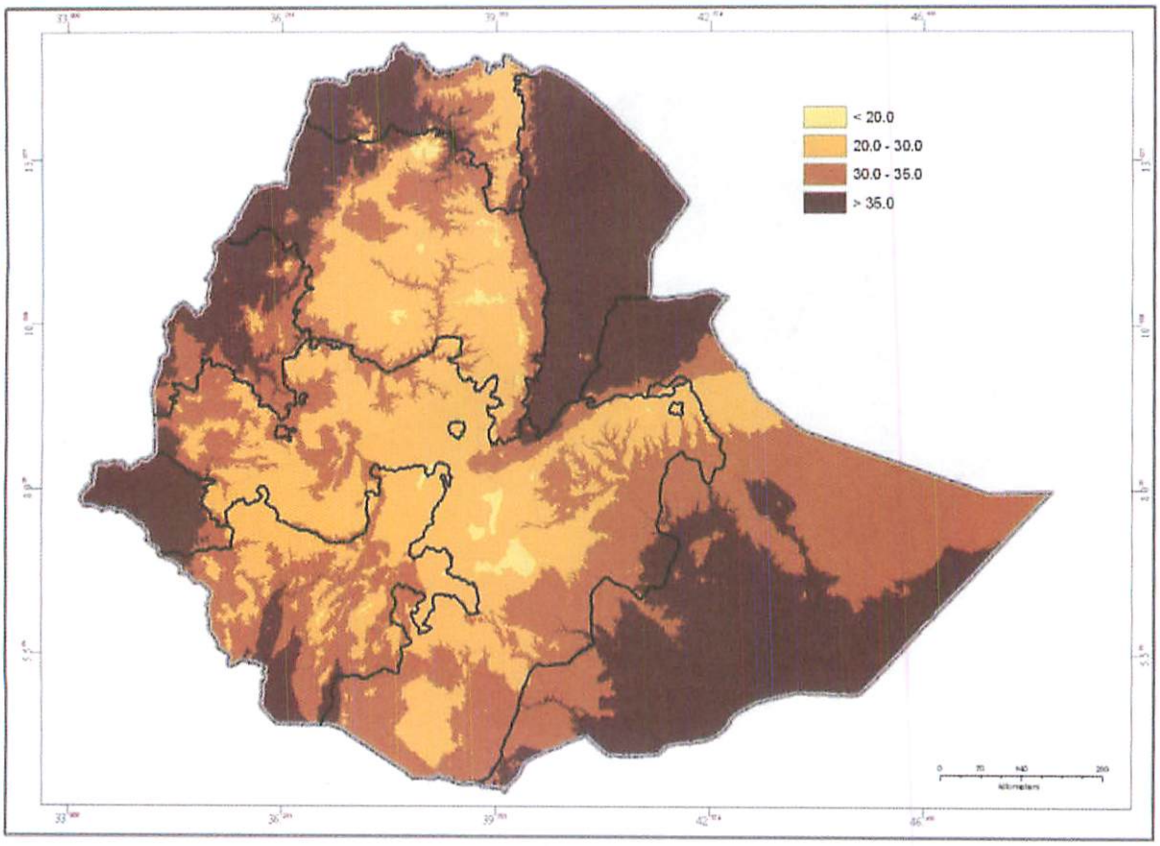


Fig. 2. Average maximum temperatures during the growing period in Ethiopia (degree Celsius).

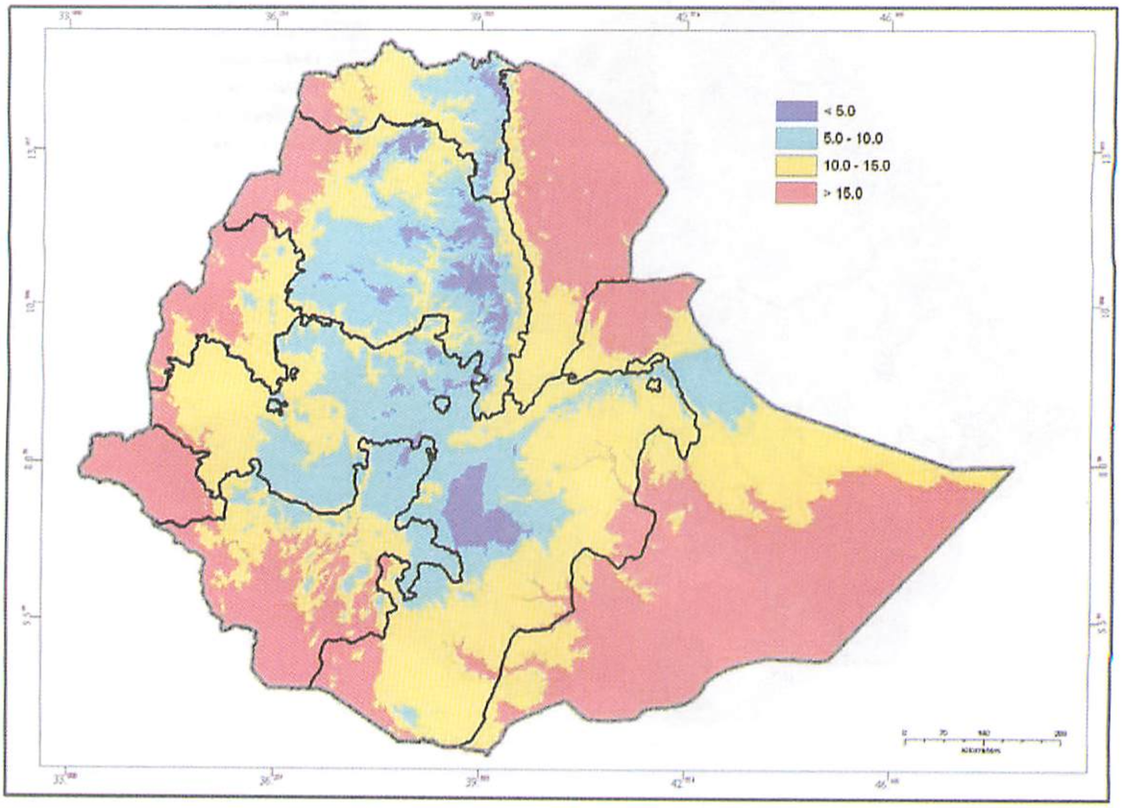


Fig. 3. Average minimum temperatures during the growing period in Ethiopia.

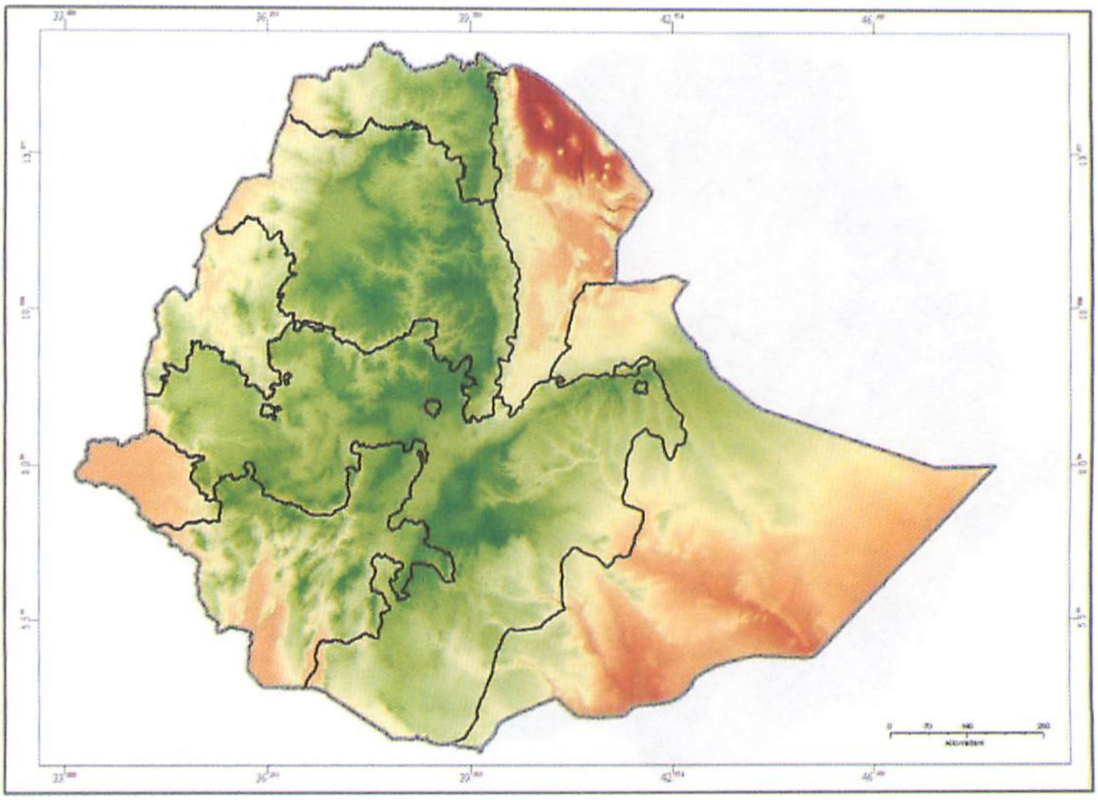


Fig 4. Topographic diversity of Ethiopian landscape.

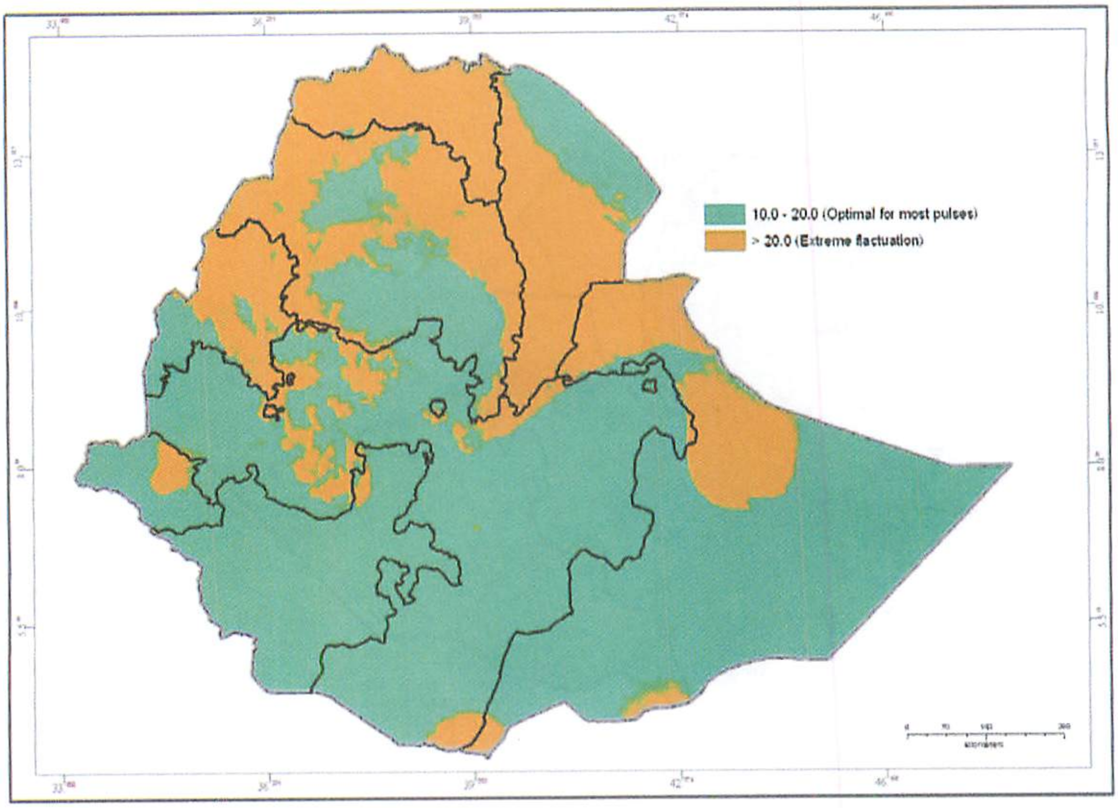


Fig. 5. Variablitity of the difference between maximum and minimum temperatures in Ethiopia.

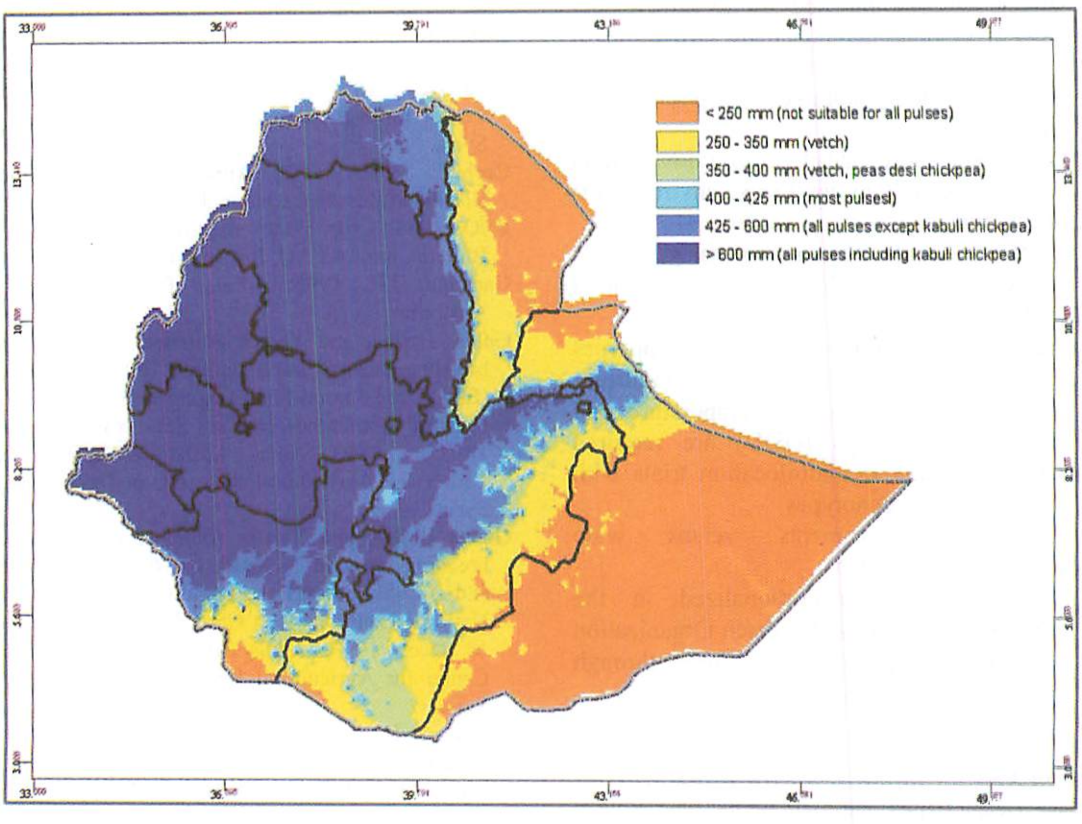


Fig. 6. Average five months rainfall after the start of the main growing period.

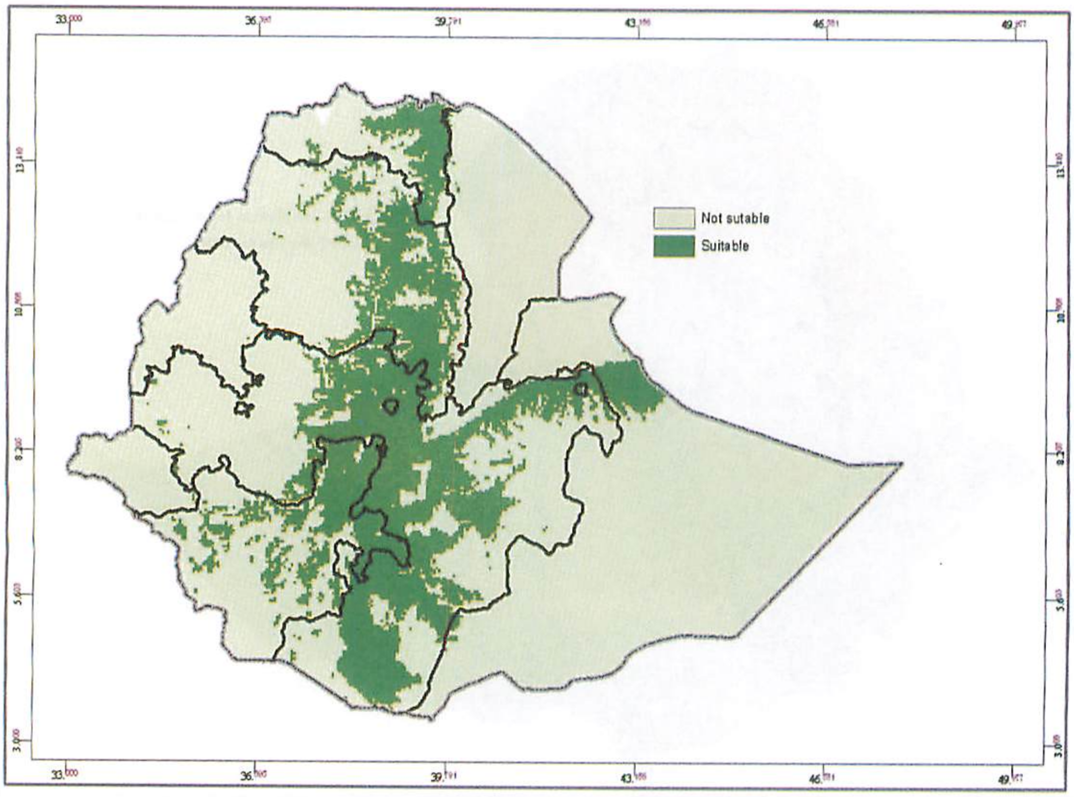


Fig. 7 Suitable areas for growing haricot bean cv. Awash-Melka based on average annual temperatures and main season rainfall.

CONCLUSIONS AND RECOMMENDATIONS

1. GIS is an essential tool to geographically indicate climatic potentials and limitations of pulses and define their extent.
2. Holistic breeding approach is essential for pulses.
3. Pulses are more sensitive to climate than cereals especially in the diverse environments of Ethiopia.
4. Light and temperature insensitive genotypes are widely adapted, but vegetative potential could be limited.
5. Precise models on the response of genotypes to different environmental conditions, especially to photoperiod, temperature and growing degree-days (GDD) are required using laboratory or multilocation trials with wide number of genotypes.
6. Targeting environments versus wide adaptation in Ethiopia
7. GIS should be institutionalized in the Ethiopian Agricultural Research Organization (EARO) and the country at large through efficient database system.

REFERENCES

Asfaw Tilaye, Geletu Bejiga, and Alem Berhe. 1994. Role of cool-season food legumes and their production constraints in Ethiopian agriculture. p. 3-18. In Asfaw Telaye et al. (Eds.) Cool Season Food Legumes of Ethiopia. Proc. First National Conference on Cool-season Food Legumes, 16-18 Dec., 1993, Addis Ababa, Ethiopia. International Center for Agricultural Research in Dry Areas. Aleppo, Syria.

Corbet, John. 1997. Almanac characterization tool. Blackland Research Center. Texas Tech University, USA.

FAO. 1984. Crop Water requirement. p. 15-30. In FAO Bulletin, No. 24.FAO, Rome,Italy.

Garlinge, J.R. 1998. Pulse Pak National (CLIMA), Australia.

Geletu Bejiga, and Yadeta Anbessa. 1994a. Genetics and breeding research in chickpea. p.162-182. In Asfaw et al. (Eds.) Cool Season Food Legumes of Ethiopia. Proc. First National Conference on Cool Season Food Legumes, 16-18 Dec., 1993, Addis Ababa, Ethiopia. International Center for Agricultural Research in Dry Areas. Aleppo, Syria.

Geletu Bejiga, and Yadeta Anbessa. 1994b. Genetics and breeding research in lentil. p. 162-182. In Asfaw et al. (Eds.) Cool Season Food Legumes of Ethiopia. Proc. First National Conference on Cool Season Food Legumes, 16-18 Dec., 1993, Addis Ababa, Ethiopia. International Center for Agricultural Research in Dry Areas, Aleppo, Syria.

Wallace D.H. and Yan W. 1996 . Plant breeding and whole system crop physiology: Improving adaptation, maturity and yield. CAB International, U.K. 456 pp.

Section IV. Crop Protection

Harnessing Biotechnology to Improve Food and Forage Legumes: The Case of Plant Disease Resistance

Segenet Kelemu and George Mahuku

Centro Internacional de Agricultura Tropical (CIAT)
A.A. 6713, Cali, Colombia, South America

ABSTRACT

Biotechnology comprises numerous technologies, ranging from the traditional to the modern. These greatly enhance our ability to diagnose diseases and develop durable strategies for their management; determine the genetic diversity of pest and pathogen populations, and understand host-pathogen interactions; enhance plant nutritional qualities; develop effective and novel strategies for abiotic stress tolerance; and combine genes from a wide array of organisms using transgenic technologies. One application involves cloning and introducing specific resistance genes of plant origin into crops so they may defend themselves against pathogens. Legumes have not only served as important sources of such genes, but also received foreign genes for their own improvement. Other innovative methods include pathogen-derived resistance to combat viral diseases; use of antimicrobial proteins and lysozymes from insects, animals, microbes, and even humans; and the cloning and expression of antibody molecules linked to carrier peptides in plants. As with conventionally bred crops, the pest or disease resistance genes of genetically modified crops will succumb in time to evolving pest or pathogen pressures. However, combining different forms of resistance from various sources through recombinant DNA technology may help build a fortified barrier that is more difficult for pests and pathogens to overcome. Although agricultural biotechnology in itself will not provide instant solutions to the production constraints that prevent Ethiopia from being self-sufficient in food, when applied properly and responsibly, it can play a major role in improving food and forage legumes productivity.

INTRODUCTION

Legumes play a critical role in natural ecosystems, agriculture, and agro-forestry. They are second only to Gramineae in their importance to humans (Graham and Vance, 2003), accounting for 27% of the world's primary crop production. They are major sources of dietary protein and minerals for both humans and animals (Goossens et al., 1999; Grusak, 2002; Wang et al., 2003). Legumes are grown for numerous purposes, including food (bean, pea, chickpea, faba bean, pigeon pea, cowpea, and lentil), oil (peanut and soybean), pastures and fodder (alfalfa, *Arachis*, and *Stylosanthes*), cover crops for protection and/or recuperation of degraded lands and soil fertility enhancement (*Arachis*, mucuna, and lablab), and in agro-forestry (*Tephrosia* spp., *Sesbania* spp., *Leucaena* spp., and *Crotalaria* spp.) (Graham and Vance, 2003).

However, like many other crop plants, legumes have limitations that call for improvement. Legume crop yields are low, particularly in developing countries. For example, chickpea yields are only 75% of those achieved in developed countries, and common bean yields are only 20% of the genetic potential. Such results are caused partly by (i) the unfavorable conditions under which legumes are grown (marginal areas with degraded soils and vulnerable to water stress), and (ii) susceptibility to a myriad of fungal, bacterial, and viral pathogens, and insect-pests.

Most legumes have nutritional shortcomings, such as deficiencies in one or more essential amino acids, especially those containing sulphur. They also contain antinutritional factors, including lectins and flatulence factors. Finally, they are also hard to cook (Goossens et al., 1999; Graham and Vance, 2003).

Biotechnology has great potential for addressing some of these limitations, for example, gene transfer techniques can alter the amino acid composition of seed proteins, and thus improve the nutritional quality of seeds; and molecular markers can rapidly introgress genes in disease-resistance breeding for the sustainable increase of food and forage legume production

Biotechnology applications range from old technologies such as microbial fermentation to modern ones such as genomics. The evolution of biotechnology in the last two decades has been astounding. Some major achievements are:

1. Sequencing entire plant and microbial genomes
2. Developing tools for rapid and accurate diagnosis and detection of plant pathogens
3. Tagging plant genes for traits of agronomic importance
4. Cloning and characterizing microbial and plant genes
5. Developing plant transformation and regeneration systems
6. Developing genetically modified plants containing genes from a wide range of organisms for both agricultural and biopharmaceutical purposes

Legumes have not only served as important sources of pest and pathogen resistance genes and other applications (LeBerre et al., 1997; Reis et al., 1997), but also received foreign genes for their own improvement (Table 1). Soybean, for example, is at the forefront of genetically modified crops in many countries. In legume improvement, modern biotechnology is invaluable for:

1. Characterizing, conserving, and using genetic resources (Bell et al., 2001; Capote-Mainez and Sánchez, 1997; Dixon and Sumner, 2003; Sharon and Lis, 1990)
2. Improving diagnosis, characterization, and management of pathogens and insect-pests

(Kessler and Baldwin, 2002; Louws et al., 1999; Martin et al., 2000)

3. Improving the understanding of how plants function and how they respond to biotic and abiotic stresses (Boulter et al., 1990; Martin et al., 2003; Romeis et al., 2001; Sales et al., 2000; Xiong and Yang, 2003)
4. Developing new tools to enhance the efficiency of plant breeding (Gebhardt and Valkonen, 2001; McDonald and Linde, 2002; Young, 1996; Yu et al., 2001)
5. Enabling access to a variety of genes of agronomic importance from various sources (Boulter et al., 1990; Dickman et al., 2001; Fang et al., 1997; Lorito et al., 1998; Mitra and Zhang, 1994)
6. Introducing, by means of transgenic technology, various genes from several related or unrelated sources (Angenon et al., 1999; Aragão et al., 1998, 1999,2002; Baulcombe 1996; DeGray et al., 2001; Kelemu et al., 2001; Molvig et al., 1997)
7. Making transgene-induced modifications of plant genes (Herman et al., 2003; Smith et al., 2000; Thorneycroft et al., 2001; Wang et al., 2003)

Although it is tempting to discuss the wide range of biotechnology applications, this paper will focus on those that improve plant disease resistance.

PLANT PATHOGENS

Detection, Diagnosis, and Characterization

Pathogen detection and diagnosis

The importance of pathogen detection, diagnosis, and characterization in plant disease management cannot be overemphasized. Traditional methods for these activities include identifying characteristics such as culture morphology, color, growth on various media; testing pathogenicity on various hosts; serology-based methods (e.g., enzyme-linked immunosorbent assay, or ELISA); and identifying biochemical characteristics (substrate use patterns, fatty acid compositions, and enzyme production profiles) (Louws et al., 1999).

The advent of molecular biology tools including the recent nucleic acid-based tools, have greatly improved pathogen identification, taxonomic classification, characterization, disease management, and quarantine. The invention of the polymerase chain reaction (PCR) in 1985 revolutionized the way molecular biology studies are conducted (Henson and French, 1993; Honeycutt and McClelland, 1996).

Sequencing entire genomes of plant pathogens provide useful information on their organization, allowing us to develop multiple tactics to control the pathogens. The powerful automated-sequence technologies currently available and advances in bio-informatics have made the task of sequencing entire genomes almost routine (Leach et al., 2002). Of the many genomes already sequenced or being sequenced, several are phytopathogenic, belonging to bacteria (16), fungi (5), oomycetes (2), nematodes (7), and viruses (TIGR, 2003), with the list still growing. These genomic approaches provide molecular tools for quick and refined pathogen detection, taxonomic classification, characterization, and disease diagnosis.

Rapid and reliable PCR-based detection methods have been developed, using sequences of conserved genomic regions, random genomic fragments, or other gene sequences (Kelemu et al., 2003; Louws et al., 1999; Martin et al., 2000). The internal transcribed spacer (ITS) regions of ribosomal DNA (rDNA) of pathogenic bacteria, fungi, and nematodes have proved useful for taxonomic classifications. DNA-based methods that are independent of PCR such as restriction fragment length polymorphism (RFLP) and whole chromosome separation, using pulsed-field gel electrophoresis (PFGE), have also been used to characterize pathogens (Chan and Goodwin, 1999).

It is important to note that improved techniques for DNA extractions, labelling and detection protocols, and various versions of PCR-based methods are continuously being developed. These will continue to play an important role in diagnosing and characterizing plant pathogens as they relate to disease management and quarantine services.

Pathogen characterization and resistance breeding

One major goal of plant pathology is to devise strategies to combat plant diseases of economic importance. The most practical and cheapest strategy is to use host resistance. Pathogens, however, have several ways of evolving and adapting to resistance, thus breaking it down. Understanding the genetic structure of pathogen populations directly influences breeding for disease resistance and deploying resistance genes.

Breeders can use population genetics - the description and quantification of genetic variation in populations - to infer the evolutionary processes of pathogen populations, understand disease outbreaks, and predict future disease development. Thus, they can develop and implement effective and durable measures for disease control and breeding strategies for disease resistance (McDonald and Linde, 2002; McDonald and McDermott, 1993).

A myriad of molecular techniques have been adopted by plant pathologists to study the population genetics of plant pathogens, including:

1. Molecular markers such as allozymes (Goodwin et al., 1993)
2. Repetitive extragenic palindromic PCR (REP-PCR) (Bruijn, 1992; Jedryczka et al., 1999)
3. Random amplified polymorphic DNA (RAPD) (Kelemu et al., 1999; Mahuku et al., 2002a)
4. Restriction fragment length polymorphism (RFLP) (Milgroom et al., 1992)
5. Amplified fragment length polymorphism (AFLP) (Mueller et al., 1996)

6. Random amplified microsatellites (RAMS) (Hantula et al., 1996; Mahuku et al., 2002b; Müller and Hantula, 1998)

Random amplified microsatellites have extensively been, and continue to be used to examine the genetic diversity of pathogen populations, including those of important legumes. However, to fully use the information gained from studying populations, and make it useful to breeders, closer collaboration and integration of phytopathological and plant-breeding programs are required.

Table 1. Examples of legumes as sources of important genes and as recipients of foreign genes.

Plant	Gene/protein	Application/function
Common bean (*Phaseolus vulgaris*)	A mannose-specific lectin	Preserves hematopoietic stem cells
	Chitinase	Fungal inhibition; insect-pest control
	Methionine-rich albumin gene from Brazil nut	High-methionine transgenic beans (Aragão et al., 1999)
	Viral antisense RNA	Transgenic beans resistant to bean golden mosaic geminivirus (Aragão et al., 1998)
	Bar gene	Transgenic beans (expressing the bacterial gene) resistant to the herbicide glufosinate ammonium (Aragão et al., 2002)
Black-eyed bean	HIV epitope (gp120)	Production of HIV vaccines in transgenic black bean plants (Doran, 2000)
	Human rhinovirus epitope (HR14)	Production of rhinovirus vaccine in transgenic black bean plants (Tacket and Mason, 1999)
	Foot and mouth virus epitope (VP1)	Production of foot and mouth vaccine in transgenic plants (Tacket and Mason, 1999)
	Amylase inhibitor (BAAI)	Insect-pest resistance (expressed in pea for resistance to pea weevil [Schroeder et al., 1995] and bruchid beetles [Shade et al., 1994])
Cowpea	Trypsin inhibitor (CpTI)	Insect-pest control (e.g., expressed in tobacco plants at nearly 1% [Hilder et al., 1987]; in cotton to effectively control cotton bollworm [Li et al., 1998]; in rice to enhance resistance to the borers *Chilo suppressalis* and *Sesamia inferens* [Xu et al., 1996]; in *Brassica oleracea* [Fang et al., 1997]). The gene is considered useful because it is not deleterious to mammals or beneficial insects such as honey bees
	HIV epitope (gp41)	Production of HIV vaccine in transgenic cowpea plants (Giddings et al., 2000)
Soybean	Trypsin inhibitor (SBTI)	Insect-pest control (e.g., expressed in tobacco)
	Kunitz trypsin inhibitor (SKTI)	Insect-pest control (e.g., in rice for the control of brown plant hopper [Lee et al., 1999])
	Roundup® resistance	Transgenic soybean varieties resistant to the herbicide Roundup®, currently adopted in USA, Argentina, and, recently, Brazil
	Bt gene	Transgenic soybeans containing a gene from the bacterium *Bacillus thuringiensis* (Bt) for resistance to velvet bean caterpillar, soybean looper, and other defoliators and pod feeders (Stewart et al., 1996)
Pea	Pea lectin	Insect-pest resistance (e.g., expressed in tobacco against *Heliothis virescens* [Boulter et al., 1990])
	Bean α-amylase inhibitor	Transgenic peas resistant to pea weevil (Morton et al., 2000)
	Viral replicase (N1b) gene	Transgenic peas resistant to pea seed-borne mosaic potyvirus (Jones et al., 1998)
Chickpea	Bt gene	Transgenic chickpea for resistance to pod borer (Kar et al., 1997)
	Cowpea trypsin inhibitor	Transgenic chickpea for resistance to pod borer (Pental, 1998)
Stylosanthes guianensis	Rice chitinase gene	Transgenic *Stylosanthes* plants for resistance to *Rhizoctonia* foliar blight disease (Kelemu et al., 2001)

SOURCES OF DISEASE RESISTANCE: IS THERE A LIMIT?

One practical means of increasing crop production is to minimize pest-associated losses, which are currently estimated at 14% of total agricultural production (Sharma et al., 2001). Through the years, plant pathologists and breeders have been engaged in identifying and characterizing sources of resistance within plant species that are amenable to crossing.

The advent of recombinant DNA technology and genetic engineering has greatly expanded the pool of resistance sources to a potpourri of organisms. Genetic engineering, specifically, not only widens the pool of useful genes to use for disease management, but also allows the use of several desirable genes in a single event, thus reducing the time needed to incorporate novel genes into elite background. That is, it not only brings in a desirable character from closely related plants, but also adds desirable characteristics from unrelated species. After transformation, the new plant becomes a parent for use in conventional breeding programs.

Plants defend themselves from pathogens with preformed defence mechanisms and responses triggered by pathogens themselves (Heath, 2000; Rommens and Kishore, 2000). Studies of the molecular basis of host-pathogen interactions have enhanced our understanding of resistance (Cohn et al., 2001; Martin et al., 2003) and, hence, our ability to engineer plants with durable resistance to a wide range of pathogens. Many disease-resistant genes of plant origin have been cloned and characterized (Hammond-Kosack and Jones, 1997; Hulbert et al., 2001; Martin et al., 2003). By removing the species barriers encountered in traditional plant-breeding methods, genetic engineering allows us to introduce these genes into any plant of interest.

The concept of pathogen-derived resistance is being exploited to control plant viruses (Sanford and Johnston, 1985). Viral-coat-protein-mediated plant protection has been used to effectively control several homologous or closely related viruses, as demonstrated in the control of tobacco mosaic virus - the first virus-derived resistance in transgenic plants (Powell-Abel et al., 1986). Various forms of pathogen-derived resistance have been engineered since then (Baulcombe, 1996; Lincoln et al., 2002; Satyavathi et al., 2003).

Plants engineered to produce defective viral movement proteins have been shown to have resistance (Lapidot et al., 1993). Other pathogen-derived resistance to combat viruses includes RNA or DNA-mediated resistance, which is perhaps caused by direct inhibition of the viral infection cycle (Gerlach et al., 1987; Stanley et al., 1990). Transgenic expression of antisense RNA is another form of pathogen-derived resistance (Yepes et al., 1996). Sequences from viral replicase genes have also been engineered into plants, resulting in their becoming resistant (Palukaitis and Zaitlin, 1997). Concerns have been raised on the possibilities of recombination between the incoming infecting virus and the transgene leading to the creation of new and more aggressive viral strains.

Sources described as improving plant resistance to pathogens have included antimicrobial proteins and lysozymes from insects (Jaynes et al., 1987), animals (DeGray et al., 2001; Li et al., 2001; Vunnam et al., 1997), microbes (Lorito et al., 1998), even humans (Mitra and Zhang, 1994; Mitra et al., 1996; Nakajima et al., 1997), and other genes from animals and humans (Dickman et al., 2001). The cloning and expression of antibody molecules linked to carrier peptides in plants to combat diseases (Franconi et al., 1999) and nematodes (Baum et al., 1996) are further examples of the possibilities that biotechnology can offer to control plant diseases. Novel strategies for engineering plants with nematode resistance have also been recently reviewed (Atkinson et al., 2003).

The rational use of biotechnology can obviously reduce disease-associated losses in harsh tropical environments. Genomic approaches are increasing our understanding of the genetic basis of plant disease resistance by enabling us to better understand resistance genes themselves, and other genes, and the pathways they regulate. Transformation of field crops to impart resistance to targeted diseases and adaptation to different abiotic stress factors and to enhance the nutritional quality of produce can now be achieved.

Such efforts will significantly minimize disease-associated losses, increase crop production, and improve the quality of life of rural poor. As the possibilities of combining genes from various sources expand the need for bio-safety regulations and risk assessment increases. Bio-safety concerns must be adequately addressed to exploit the potential benefits of these developments.

MOLECULAR PLANT BREEDING AND DISEASE RESISTANCE

A crop's resistance to pathogens, pests, and abiotic stresses is an important prerequisite for that crop's yield stability and high product quality. Such resistance contributes to reducing or minimizing the use of chemicals to protect plants on farms and thus, to lowering inputs and increasing protection of the environment.

One principal goal of plant breeding is to develop crop varieties with high levels of disease resistance along with other desirable agronomic traits. For many years, plant breeders, using conventional methods, have successfully modified plants and are speeding up natural processes by combining genes for resistance to biotic (diseases and pests) and abiotic (e.g., low soil fertility, drought, and salinity) stress factors, crop yield, nutritional quality, seed colour, and many other traits of agronomic importance.

To develop disease-resistant cultivars, plant breeders have formulated several resistance management strategies. One involves attempting to identify resistance genes for which tolerant (i.e., intermediately resistant) individuals are unknown and for which pathogen mutations in avirulence genes are unlikely. Thus, lasting resistance and even 'immune' plant lines can be developed. Another strategy, commonly known as gene 'pyramiding', involves incorporating as many resistance genes into a single plant genotype as is practical, in the hope that it will be statistically unlikely for a pathogenic race to develop (by recombination or mutation) that can overcome all the resistance genes simultaneously. However, combining several resistance genes simultaneously in one background is impossible without using markers for each gene. In this context, the use of biotechnological tools to contain pest damage becomes all the more important.

Most microbes are not pathogenic on a given host. This implies that resistance is more of a norm than an exception. Plants have preformed and/or inducible defence mechanisms to fend off pathogen attack. Preformed defence mechanisms include cell-wall components, secondary metabolites, and antimicrobial proteins and peptides. The use of resistant cultivars is an important and practical disease-control strategy. At the same time, pathogens have their own evolving mechanisms to overcome plants' defence systems. Thus, plant breeding and plant pathology strategies are engaged in a continuous battle of keeping one step ahead of any given pathogen.

Genetically simple types of disease resistance have been analysed, using conventional methods of breeding, genetics, and pathology (Flor, 1955). Resistance in this type of host-pathogen interaction is provisional on the interaction of a specific pathogen avirulence gene with a specific (usually dominant) resistance gene (Dangl and Jones, 2001).

Where host-plant resistance to disease is controlled by quantitative traits at several loci, the development of resistant cultivars through conventional breeding approaches has been slow and, at times, difficult. The more complex forms of resistance are not well understood. Molecular markers enable one to identify and map quantitative trait loci (QTLs) and, thus, increase the efficiency of plant breeding (Castro et al., 2003; Freyre et al., 1998; Gebhardt and Valkonen, 2001; Jung et al., 2003; Miklas et al., 2001; Yin et al., 2003; Young, 1996).

Molecular linkage maps help provide the structure for disease-resistant gene locations. Many disease-resistant genes in various crop plants have been mapped and linked to DNA markers (Arru et al., 2003; Geffroy et al., 2000; Kelly, 1995; Mammadov et al., 2003; Miklas et al., 2001; Tsai et al., 1998). Molecular markers have been used to tag disease-resistant genes in common beans (Jung et al., 2003; Miklas et al., 1996; Park et al., 2001), chickpea (Santra et al., 2000), pea (Timmerman-Vaughan et al., 2002), and soybean (Jeong et al., 2002; Mian et al., 1999). More useful genes in other legume crops are being tagged and used in marker-assisted-selection breeding to speed the introgression of desired resistance genes into elite backgrounds (Geffroy et al., 1998; Menéndez et al., 1997). Molecular maps have been developed for several food and forage legumes (Gepts, 1999; Keim et al., 1997; Laucou et al., 1998; Menéndez et al., 1997; Ouédraogo et al., 2002; Winter et al., 2000; Yu et al., 2000).

The accurate estimation of a QTL location is important in the optimal use of marker-assisted selection (Spelman and van Arendonk, 1997). Such accuracy is dependent on several factors, including marker density or marker interval size, the size of QTL effect, the number of meiosis events observed, and the level of marker loci heterozygosity. Theoretically, marker-assisted selection is more efficient than phenotypic-based selection for (i) low heritable traits, (ii) tight QTL-marker linkages , (iii) large population sizes, and (iv) earlier generations of selections where dissociation of marker and QTL linkage through recombination is low (Frisch et al., 1999; Knapp, 1998; Moreau et al., 1998; Yousef and Juvik, 2001).

Several markers have been developed for many legumes (Jeong et al., 2002; Jung et al., 2003; Santra et al., 2000; Timmerman-Vaughan et al., 2002), and can be used in molecular breeding through marker-assisted selection. Although the use of marker-assisted selection in plant breeding appears attractive, the cost associated with it should be taken into account to justify its practical application.

GENETICALLY MODIFIED CROPS: DO WE NEED THEM?

Agricultural biotechnology offers some hope for certain major diseases for which currently available management strategies are not effective. One strategy is to introduce foreign genes from a wide range of organisms into crop plants of interest or modify the plants' own genes, resulting in genetically modified crops (GMCs; also called transgenic or genetically engineered crops).

Transformation and regeneration protocols for several food and forage legumes have been developed (Dillen et al., 2000; VandenBosch and Stacey, 2003; Somers et al., 2003). In addition, several genes for different traits from the same or related species and different organisms are available for conditioning resistance (Atkinson et al., 2003; Giri and Kachole, 1998; Li et al., 2001; Lorito et al., 1998; Stanley et al., 1990). Once the desired trait has been incorporated, the transgenic plants can be used as parents in conventional breeding to introgress these genes to other cultivars.

Genetic engineering of crops is still largely dependent on conventional breeding. For example, commercial GMCs currently on the market are productive varieties developed by conventional breeding methods, with a final touch of an additional gene or two inserted through recombinant gene technology. However, when more and more cloned genes of agronomic importance become available in the future, we may be able to combine these genes in a variety through modern technologies at a much faster rate than conventional breeding can.

It is also important to remember that GMCs alone will not solve all agricultural problems. Like the crop varieties created through conventional breeding strategies, they have to be combined with other conventional approaches such as good soil-fertility management to achieve optimal conditions for crop production. Pest- or disease-resistant GMCs, just like those developed through conventional breeding methods, will, with time, succumb to pest or pathogen pressures. Pests and pathogens have various mechanisms for overcoming resistance. However, combining different forms of resistance from different sources (organisms) through recombinant DNA technology may provide an advantage in dramatically building a fortified barrier more difficult for the pest or pathogen to overcome.

Of the many applications of biotechnology, the issue of GMCs is contentious, highly charged, polarized, emotional, poorly informed, and sometimes deceptive. A wide gap exists between the fast-advancing modern biotechnological tools and the general public's understanding of these tools and the processes involving them. For example, a survey conducted in Europe shows that about 80% of both supporters and opponents of biotechnology admit that they are 'insufficiently informed about biotechnology', and yet they are able to form strong opinions (Gaskell et al., 2000).

The controversy over GMCs will undoubtedly continue for years to come. It is important to reckon that GMCs are here to stay. The onus is on each country to evaluate the potential benefits it can gain by adopting or generating GMCs while developing a rigorous biosafety regulation policy.

When used responsibly, transgenic technology offers the following advantages:

1. Many undesirable traits are not inherited together with the traits of interest
2. Substantial time is saved from no longer needing to repeatedly back-cross to the elite donor parent
3. Use of resistance genes from various sources, including artificial constructs, make plant breeders less dependent on natural variation for these genes
4. Durable and/or multiple resistances are achieved over a short period through engineering plant-defence mechanisms.

THE CHALLENGE

Many reasons exist to believe that agricultural biotechnology will contribute to finding solutions to production and environmental problems. The ethical, environmental, socio-economic, and food-safety issues that underlie public concerns must be addressed. Efforts must be made to narrow the gap between public understanding of basic biotechnology tools and applications and the rapidly advancing science.

Developing countries, including Ethiopia, need to fully exploit their crop production capacity by using available conventional methods at the levels achieved elsewhere. Nevertheless, where genetic engineering or other biotechnological applications provide the best or only way to achieve certain agricultural benefits, then the use of these technologies should be considered. Risks are always associated with technologies; countries must be willing to take some potential risks to obtain potentially substantial benefits.

Developed countries have no food shortages, so it is understandable that some see no reason or benefit in modifying their method of food production in a way they perceive as 'meddling with nature'. At the same time, in these very same countries, medical biotechnology applications and environmental biotechnologies are perceived very positively and given strong support. Indeed, genetically modified organisms in health-care products are in worldwide use (e.g., insulin, the anticoagulant hirudin for thrombosis, hepatitis vaccine, medication for cardiovascular diseases, and gene therapy), as are products for industrial purposes such as bioremediation, food additives, and food processing. Such products have elicited little or no controversy. It boils down to a question of need. The top priorities for countries with food shortages should include crop productivity, food security, and alleviation of poverty, in much the same way as rich countries perceive health-care products as one of their top priorities.

Biotechnology should be viewed as a component of a comprehensive strategy to alleviate poverty that needs to go hand-in-hand with an investment programme in agricultural growth. Public-sector research, particularly through partnerships among international agricultural research centres (IARCs) and national agricultural research systems (NARS), is essential for ensuring that molecular biology-based science serves the needs of the poor.

REFERENCES

Angenon, G., J. De Clercq, W. Dillen, A. Goossens, J. Kapila, M. Zambre, and M. van Montagu. 1999. Strategies for improving the nutritional quality of *Phaseolus* beans through gene engineering. *Biotech Agron Soc. Environ* 3: 233-236.

Aragão, F.J.L., G.R. Vianna, M.M.C. Albino, and E.L. Rech. 2002. Transgenic dry bean tolerant to the herbicide glufosinate ammonium. *Crop Sci.* 42: 1298-1302.

Aragão, F.J.L., L.M.G. Barros, M.V. Sousa, M.F. Grossi-de-Sã, E.R.P. Almeida, E.S. Gander, and EL Rech. 1999. Expression of a methionine-rich storage albumin from Brazil nut (*Bertholletia excelsa* HBK, Lecythidaceae) in transgenic bean plants (*Phaseolus vulgaris* L., Fabaceae). *Gen. Mol. Biol.* 22: 445-449.

Aragão, F.J.L., S.G. Ribeiro, L.M.G. Barros, A.C.M. Brasileiro, D.P. Maxwell, E.L. Rech, and J.C. Faria. 1998. Transgenic beans (*Phaseolus vulgaris* L.) engineered to express viral antisense RNAs show delayed and attenuated symptoms to bean golden mosaic geminivirus. *Mol. Breed.* 4: 491-499.

Arru, L., N. Faccini, C. Govoni, L. Cattivelli, N. Pecchioni, G. Delogu, A.M. Stanca, and G. Valè. 2003. The PCR-based marker MWG2018 linked to the *RDG2A* leaf stripe resistance gene is a useful tool for assessing barley resistance in breeding programs. *Crop Sci.* 43: 1036-1042.

Atkinson, H.J., P.E. Urwin, and M.J. McPherson. 2003. Engineering plants for nematode resistance. *Annu Rev. Phytopathol.* 41: 26.1-26.25.

Baulcombe, D.C. 1996. Mechanisms of pathogen-derived resistance to viruses in transgenic plants. *Plant Cell* 8: 1833-1844.

Baum, T.J., A. Hiatt, W.A. Parrott, L.H. Pratt, and R.S. Hussey. 1996. Expression in tobacco of a functional monoclonal antibody specific to stylet secretions of the root-knot nematode. *Mol. Plant-Microbe Interactions* 9: 382-387.

Bell, C.J.,R.A. Dixon, A.D. Farmer, R. Flores, J. Inman, R.A. Gonzales, M.J. Harrison, N.L. Paiva, A.D. Scott, J.W. Weller, and G.D. May. 2001. The *Medicago* genome initiative: A model legume database. *Nucleic Acids Res.* 29: 114-117.

Boulter, D. G.A. Edwards, A.M.R. Gatehouse, J.A. Gatehouse, and V.A. Hilder. 1990. Additive protective effects of incorporating two different higher plant-derived insect resistance genes in transgenic tobacco plants. *Crop Prot.* 9: 351-354.

Bruijn, F.J. 1992. Use of repetitive (extragenic palindromic and enterobacterial repetitive intergenic consensus) sequences and polymerase chain reaction to fingerprinting the genomes of *Rhizobium meliloti* isolates and other soil bacteria. *Appl. Environ. Microbiol.* 58: 2180-2187.

Capote-Mainez, N., and F. Sánchez. 1997. Characterization of the common bean uricase II and its expression in organs other than nodules. *Plant Physiol.* 115: 1307-1317.

Castro, A J., X. Chen, P.M. Hayes, and M. Johnston. 2003. Pyramiding quantitative trait locus (QTL) alleles determining resistance to barley stripe rust: effects on resistance at the seedling stage. *Crop Sci.* 43: 651-659.

Chan, J.W.Y.F., and P.H. Goodwin. 1999. Diffrentiation of *Xanthomonas campestris* pv. *phaseoli* from *Xanthomonas campestris* pv. *phaseoli* var. *fuscans* by PFGE and RFLP. *Eur. J. Plant Pathol.* 105: 867-878.

Cohn, J., G. Sessa, and G.B. Martin. 2001. Innate immunity in plants. *Curr. Opin. Immunol.* 13: 55-62.

Dangl, J.L., and J.D. Jones. 2001. Plant pathogens and integrated defence responses to infection. *Nature* 411: 826-833.

DeGray, G., K. Rajasekaran, F. Smith, J. Sanford, and H. Daniell. 2001. Expression of antimicrobial peptide via the chloroplast genome to control phytopathogenic bacteria and fungi. *Plant Physiol.* 127: 852-862.

Dickman, M.B., Y.K.Park, T. Oltersdorf, W. Li, I. Clemente, and R. French. 2001. Abrogation of disease development in plants expressing animal antiapoptotic genes. *Proc. Natl. Acad. Sci. USA* 98: 6957-6962.

Dillen, W. M. Zambre, J. De Clercq, A. Goossens, J. Kapila E. Vranová, M. Van Montagu, and G. Angenon. 2000. *In vitro* regeneration and *Agrobacterium*-mediated transformation of *Phaseolus vulgaris* L. (common bean) and *P. acutifolius* A. Gray (tepary bean). *ISHS (Int. Soc. Hortic. Sci.) Acta Hortic.* 521: 59-64.

Dixon, R.A., and L.W. Sumner. 2003. Legume natural products: understanding and manipulating complex pathways for human and animal health. *Plant Physiol.* 131: 878-885.

Doran, P.M. 2000. Foreign protein production in plant tissue cultures. *Curr. Opin. Biotechnol.* 11:199-204.

Fang, H.J., D.L. Li, G.L.Wang, and Y.H. Li. 1997. An insect-resistant transgenic cabbage plant with the cowpea trypsin inhibitor (CpTi) gene. *Acta Bot. Sinica* 39: 940-945.

Flor, H.H. 1955. Host-parasite interaction in flax rust: its genetics and other implications. *Phytopathology* 45: 680-685.

Franconi, A., P. Roggero, P. Pirassi, F.J. Arias, A. Desiderio, O. Bitti, D. Pashkoulov, B. Mattei, L. Bracci, V. Masenga, R.G. Milne, and E. Benvenuto. 1999. Functional expression in bacteria and plants of an scFv antibody fragment against topoviruses. *Immunotechnology* 4: 189-201.

Freyre, R., P. Skroch, V. Geffroy, A-F Adam-Blondon, A. Shirmohamadali, W. Johnson, V. Llaca, R. Nodari, P. Pereira, S-M Tsai, J. Tohme, M. Dron, J. Nienhuis, C.E. Vallejos, and P. Gepts. 1998. Towards an integrated linkage map of common bean: 4. Development of a core map and alignment of RFLP maps. *Theor. Appl. Genet.* 97: 847-856.

Frisch, M., M. Bohn, and A.E. Melchinger. 1999. Comparison of selection strategies for marker-assisted backcrossing of a gene. *Crop Sci.* 39: 1295-1301.

Gaskell, G., N. Allum, M. Bauer, J. Durant, A. Allansdottir, H. Bonfadelli, D. Boy, S. de Cheveigné, B. Fjaestad, J.M. Gutteling, J. Hampel, E. Jelsøe, J.C. Jesuino, M. Kohring, N. Kronberger, C. Midden, T.H. Nielsen, A. Przestalski, T. Rusanen, G. Sakellaris, H. Torgersen, T. Twardowski, and W. Wagner. 2000. Biotechnology and the European public. *Nature Biotechnol.* 18: 935-938.

Gebhardt, C., and J.P.T. Valkonen. 2001. Organization of genes controlling disease resistance in the potato genome. *Annu. Rev. Phytopathol.* 39: 79-102.

Geffroy, V.,F. Creusot, J. Falquet, M. Sévignac, A_F Adam-Blondon, P. Gepts, and M. Dron. 1998. A family of LRR sequences at the Co-2 locus for anthracnose resistance in *Phaseolus vulgaris* and its potential use in marker-assisted selection. *Theor. Appl. Genet.* 96: 494-502.

Geffroy, V., M. Sévignac, J.C.F. De Oliveira, G. Fouilloux, P. Skroch, P. Thoquet, P. Gepts, T. Langin, and M. Dron M. 2000. Inheritance of partial resistance against *Colletotrichum lindemuthianum* in *Phaseolus vulgaris* and co-localization of quantitative trait loci with genes involved in specific resistance. *Mol. Plant-Microbe Interactions* 13: 287-296.

Gepts, P. 1999. Development of an integrated linkage map. p. 53-91, 389-400. *In* S.P. Singh (Ed.) *Common Bean Improvement for the Twenty-first Century.* Kluwer, Dordrecht.

Gerlach, W.L., D. Llewellyn, and J. Haselott. 1987. Construction of a disease resistance gene using the satellite RNA of tobacco ringspot virus. *Nature* 328: 802-806.

Giddings, G., G. Allison, D. Brooks, and A. Carter. 2000. Transgenic plants as factories for biopharmaceuticals. *Nature Biotechnol.* 18: 1151-1155.

Giri, A.P., and M.S. Kachole. 1998. Amylase inhibitors of pigeonpea (*Cajanus cajan*) seeds. *Phytochemistry* 47: 197-202.

Goodwin, S.B., M.A. Saghal-Maroof, R.W. Allard, and R.K Webster. 1993. Isozyme variation within and among populations of *Rhynchsporium secalis* in Europe, Australia and the United States. *Mycol. Res.* 97: 49-58.

Goossens, A., W. Dillen, J. De Clercq, M. Van Montagu, and G. Angenon. 1999. The arcelin-5 gene of *Phaseolus vulgaris* directs high seed specific expression in transgenic *Phaseolus acutifolius* and *Arabidopsis* plants. *Plant Physiol.* 120:1095-1104.

Graham, P.H., and C.P. Vance. 2003. Legumes: importance and constraints to greater use. *Plant Physiol.* 131: 972-877.

Grusak, M.A. 2002. Enhancing mineral content in plant food products. J. Am. Coll. Nutr. 21: 178S-183S.

Hammond-Kosack, K.E., and J.D.G. Jones. 1997. Plant disease resistance genes. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 48: 575-607.

Hantula, J., M. Dusabenyagasani, and R.C. Hamelin. 1996. Random amplified microsatellites (RAMS): A novel method for characterizing genetic variation within fungi. *Eur. J. Forest Pathol.* 26: 159-166.

Heath, M.C. 2000. Nonhost resistance and nonspecific plant defenses. *Curr. Opin. Plant Biol.* 3: 315-319.

Henson, J.M., and R. French. 1993. The polymerase chain reaction and plant disease diagnosis. *Annu. Rev. Phytopathol.* 31: 81-109.

Herman, E.M., R.M. Helm,R, Jung, and A.J. Kinney. 2003. Genetic modification removes an immunodominant allergen from soybean. *Plant Physiol.* 132: 36-43.

Hilder, V.A., A.M.R. Gatehouse,S.E. Sheerman,R.F. Baker, and D. Boulter. 1987. A novel mechanism of insect resistance engineered into tobacco. *Nature* 330: 160-163.

Honeycutt, R.J., and M. McClelland. 1996. Application of the polymerase chain reaction for the detection of plant pathogens. p. 187-201. *In* B.W.S. Sobral (Ed.) *The Impact of Plant Molecular Genetics*. Birkhauser, Boston, MD.

Hulbert, S.H., C.A. Webb, S.M. Smith, and Q. Sun. 2001. Resistance gene complexes: evolution and utilization. *Annu. Rev. Phytopathol.* 39: 285-312.

Jaynes, J.M., K.G. Xanthopoulos, L. Destéfano-Beltrán, and J.H. Dodds. 1987. Increasing bacterial disease resistance in plants utilizing antibacterial genes from insects. *Bioassays* 6: 263-270.

Jedryczka, M., T. Rouxel, and M.H. Balesdent. 1999. Rep-PCR based genomic fingerprinting of isolates of *Leptosphaeria maculans* from Poland. *Eur. J. Plant Pathol.* 105: 813-823.

Jeong, S.C., S. Kristipati, A.J. Hayes, P.J. Maughan, S.L. Noffsinger, I. Gunduz, G.R. Buss, and M.A.S. Maroof. 2002. Genetic and sequence analysis of markers tightly linked to the s*oybean mosaic virus* resistance gene, *Rsv*3. *Crop Sci.* 42: 265-270.

Jones, A.L., I.E. Johansen, S.J. Bean, I. Bach,, and A.J. Maule. 1998. Specificity of resistance to pea seed-borne mosaic potyvirus in transgenic peas expressing the viral replicase (Nlb) gene. *J. Gen. Virol.* 79: 3129-3137.

Jung, G., H.M. Ariyarathne, D.P. Coyne, and J. Nienhuis. 2003. Mapping QTL for bacterial brown spot resistance under natural infection in field and seedling stem inoculation in growth chamber in common bean. *Crop Sci.* 43: 350-357.

Kar, S., D. Basu, S. Das, N.A. Ramakrishnan, P. Mukherjee, P. Nayak, and S.K. Sen. 1997. Expression of Cry 1 A (c) gene of *Bacillus thuringiensis* in transgenic chickpea plants inhibits development of pod-borer (*Heliothis armigera*) larvae. *Transgen Res.* 6: 177-185.

Keim, P., J.M. Schupp, S.E. Travis, K. Clayton, T. Zhu, L. Shi, A. Ferreira, and D.M. Webb. 1997. A high-density genetic map of soybean based upon AFLP markers. *Crop Sci.* 37:537-543.

Kelemu, S., H. Dongyi, H. Guixiu,, and Y. Takayama. 2003. Detecting and differentiating *Acremonium implicatum*: developing a PCR-based method for an endophytic fungus associated with the genus *Brachiaria. Mol. Plant Pathol.* 4: 115-118.

Kelemu, S., H. Guixiu, and G. Segura. 2001. *Stylosanthes guianensis* plants transformed with a rice chitinase gene confer resistance to *Rhizoctonia* foliar blight disease. *Phytopathology* 91: S47.

Kelemu, S., D.Z. Skinner, J.L. Badel, C.X. Moreno, M.X. Rodríguez, C.D. Fernandes, M.J.D.'A. Charchar, and S. Chakraborty. 1999. Genetic diversity in South American *Colletotrichum gloeosporioides* isolates from *Stylosanthes guianensis*, a tropical forage legume. *Eur. J. Plant Pathol.* 105: 261-272.

Kelly, J.D. 1995. Use of RAPD markers in breeding for major gene resistance to plant pathogens. *Hort. Sci.* 30: 461-465.

Kessler, A., and I.T. Baldwin. 2002. Plant responses to insect herbivory: the emerging molecular analysis. *Annu. Rev. Plant Biol.* 53: 299-328.

Knapp, S.J. 1998. Marker-assisted selection as a strategy for increasing the probability of selecting superior genotypes. *Crop Sci.* 38: 1164-1174.

Lapidot, M., R. Gafny, B. Ding, S. Wolf, W.J. Lucas, and R.N. Beachy. 1993. A dysfunctional movement protein of tobacco mosaic virus that partially modifies the plasmodesmata and limits virus spread in transgenic plants. *Plant J.* 4: 959-970.

Laucou, V., K. Haurogue, N. Ellis, and C. Rameau. 1998. Genetic mapping in pea: 1. RAPD-based genetic linkage map of *Pisum sativum. Theor. Appl. Genet.* 97: 905-915.

Leach, J.E., S. Gold, S.A. Tolin, and K. Eversole. 2002. A plant-associated microbe genomics initiative: What is it and why do we need it? APSnet Feature. (http://www.apsnet.org/online/feature/microbe)

LeBerre, A.V., G.C. Bompard, F. Payan, and P. Rouge. 1997. Characterization of functional properties of the alpha-amylase inhibitor (alpha-AI) from kidney bean (*Phaseolus vulgaris*) seeds. *Biochim. Biophys. Acta* 1343: 31-40.

Lee, S.I., S.H. Lee, J.C. Koo, H.J. Chun, C.O. Lim, J.H. Mun, Y.H. Song, and M.J. Chao. 1999. Soybean Kunitz trypsin inhibitor (SKTI) confers resistance to the brown planthopper (*Nilaparvata lugens* Stal) in transgenic rice. *Mol. Breed.* 5: 1-9.

Li, Q., C.B. Lawrence, H-Y Xing, R.A. Babbitt, W.T. Bass, I.B. Maiti, and, N.P. Everett. 2001. Enhanced disease resistance conferred by expression of antimicrobial magainin analog in transgenic tobacco. *Planta* 212: 635-639.

Li, Y.E., Z. Zhu, Z.X. Chen, X. Wu, W. Wang, and S.J. Li. 1998. Obtaining transgenic cotton plants with cowpea trypsin inhibitor. Acta Gossypii *Sinica* 10: 237-243.

Lincoln, J.E., C. Richael, B. Overduin, K. Smith, R. Bostock, and D.G. Gilchrist. 2002. Expression of the antiapoptotic baculovirus p35 gene in tomato blocks programmed cell death and provides broad-spectrum resistance to diseases. *Proc. Natl. Acad. Sci. USA* 99: 15217-15221.

Lorito, M., S.L. Woo, I.G. Fernandes, G. Colucci, G.E. Harman, J.A. Pintor-Toro, E. Filippone, S. Muccifora, C.B. Lawrence, A. Zoina, S. Tuzun, and F. Scala. 1998. Genes from mycoparastitic fungi as a source for improving plant resistance to fungal pathogens. *Proc. Natl. Acad. Sci. USA* 95: 7860-7865.

Louws, F.J., J.L.W. Rademaker, and F.J. de Bruijn. 1999. The three Ds of PCR-based *Rev. Phytopathol.* 37: 81-125.

McDonald, B.A., and C. Linde. 2002. Pathogen population genetics, evolutionary potential, and durable resistance. *Annu. Rev. Phytopathol.* 40: 349-379.

McDonald, B.A., and J.M. McDermott. 1993. Population genetics of plant pathogenic fungi. *Bioscience* 43: 311-319.

Mahuku, G.S., C. Jara, J.B. Cuasquer, and G. Castellanos. 2002a. Genetic variability within *Phaeoisariopsis griseola* from Central America and its implications for resistance breeding of common bean. *Plant Pathol.* 51: 594-604.

Mahuku, G.S., M.A. Henríquez, J. Munõz, and R.A. Buruchara. 2002b. Molecular markers dispute the existence of the Afro-Andean group of the bean angular leaf spot pathogen, *Phaeoisariopsis griseola*. *Phytopathology* 92: 580-589.

Mammadov, J.A., J.C. Zwonitzer, R.M. Biyashev, C.A. Griffey, Y. Jin, B.J. Steffenson, and M.A.S. Maroof. 2003. Molecular mapping of leaf rust resistance gene *Rph5* in barley. *Crop Sci.* 43: 388-393.

Martin, R.R., D. James, and Levesque. 2000. Impact of molecular diagnostic technologies on plant disease management. *Annu. Rev. Phytopathol.* 38: 207-239.

Martin, G.B., A.J. Bogdanove, and G. Sessa. 2003. Understanding the functions of plant disease resistance proteins. *Annu. Rev. Plant Biol.* 54: 23-61.

Menéndez, C.M., A.E. Hall, and P. Gepts. 1997. A genetic linkage map of cowpea (*Vigna unguiculata*) developed from a cross between two inbred, domesticated lines. *Theor. Appl. Genet.* 95: 1210-1217.

Mian, M.A.R., T. Wang, D.V. Phillips, J. Alvernaz, and H.R. Boerma. 1999. Molecular mapping of the *Rcs3* gene for resistance to frogeye leaf spot in soybean. *Crop Sci.* 39: 1687-1691.

Miklas, P.N., L. Afanador, and J.D. Kelly. 1996. Recombination-facilitated RAPD marker-assisted selection for disease resistance in common bean. *Crop Sci.* 36: 86-90.

Miklas, P.E., W.C. Johnson, R. Delorme, and P. Gepts. 2001. Identification of QTL conditioning physiological resistance and avoidance to white mold in dry bean G 122 (PI 163120). *Crop Sci.* 41: 309-315.

Milgroom, M.G., S.E. Lipari, and W.A. Powell. 1992. DNA fingerprinting and analysis of population structure in the chestnut blight fungus, *Cryphonectria parasitica*. *Genetics* 131: 297-306.

Mitra, A., and Z. Zhang. 1994. Expression of a human lactoferrin cDNA in tobacco cells produces antibacterial protein(s). *Plant Physiol.* 106: 977-981.

Mitra, A., D.W. Higgins, W.G. Langenberg, H. Nie, D.N. Senguta, and R.H. Silverman. 1996. A mammalian 2-5A system functions as an antiviral pathway in transgenic plants. *Proc. Natl. Acad. Sci. USA* 93: 6780-6785.

Molvig, L., L.A. Tabe, B.O. Eggum, A.E. Moore, S. Graig, D. Spencer, and T.J. Higgins. 1997. Enhanced methionine levels and increased nutritive value of seeds of transgenic lupins (*Lupinus angustifolius* L.) expressing sunflower seed albumin gene. *Proc. Natl. Acad. Sci. USA* 94: 8393-8398.

Moreau, L., A. Charcosset, F. Hospital, and A. Gallais. 1998. Marker-assisted selection efficiency in population of finite size. *Genetics* 148: 1353-1365.

Morton, R.L., H.E. Schroeder, K.S. Bateman, M.J. Chrispeels, E. Armstrong, and T.J.V. Higgins. 2000. Bean-amylase inhibitor 1 in transgenic peas (*Pisum sativum*) provides complete protection from pea weevil (*Bruchus pisorum*) under field conditions. *Proc. Natl. Acad. Sci. USA* 97: 3820-3825.

Mueller, U., S.E. Lipari, and M.G. Milgroom. 1996. Amplified fragment length polymorphism (AFLP) fingerprinting of symbiotic fungi cultured by the fungus-growing ant *Cyphomyrmex minutus*. *Mol. Ecol.* 5: 119-122.

Müller, M.M., and J. Hantula. 1998. Diversity of *Tiarosporella parca* in Finland, Norway and Switzerland. *Mycol. Res.* 102: 1163-1168.

Nakajima, H., T. Muranaka, F. Ishige, K. Akutsu, and K. Oeda. 1997. Fungal and bacterial disease resistance in transgenic plants expressing human lysozyme. *Plant Cell Rep.* 16: 674-679.

Ouédraogo, J.T., B.S. Gowda, M. Jean, T.J. Close, J.D. Ehlers, A.E. Hall, A.G. Gillaspie, P.A. Roberts, A.M. Ismail, G. Bruening, P. Gepts, M.P. Timko, and F.J. Belzile. 2002. Construction of an improved genetic linkage map of cowpea (*Vigna unguiculata* L.) combining AFLP, RFLP and RAPD markers. *Genome* 45: 175-188.

Palukaitis, P.,and M. Zaitlin. 1997. Replicase-mediated resistance to plant virus diseases. *Adv. Virus Res.* 48: 349-377.

Park, S.O., D.P. Coyne, J.R. Steadman, and P.W. Skroch. 2001. Mapping of QTL for resistance to white mold disease in common bean. *Crop Sci.* 41: 1253-1262.

Pental, D. 1998. Plant molecular biology and biotechnology in India. *Plant Mol. Biol. Rep.* 16: 93-97.

Powell-Abel, P., R.S. Nelson, B. De, N. Hoffmann, S.G. Rogers, R.T. Fraley, and R.N. Beachy. 1986. Delay of disease development in transgenic plants that express the tobacco mosaic virus coat protein gene. *Science* 232: 738-743.

Reis, C.M., M.M. Calvert, M.P. Sales, K.V.S. Fernandes, V.M. Gomes, and J. Zavier. 1997. Alpha-amylase inhibitors of legume seeds and their involvement in the resistance to bruchid beetles. *Arqu Biol. Tecnol.* 40: 413-418

Romeis, T., A.A. Ludwig, R. Martin, and J.D.G. Jones. 2001. Calcium-dependent protein kinases play an essential role in a plant defence response. *EMBO J.* 20: 5556-5567.

Rommens, C.M., and G.M. Kishore. 2000. Exploiting the full potential of disease-resistance genes for agricultural use. *Curr. Opin. Biotechnol.* 11: 120-125.

Sales, M.P., I.R. Gerhardt, M.F. Grossi-de-Sá, and J. Xavier-Filho. 2000. Do legume storage proteins play a role in defending seeds against bruchids? *Plant Physiol.* 124: 515-522.

Sanford, J.C., and S.A. Johnston. 1985. The concept of parasite-derived resistance: deriving resistance genes from the parasite's own genome. *J. Theor. Biol.* 113: 395-405.

Santra, D.K., M. Tekeoglu, M. Ratnaparkhe, W.J. Kaiser, and F.J. Muehlbauer. 2000. Identification and mapping of QTLs conferring resistance to ascochyta blight in chickpea. *Crop Sci.* 40: 1606-1612.

Satyavathi, V.V., V. Prasad, A. Khandelwal, M.S. Shaila, and G. Lakshmi Sita. 2003. Expression of hemagglutinin protein of rinderpest virus in transgenic pigeon pea [*Cajanus cajan* (L.) Millsp.] plants. *Plant Cell Rep.* 21: 651-658.

Schroeder, H.E., S. Gollasch, A. Moore, L.M. Tabe, S. Craig, D.C. Hardie, M.J. Chrispeels, D. Spencer, and T.J.V. Higgins. 1995. Bean alpha-amylase inhibitor confers resistance to pea weevil (*Bruchus pisorum*) in transgenic peas (*Pisum sativum* L.). *Plant Physiol.* 107: 1233-1239.

Shade, R.E., H.E. Schroeder, J.J. Pueyo, L.M. Tabe, L.L. Murdock, , T.J.V. Higgins, and M.J. Chrispeels. 1994. Transgenic pea seeds expressing α-amylase inhibitor of the common bean are resistant to bruchid beetles. BioTechnology 12: 793-796.

Sharma, H.C., K.K. Sharma, N. Seetharama, and R. Ortiz. 2001. Genetic transformation of crop plants: risks and opportunities for rural poor. *Curr. Sci.* 80: 1495-1508.

Sharon, N., and H. Lis. 1990. Legume lectins - a large family of homologous proteins. *FASEB J.* 4: 3198-3208.

Smith, N.A., S.P. Singh, M.B. Wang, P.A. Stoutjesdijk, A.G. Green, and P.M. Waterhouse. 2000. Total silencing by intron-spliced hairpin RNAs. *Nature* 407: 319-320.

Somers, D.A., D.A. Samac, and P.M. Olhoft. 2003. Recent advances in legume transformation. *Plant Physiol.* 131: 892-899.

Spelman, R.J., and J.A.M. van Arendonk. 1997. Effect of inaccurate parameter estimates on genetic response to marker-assisted selection in an outbred population. *J. Dairy Sci.* 80: 3399-3410.

Stanley, J., T. Frischmuth, and S. Ellwood. 1990. Defective viral DNA ameliorates symptoms of geminivirus infection in transgenic plants. *Proc. Natl. Acad. Sci. USA* 87: 6291-6295.

Stewart, C.N., M.J. Adang, J.N. All, H.R. Boerma, G. Cardineau, D. Tucker, and W.A. Parrott. 1996. Genetic transformation, recovery, and characterization of fertile soybean transgenic for a synthetic *Bacillus thuringiensis* cryIAc gene. *Plant Physiol.* 112: 121-129.

Tacket, C.O.,and H.S. Mason. 1999. A review of oral vaccination with transgenic vegetables. *Microbes Infect.* 1: 777-783.

Thorneycroft, D., S.M. Sherson, and S.M. Smith. 2001. Using gene knockouts to investigate plant metabolism. *J. Expl. Bot.* 52: 1593-1601.

TIGR (The Institute for Genomic Research). 2003. TIGR gene indices. (http://www.tigr.org/tdb/tgi (accessed 15 May 2003).

Timmerman-Vaughan, G.M., T.J. Frew, A.C. Russell, T. Khan, R. Butler, M. Gilpin, S. Murray, and K. Falloon. 2002. QTL mapping of partial resistance to field epidemics of ascochyta blight of pea. *Crop Sci.* 42: 2100-2111.

Tsai, S.M.,R.O. Nodari, D.H. Moon, L.E.A. Camargo, R. Vencovsky, and P. Gepts. 1998. QTL mapping for nodule number and common bacterial blight in *Phaseolus vulgaris* L. *Plant Soil* 204: 135-145.

VandenBosch, K.A., and G. Stacey. 2003. Summaries of legume genomics projects from around the globe. Community resources for crops and models. *Plant Physiol.* 131: 840-865.

Vunnam, S., P. Juvvadi, and R.B. Merrifield. 1997. Synthesis and antibacterial action of cecropin and proline-arginine-rich peptides from pig intestine. *J. Peptide Res.* 49: 59-66.

Winter, P., A-M. Benko-Iseppon, B. Hüttel, M. Ratnaparkhe, A. Tullu, G. Sonnante, T. Pfaff, M. Tekeoglu, D. Santra, V.J. Sant, P.N. Rajesh, G. Kahl, and F.J. Muehlbauer. 2000. Linkage map of the chickpea (*Cicer arietinum* L.) genome based on recombinant inbred lines from a *C. arietinum* × *C. reticulatum* cross: Localization of resistance genes for *Fusarium* wilt races 4 and 5. *Theor. Appl. Genet.* 101: 1155-1163.

Wang, T.L., C. Domoney, C.L. Hedley, R. Sasey, and M.A. Grusak. 2003. Can we improve the nutritional quality of legume seeds? *Plant Physiol.* 131: 886-891.

Xiong, L., and Y. Yang. 2003. Disease resistance and abiotic stress tolerance in rice are inversely modulated by an abscisic acid-inducible mitogen-activated protein kinase. *Plant Cell* 15: 745-759.

Xu, D.P., Q.Z. Xue, D. McElroy, Y. Mawal, V.A. Hilder, and R. Wu. 1996. Constitutive expression of a cowpea trypsin inhibitor gene, CpTi, in transgenic rice plants confers resistance to two major rice insect pests. *Mol. Breed.* 2: 167-173.

Yepes, L.M., M. Fuchs, J.L. Slightom, and D. Gonsalves. 1996. Sense and antisense coat protein gene constructs confer high-levels of resistance to tomato ringspot nepovirus in transgenic Nicotiana species. *Phytopathology* 86: 417-424.

Yin, X., P. Stam, M.J. Kropff, and A.H.C.M. Schapendonk. 2003. Crop modeling, QTL mapping, and their complementary role in plant breeding. *Agron. J.* 95: 90-98.

Young, N.D. 1996. QTL mapping and quantitative disease resistance in plants. *Annu. Rev. Phytopathol.* 34: 479-501.

Yousef, G.G., and J.A. Juvik. 2001. Comparison of phenotypic and marker-assisted selection for quantitative traits in sweet corn. *Crop Sci.* 41: 645-655.

Yu, K., S.J. Park, V. Poysa, and P. Gepts. 2000. Integration of simple sequence repeat (SSR) markers into a molecular linkage map of common bean (*Phaseolus vulgaris* L.). *J. Hered.* 91: 429-434.

Yu, M.H, L.M. Pakish, and H. Zhou. 2001. An isozyme marker for resistance to root knot nematode in sugarbeet. *Crop Sci.* 41: 1051-1053.

Chickpea, Lentil, Grass pea, Fenugreek and Lupine Disease Research in Ethiopia

Seid Ahmed [1] and Melakmu Ayalew [2]

[1] *Ethiopian Agricultural Research Organization, P. O. Box 2003, Addis Ababa*
[2] *Adet Agricultural Research Center, P. O. Box, 8, Bahir Dar*

ABSTRACT

Chickpea, lentil, grass pea, fenugreek and lupine are the most important cool season legumes in the highlands of Ethiopia. The acreage of these crops is increasing from year to year due to their increasing demand both in the local and international markets. The productivity of these crops at national level is less than 1 t/ha due to low yielding potential of the landraces, and biotic and abiotic stresses. Among the biotic stresses, foliar and soil-borne diseases play a major role in affecting productivity of these crops. Research on surveys and different control measures were done based on the recommendations of the first national food legume workshop held in 1993. Most of the research activities in the legume improvement programs of different centers were concentrated in managing chickpea and lentil diseases. Among the research activities in controlling chickpea and lentil diseases, host plant resistance was given top priority. In this endeavor, resistant varieties of chickpea and lentil to soil-borne and foliar diseases were developed and released to the farming communities. Little research was done on diseases of grass pea, lupine and fenugreek during the period under review. In general, this review attempts to summarize the achievements gained during the review period, and suggests critical areas to be addressed in the foreseeable future.

INTRODUCTION

Chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), grass pea (*Lathyrus sativus*), fenugreek (*Trigonella foenum-graecum)* and lupine (*Lupinus* spp.) are the major highland food and spice legumes grown in Ethiopia (CASC, 2002). Chickpea, lentil and grass pea are important sources of dietary protein for the majority of the population and cash for the farmers and the country. Fenugreek is used as a spice and fetches high prices in the local market, whereas lupine production is limited in northwest Ethiopia and mainly used to prepare local drinks. These five legumes play an important role in improving soil fertility through nitrogen fixation. They are also used as a break crop to reduce insect-pests, diseases and weeds, and as a result, to sustain cereal production.

The productivity of these five legumes is very low (less than one ton/ha) due to low yielding land races, diseases, insect-pests and weeds. Pathogenic fungi affecting both under- and above-ground plant parts cause the major yield reductions in the country (Mengistu and Negussie, 1994). Research results on diseases affecting chickpea were reviewed by Dereje (1994) and those affecting lentil and grasspea by Mengistu and Negussie (1994). This paper reviews research results carried out on diseases of these legumes during the last decade.

BASIC STUDIES

Survey and Identification

Surveys were done on farmers' fields, research stations and testing sites to determine the distribution and importance of diseases affecting the five legumes. In the 1996/97 cropping season, survey was conducted in northwest Ethiopia (Gojam and Gonder Zones) to determine the relative importance of diseases associated with chickpea and lentil (Negussie et al., 1998). The major diseases observed on chickpea were wilt (7-18% incidence), root rots (1-34% incidence) and stunt virus disease (2-5% incidence). The major pathogens associated with wilt/root rots were *Fusarium oxysporum* f. sp. *ciceri* (40% frequency), *Rhizoctonia bataticola* (18% frequency), *R. solani* (13% frequency) and *Sclerotium rolfsii* (7% frequency). In lentil fields, the diseases observed were wilt/root rots (5-40% incidence) and powdery mildew (0-100% incidence). The major pathogens associated with wilt/root rots were F. *oxysporum* f. sp. *lentis* (52% frequency), *S. rolfsii* (16% frequency), *R. solani* (16% frequency), and *R. bataticola* (14% frequency). The survey results showed that fusarium wilt and root rots are the major root diseases of chickpea and lentil in northwest Ethiopia. Since the two crops are planted on residual moisture on Vertisols, major foliar diseases were not recorded. The effect of stunt on chickpea and powdery mildew on lentil is usually minimal when planting is done late in the season.

In 1994, a survey of chickpea and lentil was conducted and the results showed that chickpea and lentil affected with stunting, leaf curling, reddening and yellowing symptoms were infected by beet western yellows polerovirus (BWYV) (Negussie *et al.*, 1999a). In the 1998 cropping season, viral disease survey on chickpea and lentil was conducted in central highlands of Ethiopia (Negussie *et al.*, 1999b; Tadesse *et al.*, 1999). The results showed that lentil was infected by faba bean necrotic yellow virus (FBNYV) (0.5% incidence), pea seed-borne mosaic virus (PSbMV) (10% incidence), broad bean stain virus (BBSV) (0.02% incidence), bean yellow mosaic virus (BYMV) (0.02% incidence) and cucumber mosaic virus (CMV) (0.04% incidence). On the contrary, chickpea was infected by FBNYV (0.06 % incidence) and broad bean wilt virus (BBWV) (0.09 % incidence).

The survey results in 1997/98 in Tigrai and Wello indicated that the incidence of wilt ranged from 1-5%

and that of root rots ranged from 10-15%, while in Wello, wilt ranged from 1-5%; stunt ranged from 1-20%, and other root rots ranged from 5-30%. In addition to wilt/root rots, ascochyta blight (1-15% incidence) and root-knot nematodes (5-20% incidence) were recorded in Wello. The root-knot nematode incidence was high on chickpea grown on sandy loam soil. Nematodes could be problematic if chickpea and lentil are pushed in irrigated lowlands. Past observations had shown that chickpea and lentil grown on sandy soils in the lowlands were severely infected by root-knot nematodes (Mengistu and Negussie, 1994).

In the 1998/99 cropping season, a survey was done by Sinana Agricultural Research Center (SnARC) on lentil in the Bale highlands of the southeastern parts of the country. The results showed that lentil rust (*Uromyces fabae*) was widely distributed, and all the land races were susceptible. As a result, disease-screening activities were initiated to identify high yielding and rust-resistant cultivars. Ascochyta blight (*Ascochyta fabae* f. sp. *lentis*) was observed on local landraces planted in yield trials at the Center, which could be introduced through germplasm exchange.

In the 1999/2000 cropping season, phyllody disease was observed in some chickpea plots planted in the irrigated cotton belt in the Awash Valley with less than 5% incidence. The infected plants did not flower, and no pods were formed. The vector could be a common insect-pest on cotton. The yield trials showed that some Kabuli chickpea genotypes could be produced during the off- season and the situation of the phyllody and its vectors needed a follow-up.

It is only recently that the pulses research program started working to improve fenugreek and lupine. Although no systematic disease surveys have been done, powdery mildew and leaf spots were recorded as the major diseases on fenugreek in research trial plots and, thus, warrant an immediate attention. In the case of lupine, the sweet type was found severely affected by powdery mildew and collar rot but the bitter type was resistant. Some control measures should now be thought of for fenugreek and sweet lupine diseases.

Epidemiology

Basic knowledge of the epidemiology of diseases affecting the five legumes is crucial to design effective control measures in Ethiopia. However, efforts made were minimal during the period under review.

Ascochyta fabae f. sp. *lentis* is known to be seed-borne in nature and can be primary source of inoculum to initiate epidemics under favorable conditions in the field. The pathogen was routinely isolated from the infected lentil seeds stored at room temperature at 22 ^{o}C in the store and in refrigerator at 5 ^{o}C (Ahmed and Beniwal, 1998). The findings indicated that the pathogen could survive and initiate epidemic in the field, and also could be introduced to new areas in the country through germplasm exchange from gene bank or research centers. Therefore, during germplasm exchange, there is a need to treat seeds with fungicides or seed should be produced during the dry season using irrigation.

The pathogenic variability of *F. oxysporum* f. sp. *lentis* affecting lentil was studied using three genotypes (ILL-6031, -590 and -669), and the result showed the presence of variations in pathogenicity among the tested isolates (Negussie Tadesse, unpublished data). On the contrary, the isolates of *F. oxysporum f. sp. ciceri* that causes wilt of chickpea were grouped into three pathotypes (northwest, central and north) using 10 standard differentials (Negussie and Geletu, unpublished data).

Seven races of the chickpea fusarium wilt pathogen are known in the world (Dolar, 1997) and knowledge on the race structure in Ethiopia is very essential for development of resistant gene pool and to utilize gene deployment in the major chickpea growing regions of the country.

Control Measures

Major emphasis was given to develop host plant resistance to the major diseases of chickpea and lentil. Only limited studies were done on other control options.

Biological control. Biological control methods play a vital role in managing soil-borne diseases affecting cool season food legumes (Kaiser et. al., 1989; Landa et. al., 1997). There were no efforts made on the biological control of legume diseases in Ethiopia except a preliminary work on in vitro inhibition of *Trichoderma* and *Penicillium* spp. on *F. oxysporum f. sp. ciceri* (ARARI, 2002), and effect of neem seed extract in reducing the incidence of wilt/root rots of chickpea at seedling stage (Meki Shehabu, unpublished data).

Host plant resistance. Most of the research activities conducted during the review period have been concentrated in identifying high yielding varieties of chickpea and lentil resistant to the major soil-borne and foliar diseases. As a result, cultivars resistant to ascochyta blight of chickpea, rust of lentil and wilt/root rots of chickpea and lentil were developed. Some of the genotypes selected were released and others are at different stages of yield trials.

Lentil rust: Rust (*Uromyces fabae*) is the most important yield-limiting factor where lentil is grown in the country (Geletu and Yadeta, 1999; Abashamo et. al., 2000). Rust screening nurseries from local collections and introductions from International Center for Agricultural Research in the Dry Areas (ICARDA) were evaluated in the field under natural infection from 1995-2002 at Akaki, Sinana and Chefe Donsa, and a number of resistant genotypes with useful agronomic traits were selected (Table 1).

After resistant genotypes were selected from rust screening nurseries, they were tested for their yield potential in replicated trials across locations and seasons. During yield trials, further selections were made for rust resistance and yield in locations where disease pressure was heavy (Table 2).

Most of the local collections were early-maturing but susceptible to rust and their coping mechanism is escape through early-maturity. Most of the resistance sources are introduced materials from ICARDA. From the pre-national and national yield trials, specifically adapted and resistant genotypes were selected by different centers, and one genotype (FLIP-88-46L) has been released for Bale highlands, and a number of others were under advanced regional trials for release purposes (Table 3).

***Wilt/root rots*:** Wilt/root rots caused by a number of soil-borne pathogenic fungi are the major diseases of chickpea and lentil that reduce yield through crop stand reduction. Screening of lentil from local collections and introductions from ICARDA were done at multiple sick-plot at Debre Zeit Agricultural Research Center (DZARC) since 1995/96 cropping season, and resistant genotypes with desirable characters like ILL1861, R-186 were identified (Table 4) including the popular rust resistant cultivars Adaa and Alemaya (Negussie and Geletu, 1998; Geletu and Yadeta, 1998; Teklu et. al., 2000).

At DZARC, chickpea genotypes from local collections, introductions from ICARDA and Nile Valley Regional Program were screened in the multiple sick-plot and genotypes that showed less than 20% mortality were selected. At Adet, the screening was focused on local genotypes collected from North-West Ethiopia. Most of the the tested genotypes were susceptible to wilt/root rots, and only a few genotypes were selected.(Table 5).

Table 1. Number of genotypes tested and selected from lentil rust screening nurseries, 1996-1999 cropping seasons (based on 1-9 rating scale[1]).

Cropping season	Number of genotypes evaluated	Number of genotypes selected	Source of genotypes
1996/97	106	43	ICARDA, IBCR
1997/98	107	15	ICARDA
1998/99	30	0	ICARDA

[1] 1-9 rating scale, where 1= highly resistant and 9 = highly susceptible (Singh and Sandhu, 1988).

Table 2. Number of genotypes resistant to rust in different stages of yield trials[1]

Cropping season	Stage of yield trial	Number of test genotypes	Number of genotypes selected[2]
1997/98	NYT-Late Set	12	9
	PNYT-Late Set	6	3
	AYT-Late Set	6	4
1998/99	NYT-Late Set	12	8
	AYT-Late Set	13	7
	PYT-Late Set	17	13
2000/2001	PNYT-Late Set	15	10
1997/98	PNYT-Early Set	7	2
	PNYT-Early Set	8	2
	NYT-Early Set	11	3
	AYT-Early Set	8	2
1998/99	NYT-Early Set	13	5
	AYT-Early Set	16	10

[1] AYT = Advanced yield trial; PNYT= Pre-national yield trial; NYT= National Yield trial, and PYT= Preliminary yield trial, [2] 1= Highly resistant and 9= highly susceptible.

Table 3. Genotypes selected from pre-national and national yield trials for their yield and resistance to rust by different research centers.

Center	Selected genotype	Rust reaction (1-9 rating scale) [1]
Sinana	FLIP88-46L	3
	Precoz 7/92-DZ/2	2
	FLIP86-16L	2
Kulumsa	FLIP87-68L	2
	FLIP95-69L	2
	FLIP88-43L	2

[1] 1-9 rating scale, where 1= highly resistant and 9 = highly susceptible (Singh and Sandhu, 1988).

Table 4. Number of local and exotic lentil genotypes screened and selected at Debre Zeit during 1996-2001 cropping seasons.

Cropping season	Number of test genotypes	Number of genotypes selected [1]	Sources of materials[2]
1996/97	120	10	NVRSRP, ICARDA, IBCR
1997/98	52	0	IBCR, ICARDA, NVRSRP
1998/99	80	4	ICARDA, IBCR
1999/00	41	0	ICARDA, IBCR
2000/01	99	3	ICARDA, IBRC

1 = Genotypes showing ≤ 20% mortality, 2 = NVRSRP = Nile Valley and Red Sea Regional Program; IBCR = Institute of Biodiversity Conservation and Research; and ICARDA = International Center for Agricultural Research in Dry Areas.

Table 5. Number of local and exotic chickpea genotypes screened and selected at Debre Zeit during 1996-2001 cropping seasons

Cropping season	Number of test genotypes	Number of genotypes selected[1]	Sources of materials[2]
1996/97	74	10	ICRISAT/ICARDA, IBCR
1997/98	77	0	IBCR, ICRISAT, ICARDA
1998/99	107	4	ICRISAT,IBCR, ICARDA
1999/00	41	2	ICRISAT, ICARDA, IBCR
2000/01	239	25	ICRISAT, ICARDA, IBRC

[1] Genotypes showing ≤ 20% mortality, 2 ICRISAT= International Crops Research Institute for Semi Arid Tropics; IBCR = Institute of Biodiversity Conservation and Research; and ICARDA = International Center for Agricultural Research in Dry Areas.

In Ethiopia, there is preference of the local chickpea from Gondar but these collections were susceptible to wilt/root rots. Hence, there is a need to transfer resistance from exotic sources to the local materials that have good niche market (Etagegn Geremew, personal communication).

The field screening at both Adet and Debre Zeit sick-plots has faced problems in different seasons. Either the soil moisture has been too much that killed all the tested genotypes or the prevalence of extreme dry season due to which the tested genotypes either failed to germinate or showed minimal mortality. From the Nile Valley and Red Sea Regional Wilt/Root rots Screening Nursery, chickpea and lentil genotypes with good levels of resistance in Ethiopia, Egypt and Sudan were identified.

Stunt resistance in chickpea: Multiple resistance to wilt/root rots and stunt disease is important. Chickpea wilt/root rots and stunt diseases screening nurseries were received from ICRISAT but no selections were made due to low level of stunt incidence.

Ascochyta blight of chickpea and lentil: Ascochyta blight of chickpea (*A. rabiei*) was considered less important in the past (Alemu, 1979) but due to weather changes in the country and the shift in planting as well as introductions of chickpea to non-traditional areas, the disease is becoming a threat to its production. Therefore, screening for resistance was done for two seasons (2000-2002). Of the genotypes (Kabuli- and-*desi*-types) tested only three genotypes (FLIP 85-33L, -86-38L and -89-63L) were resistant and possessed desirable characters. All the desi-types were killed. Also, all the elite chickpea genotypes in replicated trials tested at different locations and seasons were evaluated for ascochyta blight resistance and yield, and the resistant ones were selected (Table 6).

Genotypes that gave high yield and were resistant to Ascochyta blight for two consecutive years were selected from the replicated yield trials (Table 7). Two kabuli chickpea cultivars (Shasho and Arerti) were released for large-scale production. Both cultivars are also resistant to wilt/root rots. Most of the *desi* genotypes in the screening nurseries and yield trials were susceptible to Ascochyta blight, and thus more emphasis should be given to Kabuli-types in the short-term until resistant and high yielding *desi* types are available in Ascochyta blight-prone areas.

Grass pea powdery mildew: Genotypes were evaluated in the breeding block for their resistance to powdery mildew. All the genotypes tested were highly susceptible to powdery mildew. However, the local collections with high ODAP contents though showed high severity, the level of yield reduction is minimal compared to the introduced genotypes.

Integrated Disease Management

Even though resistant cultivars with less than 20% mortality are selected and released, pathogens that are not controlled by host plant resistance can cause high mortality and yield losses when conditions favor their development. Because of this problem limited efforts were done to combine host resistance, cultural practices and fungicide seed treatment to minimize wilt/root rots in chickpea.

Table 6. Number of chickpea genotypes selected for resistance to ascochyta blight from yield trials, 1998-2002.

Cropping season	Trial stage[1]	Number of genotypes tested	Number of genotypes selected[2]
1998/99	AYT-Desi	12	0
	PNYT-Desi	18	1
	NYT-Desi	18	0
	PYT-Kabuli	17	7
	NYT-Kabuli	16	7
1999/2000	NYT-Desi	20	1
	PNYT-Desi	16	1
	AYT-Desi	15	2
	NYT-Kabuli	16	9
	PNYT-Kabuli	20	6
	AYT-Kabuli	16	11
2000/2001	NYT-Desi	17	1
	PNYT-Desi	16	0
	NYT-Kabuli	16	4
2001/2002	NYT-Desi	16	0
	NYT-kabuli	13	7

[1] AYT = Advanced yield trial; PNYT= Pre-national yield trial; NYT= National Yield trial; and PYT= Preliminary yield trial, [2] = Highly resistant; and 9= highly susceptible (Singh *et al.*, 1981).

Table 7. Chickpea genotypes resistant to ascochyta blight for two cropping seasons in replicated yield trials

Genotype	Reaction (1-9 rating scale)[1]
FLIP88-42C	1
FLIP93-64C	1
FLIP93-195C	1
FLIP93-22C	1
FLIP93-23C	1
FLIP89-84C	1
FLIP93-55C	1
ICCV93512	3
FLIP90-12C	3
Local checks	9

[1] 1= Highly resistant and 9= highly susceptible (Singh et al., 1981).

Wilt/root rots of chickpea: At Adet Agricultural Research Center (AdARC), the effects of fertilizer (NP), varieties (resistance and susceptible) and fungicide seed treatment were studied in 1996/97 cropping season. The results showed that only the resistant cultivar showed low mortality and the other factors did not show any effect in reducing wilt/root rots (Melkamu and Endaweke, 1998).

At DZARC, the effects of varieties (Mariye, moderately resistant, and JG-62, susceptible), seed bed preparations (broad bed and ridge and furrow), seed rate (120 and 140 kg/ha) and fungicides (Benlate and Apron Star) were studied at three locations (Debre Zeit, Akaki and Ambo) under natural infestation of the plots for two cropping seasons (2000-2002). The studies revealed variable results across locations and years but cultivars, seed-bed preparations and seed rates showed significant effects in reducing wilt/root rots at the three locations and years. However, fungicides did not show any significant effects in reducing diseases (data not shown). The two studies at Adet and Debre Zeit also showed that growing resistant and moderately resistant cultivars on raised beds that drain the excess water with the recommended seeding rate (140 kg/ha) could reduce mortality caused by wilt/ root rots (DZARC and AdARC, unpublished data).

Chickpea stunt: Chickpea stunt disease can cause as high as 30% yield reduction in some fields (Mengistu and Negussie, 1994). Development of wilt/root rots and stunt-resistant genotypes was not successful due to inefficient screening techniques. Thus, attempts were made to study the effects of cultivars (Mariye and DZ-10-4), seeding rate (80 and 120 kg/ha), sowing date (mid-August and mid-September) and sowing method (broad casting and row planting) at Debre Zeit, Akaki and Ambo for two seasons (1999-2001). The incidence of stunt at all the three locations was not more than 20%, and early sowing exhibited high mean levels of stunt incidence (data not shown). Furthermore, early-sowing combined with high seed rate showed low levels of stunt incidence.

FUTURE DIRECTIONS

In the first national conference on cool season food legumes, the crop protection group recommended that more emphases should be given to screening for wilt/root rots of chickpea and lentil, Ascochyta blight of chickpea, race analyses of the wilt causing pathogens, inheritance studies, and surveys of diseases of the five legumes. However, concerted efforts were only made for resistance screening to wilt/root rots of chickpea and lentil as well as Ascochyta blight of chickpea. Surveys were made only for chickpea and lentil diseases. So, the future directions should focus on the following topics:

1. In-depth study on the pathogenic variability of the *Fusarium* spp. causing wilt diseases of lentil and chickpea, pathogen causing rust in lentil, and biological race analyses should be supported by molecular pathotyping.
2. Although major diseases of chickpea and lentil are known, emphasis should be given to know the status of diseases of fenugreek, grass pea and lupine since these crops are given more emphasis in research and development. In addition, more emphasis should be given to manage powdery mildew of fenugreek and grass pea.
3. Multiple disease resistance for foliar and soil-borne diseases should be given priority in the five legumes.
4. Due to unreliability of the onset of the rain in the country, farmers started growing other legume crops such as mungbean, haricot bean, chickpea, fenugreek and lentil in sorghum and maize belts of the lowlands. Since the small rain and the prevailing temperatures favor foliar disease like rust and ascochyta blight, there must be a strategy that addresses this emerging cropping system by developing early-maturing and resistant genotypes to foliar diseases.
5. New agronomic practices like zero tillage should receive greater attention for demonstration to farmers. One of the candidate crops for zero tillage is legumes such as chickpea. As a result, root rot problems in this situation will be emerging problems and efforts should be made to design their control methods.
6. So far, most of the research efforts on chickpea and lentil disease management focused on host plant resistance. There is an urgent need to strengthen the integrated disease management approach.
7. The field screening technique using wilt/root rot sick plots should be supplemented with pot screening since pathogen dynamics change with changes in moisture and temperature during the crop season.
8. Most of the materials in the breeding program are exotic sources. The local land races are susceptible to wilt/ root rots, but have special character for export such as the Gondar-type chickpea. Thus, the exotic resistant sources should be used in germplasm improvement.

9. The role of ODAP in relation to disease susceptibility should be studied in grass pea.
10. Considering a strong interest to introduce sweet lupine, work on its diseases such as powdery mildew and collar rot needs to be initiated.
11. In lentil, the inheritance of resistance to lentil rust should be studied.
12. Development of differentials for lentil rust and fusarium wilt pathogen for characterization should be developed.
13. Ascochyta blight and anthracnose diseases on lentil, though presently minor, need greater attention as they have potential to devastate the existing cultivars. Thus, there is a need to devise a control strategy.
14. Epidemiological studies of the major diseases should be taken up to devise appropriate control methods.

REFERENCES

Abashamo Lencho, Shambel Kumbi, and Wondu Garoma. 2000. Preliminary identification of rust resistant lentil genotypes in southeastern Ethiopia. *NVRSRP Newsletter* 3&4: 5-6.

Ahmed, S., and S. P.S Beniwal. 1998. Survival of *Ascochyta fabae* f. sp. *lentis* on infected lentil seeds. *Lens Newsletter* 22 : 8-10.

Alemu Mengistu. 1979. Food legume diseases in Ethiopia. p. 106-108. *In* G. H. Hawtin and G. J. Chanceller (Eds.) *Food Legume Improvement and Development*. Proc. Workshop held at the University of Aleppo, Aleppo, Syria, 2-7 May 1978. ICARDA, Aleppo, Syria.

ARARI. 2002. Summary of research achievements, 1987-2001. Amhara Regional Agricultural Research Institute (ARARI). 87 pp.

CASC. 2002. The preliminary results of area, production and yield of temporary crops. Part II. Central Agricultural Census Commission (CASC), Addis Ababa, Ethiopia. 502 pp.

Dereje Gorfu. 1994. Diseases of lathyrus in Ethiopia. p. 315-316. *In* Asfaw Telaye et al. (Eds.) *Coo-season Food Legumes of Ethiopia*. Proc. First National Coolseason Food Legumes Review Conference, 16-20, 1993, Addis Ababa, Ethiopia. IAR/ICARDA, Aleppo, Syria.

Dolar, F. S. 1997. Determination of races of *Fusarium oxysporum* f. sp. *ciceris* in Ankara province, *Turkiye*. *J. Turk. Phytopath.* 26: 11-15.

Geletu Bejiga, and Yadeta Anbessa. 1998. 'Alemaya': Self-adjusting lentil variety to different environments in Ethiopia. *NVRSRP Newsletter* 1: 1-4.

Geletu Bejiga, and Yadeta Anbessa. 1999. Development of rust resistant lentil cultivars in Ethiopia. *Lens Newsletter* 26: 33-34.

Kaiser, W. J., R. M. Hannan, and D. M. Weller. 1989. Biological control of seed rot and pre-emergence damping-off of chickpea with fluorescent Pseudomonads. *Soil Biol. Biochem.* 21: 269-273.

Landa, B. B., A. Harves, W. Bettiol, and R. M. Jimenez-Diaz. 1997. Antagonist activity of bacteria from chickpea rhizosphere against *Fusarium oxysporum* f. sp. ciceri. Phytoparasitica 25: 305-318.

Melkamu Ayalew, and Endaweke Wondim. 1998. Evaluation of integrated control measures of chickpea wilt/root rots in Ethiopia. p. 103. *In* Nile Valley and Red Sea Regional Program on Cool Season Food Legumes and Cereals Regional Networks Annual Report 1996/1997. Cairo, Egypt, May 1998.

Mengistu Hulluka, and Negussie Tadesse. 1994. Chickpea and lentil research in Ethiopia. p. 346-366. *In* Asfaw Telaye et al. (Eds.) *Coo-season Food Legumes of Ethiopia*. Proc. First National Coolseason Food Legumes Review Conference, 16-20, 1993, Addis Ababa, Ethiopia.

Negussie Tadesse, and Geletu Bejiga . 1998. Resistance to Fusarium wilt in lentil in Ethiopia. *NVRSRP Newsletter* 1: 6-8.

Negussie Tadesse, Melkamu Ayalew, and Geletu Bejiga. 1998. Survey and identification of major organisms causing wilt and root rots and their relative importance in chickpea and lentil in Ethiopia. p. 89-90. *In* Nile Valley and Red Sea Regional Program on Cool-season Food Legumes and Cereals Regional Networks Annual Report 1996/97. Cairo, Egypt, May, 1998.

Negussie Tadesse, Abdulrazak Yusuf . and K. M, Makkouk. 1999a. Natural occurrence of Beet Western Yellows Polerovirus on chickpea and lentil in Ethiopia. *NVRSRP Newsletter* 2: 32.

Negussie T., Kemal A., Dereje G., Abdurazak, Y., Adane A., Melkamu A., Alemu L., K.M.Makkouk, K.M., and S. G, Kumari, 1999b. Survey of chickpea and lentil viruses in Ethiopia. *Phytopathol. Mediterr.* 39: 149-158.

Singh, K., and T. S. Sandhu. 1988. Screening of cultivars of lentil for resistance to rust. *LENS Newsletter* 15: 28-29.

Singh, K. B., Hawtin, G. C., Nene, Y. L., and M. V. Reddy, 1981. Resistance in chickpea ascochyta blight. *Plant Dis.* 65: 586-587.

Tadesse, N., K. Ali, D. Gorfu, A. Abraham, A. Lencho, A. Yusuf, K. M. Makkouk, and S. G., Kumari. 1999. First report of soybean dwarf virus infecting lentil and chickpea crops in Ethiopia. *Plant Dis.* 83: 589.

Teklu Tesfaye, Fasil Kelemework, Million Eshete, Yadeta Anbessa, and Teklu Erkosa. 2000. A client oriented research (COR) approach to the transfer of an improved lentil production technology. *NVRSRP Newsletter* 3&4: 31-34.

Faba Bean and Field Pea Diseases Research In Ethiopia

Berhanu Bekele[1], Getachew Muhammad [2], Teshome Galano[1] and Temesgen Belayneh[1]

[1] *Ambo Plant Protection Research Center, P.O. Box 37, Ambo, Ethiopia*
[2] *Holetta Agricultural Research Center, P.O. Box 2003, Addis Ababa, Ethiopia*

ABSTRACT

Among production constraints of faba bean and field pea, diseases caused by biotic agents (fungi, bacteria and nematodes) take a considerable share in reducing yield. In earlier reviews, more than 20 faba bean and 24 field pea diseases were reported to occur in the major growing areas of Ethiopia. The distribution and economic importance of these diseases were studied, and the major ones were identified and prioritized for research. Chocolate spot, rust and black root rot on faba bean, and Ascochyta blight, powdery mildew and foot root rot on field pea were, and still are, the most important diseases. This paper reviews current status of faba bean and field pea diseases research in Ethiopia, with particular emphasis on the epidemiology, biological control, and integrated disease management. Recent progress in survey and identification of virus diseases of faba bean and field pea is summarized. Priority areas for research and future directions are also indicated.

INTRODUCTION

Faba bean (*Vicia faba* L.) and field pea (*Pisum sativum* L.) are, in order of importance, the most predominantly grown food legumes in Ethiopia (FAO, 1998). These cool-season food legumes constitute an essential part in the daily diet of the Ethiopian population. However, yield of these crops are by far below the world average. The low yield of faba bean and field pea are mainly attributed to several biotic and abiotic stresses, among which diseases caused by biotic agents take a considerable share (Amare and Beniwal, 1988; Habtu and Dereje, 1986).

Earlier, the status of faba bean and field pea diseases from the formal inception of the legumes disease research up to 1985 was reviewed by Habtu and Dereje (1986). In this review, nine field pea and seven faba bean diseases were reported to occur in Ethiopia. Subsequent progress and research achievements on faba bean and field pea diseases were reported in a more comprehensive review made in 1993 (Dereje and Tesfaye, 1994a, b). During the second review, however, new fungal pathogens/diseases were recorded; these were 11 on field pea and 10 on faba bean. Besides, both in faba bean and field pea, four nematode diseases were reported as new records in the country.

Since 1993 till now, no new disease occurrence/records on faba bean and field pea and no shift in importance (of the already known diseases) have been reported. Thus, Aschochyta blight (*Mycosphaerella pinodes*), powdery mildew (*Erisiphe pisi*) and foot root rot (*Fusarium solani* f. sp. *pisi*) on field pea; chocolate spot (*Botrytis fabae*), rust (*Uromyces vicia-fabae*) and black root rot (*Fusarium solani*) on faba bean are still the most important and predominant diseases. Foot rot caused by *Fusarium avenaceum* has become important disease of faba bean since the past few years mainly around Holetta, Selale, Mota, and Adet. In this paper, therefore, achievements made on fungal diseases of faba bean and field pea over the last 10 years (1994-2003) is reported. Research results on biological control, epidemiological studies and integrated control measures suggested for the most important diseases are thoroughly discussed. Recent advances made and achievements scored in survey and identification of viruses infecting faba bean and field pea are included. Future research priority areas and directions are also indicated.

FABA BEAN DISEASES

1. Chocolate Spot (Botrytis fabae):

Epidemiology

Weather elements and epidemic development: Dereje (1993) determined infection rate by *B. fabae* on faba bean in a field study at Denbi, Holetta and Kulumsa. Mean minimum values of 0.164, 0.146 and 0.142 and maximum of 0.42, 0.50 and 0.54 disease units per day were reported at Denbi, Holetta and Kulumsa, respectively, which were described as a character of explosive epidemic that could lead to several epidemic occurrences before the end of the growing season. Most important weather elements for chocolate spot epidemic development were identified, and significant positive correlations between infection rate (r) and number of rainy days, duration of temperature between 10 and 23°C and relative humidity 70%+ at Holetta and 85%+ at Kulumsa were reported. In combined analysis, however, only number of rainy days and morning relative humidity had significant correlation with the infection rate.

Sowing date and epidemic development: Dereje (1993) also observed delayed disease and epidemic onset by delaying sowing date. Late-sowing also appeared to shorten epidemic period. After disease onset, the epidemic began after 10 days at Denbi, 12 days at Holetta, and 17 days at Kulumsa. Epidemic period was also shortest in the late-sown crops. The span of epidemic was 16-20 at Denbi, 18-22 at Holetta and 17-23 days at Kulumsa.

Cultivar and epidemic development: There were no differences between cultivars in chocolate spot epidemic development of the three varieties: NC-58, Local-H, and CS 20 DK that are early-, late- and intermediate-maturing types, respectively (Dereje, 1993).; Similar results were reported by others (Greenwood, 1959; Hughes and Roebuck, 1969). In contrast, Harrison (1981) found highly significant differences in chocolate spot severity when 12 faba bean varieties became naturally infected in the field. He also found highly significant differences in rates of lesion expansion after leaves of these same varieties from glasshouse grown plants were inoculated with conidia of *B. fabae* in a laboratory test.

Dereje (1993) concluded that effect of chocolate spot on faba bean grain yield progressively increased with early-sowing. However, early-sowing also increased the overall yield. He recommended the use of resistant varieties or control of the disease with fungicide to increase the grain yield of early-sown faba bean.

***Survival of B. fabae*:** Information regarding life cycle of a pathogen is an important strategy for successful and economical control. Survival in the absence of the appropriate host is one important phase in the life cycle of pathogenic fungi. Sclerotia, conidia, microconidia and mycelium all serve as perennating structures for *B. fabae*. However, sclerotia are the main survival structures (Harrison, 1988), which are highly resistant to adverse conditions. They can be found embedded in the walls of dead bean stems and after harvest, pieces of plant debris bearing sclerotia either remain on the surface of the ground or become buried in the soil. However, survival of *B. fabae* is significantly reduced when infected plant debris is buried (Dereje, 1999). He observed that sclerotia of *B. fabae* survived for more than a year under Holetta conditions on the surface of the ground, and died in four months when buried 20 cm deep. The pathogen did not survive outdoors more than two years. According to the same report, soil types also affected survival of sclerotia. The author could not recover *B. fabae* when samples were stored in Vertisols but recovery was possible after 12 months from Nitosols. He recommended deep plowing of faba bean fields with high chocolate spot infection immediately after harvest to reduce the risk of epidemic development.

***Population dynamics, pathogen variation and host resistance*:** One of the most dynamic and significant aspects of fungal pathogens is that the characteristics of individuals within a species are not fixed, and vary from individual to individual. *B. fabae* is not an exception. Dereje (1996a) reported that cultural and pathogenic variability existed among isolates of *B. fabae* collected from agro-ecologically different areas. According to the report, the most virulent isolate was collected from Inewari. The author also observed special interaction of isolates from Inewari, Kulumsa and Holetta with host genotypes Kuse and S83103-1-1 that suggested a gene-to-gene interaction. Based on the results, it was recommended that breeding and selection programs should utilize as many virulent isolates as possible from different regions. Also reported was preference of artificial media by individual isolates of the pathogen (Dereje, 1996a). Among the media used, faba bean dextrose agar (FBDA) was found as the most suitable for laboratory propagation of the fungus. On such media, however, *B. fabae* produced only sclerotia and very few conidia.

Control Measures

***Cultural*:** In many faba bean production areas of Ethiopia, faba bean and field pea are grown in mixture for weed suppression and physical support of field pea by faba bean. The major advantage, however, was found to be suppression of foliar diseases. Other advantages recognized included higher seed yield and increased land productivity (Dereje, 2000). The study revealed that by mixed cropping of faba bean with field pea, epidemic development of chocolate spot in faba bean could be significantly reduced. Final chocolate spot score decreased, on an average, from 66.5 to 55.8% as the proportion of faba bean plants decreased from 100 to 33% in the mixture.

Integrated disease management: Dereje (2000) reported that early-sowing, use of improved cultivars and fungicide protection (Chlorothalonil at a rate of 2.5 kg a.i./ha once or twice after disease infection reaches 30%) had synergetic effect to avoid epidemic occurrence of chocolate spot disease and increase seed yield of faba bean. The experiment was carried out at Holetta and Denbi, where high level of disease development naturally occurs year after year.

2. Fusarium Foot Rot:

Identification and Occurrence

Yitbarek (1983) was the first to report foot rot disease, which is caused by *Fusarium avenaceum* (Fr.) Sacc., on faba bean in Ethiopia. The disease was first observed at Holetta Agricultural Research Center (HARC) and at Quiha and Kokate experimental sites (Dereje, 1994). He also reported gradual build-up of the disease at Holetta since 1981. Foot rot disease affects faba bean plants at the stem base, from the ground level to about one-third of the plant height (Dereje, 1994). Obvious symptoms are wilting, premature death, lodging and stem breakage. Most of the severely infected plants donot produce any seeds.

Importance

Effects of foot rot on yield depend on the severity of the disease. Dereje (1994) observed that in the 1993 crop season, when the disease reached epidemic proportion at Holetta, local genotypes failed to yield. According to the same report, some specific environmental conditions, mainly high rainfall in August, favor the disease development. Based on a yield loss study using single-tiller technique, a mean yield loss ranging from 34 to 91%, depending on severity of the disease, was reported (Dereje, 1994). Occurrence of the disease seems to be affected by soil type. This disease was severe at Holetta, Selale, Mota, and Adet only on red clay soils with very low pH, usually less than 5.0 (Dereje, unpublished).

Effect on Plant Stand Establishment

Germination percentage, germination energy and seed size affect plant stand establishment and seedling vigor of plants. Dereje (1996b) reported that *F.*

avenaceum, the cause of foot rot of faba bean, severely affected the seed size. Infection by this fungus also affects germination percentage and energy. The results showed that germination percentage dropped to 77%, germination energy to 65%, and emergence to 45%, when seeds from foot rot-infected plants were used. Emergence was also delayed for the same reasons. However, a delayed emergence was observed only when seeds from severely infected plants were used. Thus, it was concluded that foot rot mainly affected the plant stand establishment of faba bean for which an increased seed rate was recommend if one was forced to use seeds from severely infected plants.

Control Measures

Cultural method: In a host-range study, *Brassica* sp. was not found to be infected by *F. avenaceum* and, therefore, rotation of faba bean with this crop was suggested to control the disease by reducing initial inoculum levels (HARC 1995). Destroying volunteer faba bean seedlings and weeds such as Setaria, Phalaris, Cayluses, Polygonum, Spergolla, and Avena, which may harbor *F. avenaceum*, could also help reduce the early build up of the inoculum.

3. Rust:

Importance

Although rust is widely distributed in Ethiopia, it is economically important only in lower and intermediate altitudes (<2300 m asl) and off-season crops (Dereje and Tesfaye, 1994b). After a three-year field experiment at Denbi, the results showed that rust was not a major problem in faba bean production in and around Denbi, where natural conditions favor epidemic development of the disease (HARC, 2000). Generally, rust comes late in the season and has no significant effect in the highland areas of the country.

Control Measures

When faba bean is grown during off-season or in lower and intermediate altitude areas, it may be necessary to control rust disease. Generally, prevention of rust is difficult because the spores can be carried long distances by wind to infect crops far away from the initial source of infection. Burning or burial of old bean stubble and crop rotation can reduce the risk of the disease. Growing resistant varieties and fungicides may be used to control the disease and prevent a rust epidemic. In areas where the disease is prevalent, several sprays will be necessary for adequate disease control. Spraying Mancozeb (Dithane M-45) at the rate of 2.5 kg a.i./ha at weekly intervals can provide good control of rust. The protection should start at about 5% infection. The spraying is beneficial when the crop is at flowering or at early pod-setting. Late grain-filling stage is not affected by rust (HARC, 2000).

4. Root Rots:

Survey and Identification

Surveys made to faba bean growing regions in different years showed that root rots had varying importance. The average root rot incidence in the samples from the communes of the prefectures of the Jirru region was 75 %, in Garba Gurracha 40 %, in Fiche 65 %, in Debre Tsige 33 %, and in Goha Tsion 55 % (PPRC, 1994). The fungi associated with root rots were: *Fusarium solani*, *Rhizoctonia* spp., *Pythium* spp. and to a lesser extent *Sclerotium rolfsii*. These fungi were also identified in a survey by PPRC (1998) (Table 1). However, the most widely occurring fungal pathogens were *Fusarium solani* and *Rhizoctonia* spp.

Table 1. Visual evaluations of the incidence of root rot in the potential faba bean growing areas in north Ethiopia, 1997.

Location	Altitude (m asl)	Mortality (%)
North Shoa		
Debre Berhan	2400-3100	25-45
Debre Sina	1950-2600	15-30
North Wello		
Woldia	1650-2400	10-15
Sirinka	1800-2000	10-20
Haik	1700-2100	5-10
South Wello		
Gerado	1450-2100	25-38
Tigrai		
Ambalage	2200-2600	10-37

Source: PPRC (1998).

5. Black Root Rot:

Economic Importance

Black root rot, which is caused by *F. solani*, is the second most important disease and is exclusively found in black clay soils (Vertisols), where water-logging, is severe. A complete crop loss may happen in favorable conditions. When the infection starts, the whole plant becomes yellowish in color and then roots disintegrate. The affected plants can be easily pulled out, and the black discoloration of the whole root system is observed. Death of the plant follows severe rotting.

In a study done in the greenhouse (PPRC, 1996b), faba bean plants (variety CS-20 DK) grown in F. solani-inoculated (non-protected) plots indicated 87 % mortality, whereas the control showed 10 % mortality at podding (Table 2). Nevertheless, a yield loss of about 45 % was estimated to have occurred in farmers' fields due to wilt/root rot in faba bean (PPRC, 1996b).

Table 2. Studies on losses due to black root rot in faba bean in the greenhouse.

Treatment	Disease incidence (%)			
	Seedling	Flowering	Podding	Mean
Protected	5	7	10	7.33
Non-protected	25	45	87	52.33

Source: PPRC (1996b).

Control Measures

Cultural: Planting crops that are not colonized by the faba bean isolate of F.solani in rotation with faba bean reduces the inoculum level in the soil. In a pot experiment, plants inoculated with *F. solani* showed that *noug* (*Guizotia abyssinica*), rapeseed (*Brassica olerace*) and linseed (*Linum usitatissimum*) were not infected by the pathogen (PPRC, 1998). The same investigation, on the contrary, revealed that lentil (*Lens esculentus*), haricot bean (*Phaseolus vulgaris*), field pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and cowpea (*Vigna unguiculata*) were infected by *F. solani*. However, only the *F. solani* isolates from field pea, chickpea, haricot bean and lentil were found to be pathogenic to faba bean. Repeated pathogenicity tests with chickpea, field pea and lentil confirmed that the roots of these crops were colonized by the faba bean isolate of *F. solani* Crop rotation and proper drainage of faba bean fields are advisable (Dereje and Tesfaye, 1994b).

Biological: Experimental results (PPRC, 1996a) demonstrated that faba bean seeds grown in soils treated with *Trichoderma viride* were protected from infection by *F. solani* under greenhouse conditions, implying the potential of *T. viride* as a biocontrol agent to inhibit the fungus (Table 3). The radial growth of *F. solani* on potato-dextrose-agar (PDA) was reduced when mixed with the culture filtrate of *T. viride* (PPRC, 1996a).

Host plant resistance: The search for host plant resistance has also shown promising results. A number of faba bean varieties were tested for black root rot resistance in a sick-plot at Ambo, and several resistant genotypes were identified as resistant. The results are summarized in Tables 4 and 5. Recently, varieties that perform better under waterlogged conditions have been released. Varieties Wayu and Salale Kasim have been released nationally by HARC and two other varieties (Girar Jarso 89-8 and Salale Kasim 89-1) have been released for north Shoa areas (Oromiya region), where this disease is severe. Two additional resistant faba bean varieties (Lalo and Dagim) were released by Sheno Agricultural Research Center (ShARC) for north Shoa areas of the Amhara region.

Integrated pest management: An experiment integrating varieties, improved drainage system and seed rates were conducted to minimize root rot damage in faba bean (PPRC, 2003). The results obtained indicated that there was no significant variation in the seedling stage disease incidence for the separate effect of treatments, and also for the combination of two or three of the treatments. But at flowering stage, disease incidence revealed significant differences for the separate effect of variety and seed rate treatments.

Table 3. Influence of Trichoderma viride on the mortality (%) of seedlings of faba bean caused by Fusarium solani.

Treatment	Pre-emergence Mortality		Post-emergence Mortality		Total emergence Mortality	
	Sterlized	Non-sterlized	Sterlized	Non-sterlized	Sterlized	Non-sterlized
Control with-out inoculum	0	9.2	2.6	4.6	2.6	13.8
Control with inoculum	44.0	43.5	33.1	34.7	77.1	78.2
T. viride with seed & soil inoculation	4.6	3.1	9.6	12.5	14.2	15.6
T.viride in soil & soil ino-culation	3.9	4.8	8.4	5.9	12.3	10.7

Source: PPRC(1995a, 1996a).

Table 4. Results of screening of faba bean cultivars for faba bean black root rot disease.

Year	Number of faba bean varieties tested	Resistant varieties	Suceptible varieties	Remarks
1994/95	208	82	126	26 of the 82 were highly resistant (8-10% mortality)
1995/96	222	72		3-20.7% mortality
1996/97	369	21		4.8-27.6% mortality
1997/98	300	45		
2002/03	72	13		6.67-20% mortality

Source: PPRC (1995b, 1996b, 1997, 1998, 2003).

Table 5. Faba bean lines resistant to *F. solani*.

Year	Resistant lines	Remarks
1994/95	Salale Kasim 89-5-2-1, Coll 13/94, 12/94	0 incidence
	Taltalle 89-8, Salale Tuli 90-1, Bichena 86, Bichena 86-2-2	Highly resistant (8-10% mortality)
	PGRC/E acc. no. 27302, Salale Tuli 90-5, Wayyu 89-36, Wayyu 89-12, Coll 17/94	Moderately resistant (11-20 % mortality)
1995/96	CS-20 DK, Salale Kasim 91-9, Kuse, Girar Jarso 89-2, NC-58, Coll 27/94, Coll 34/94, Coll 36/94, Coll 37/94, Coll 39/94, Coll 40/94, Coll 41/94, Coll 42/94, Coll 43/94, Coll 44/94, Coll 45/94, Coll 49/94, Coll 53/94, Coll 54/94, Coll 57/94, Coll 60/94, Coll 61/94, Coll 62/94, Coll 63/94, Coll 65/94, Coll 66/94, Coll 67/94, Coll 72/94, Coll 73/94, Coll 76/94, Coll 79/94, Coll 83/94, Coll 87/94, Coll 94/94, Coll 100/94, Coll 102/94, Coll 104/94, Coll 106/94, Coll 107/94	Resistant at several locations Coll 40/94, Coll 41/94, Coll 42/94, Coll 54/94, Coll 57/94, Coll 72/94, Coll 73/94, Coll 100/94 manifested high resistance (3.3- 10 %) to wilt/root rot in Ambo, Inewari, & Debre Tsigge
1997/98	Bichena 86-1, Bichena 86-3	Resistant at several locations Have additional resistance to wilt
	Eth 86-120-2	Resistant at several locations
2002/03	TFb 115, TFb 176, TFb 231, TFb 310, MFb 110, TFb 328, TFb 195, FB-Coll 234/00, FB-Coll 232/00, FB-Coll 239/00, FB-230/00, TFb 330, TFb 116	TFb 115, TFb 176 & TFb 231 exhibited 6.67-10 % mortality

Source: PPRC. (1995b, 1996b, 1998, 2003).

6. Virus Diseases:

Survey

A comprehensive and systematic survey was conducted in 1996 and 1997 main seasons to assess the status of virus diseases affecting faba bean in its major growing areas. In 1996, a total of 176 fields in 44 districts were covered. In 1997, 35 fields were inspected (Adane et al., 2000). Commonly observed virus disease symptoms included leaf yellowing, rolling, necrosis and stunting (Adane et al., 2000). Virus incidence based on visual estimation ranged from 0-85%. However, there was a wide variation in virus occurrence and incidence in different areas across the country.

Laboratory tests showed that at least one virus was detected in 86 out of the 176 fields in 1996, and no virus was detected in the remaining 90 fields (Adane et al., 2000). In this study, of the 3049 symptomatic samples collected from 211 fields from all over Ethiopia, 176 in 1996 and 35 in 1997 survey were tested by the tissue blot immunoassay (TBIA) for 14 legume viruses. A total of 1592 samples (52.2%) were positive for at least one virus. Among the infected samples, faba bean necrotic yellows virus (FBNYV) was the most frequent virus (63.2%), followed by the luteoviruses (28.5%), indicating that these viruses are the most important on faba bean in Ethiopia. There was also variation in the incidence of FBNYV and the luteoviruses in different geographical areas. FBNYV seemed to be more frequent in northeastern and southeastern Ethiopia, while the luteoviruses were more common in central Ethiopia, particularly in the Shoa region. The yellowing, rolling and stunting symptoms observed at a high rate in the Wello and Ankober region of north Shoa and in the Asassa areas of Arsi were confirmed by laboratory testing to be exclusively caused by FBNYV.

Some of the samples that were positive with the broad-spectrum legume luteovirus monoclonal antiserum (5G4) were tested with polyclonal antibody against BWYV and BLRV and were found positive to one, or both. However, since the BWYV polyclonal antiserum used is known to cross-react with a large number of luteoviruses, the exact identity of these viruses needs to be confirmed using specific monoclonals. Accordingly, in this study, the luteoviruses are reported as a group. CCDV was also detected in some (3%) of the samples with yellowing, rolling, stunting and necrosis symptoms. Mosaic/mottle symptoms, although observed in many fields were found to be present at only a very low rate (< 1%). In such samples, BYMV, PSbMV, BBSV and BBTMV were identified. From all virus-infected samples, only 3.1% were shown to host one of these viruses. No virus was identified in nearly half (47.8%) of symptomatic samples tested, suggesting that either some viruses were undetected by the antisera used or that the symptoms were caused by factors other than viruses.

FIELD PEA DISEASES

1. Ascochyta blight:

Importance

Ascochyta blight is the major disease that causes blighting/spotting in field pea mainly in the wetter parts of the country. Blight infection as high as 85% was reported around Denbi with a mean infection of 18.7% for all areas surveyed (HARC, 1995). *Ascochyta pinodes* [teleomorph *Mycosphaerella pinodes* (Berk. and Blox.)] is important from the *Ascochyta spp.* that causes blighting/spotting disease of field pea in Ethiopia (HARC, 1995, 2002). Severe infection of Ascochyta blight causes significant yield reduction (Dereje, 2000). The mean seed yield reduction from 1.68 to 1.31 t/ha as final disease score increased from 14 to 66% was reported by Dereje (2000). The disease affected pod set and seed size more than any other yield components.

Disease Cycle and Epidemiology

The fungus survives as sclerotia (thickened mycelia), chlamydospores and pycnidia on straw fragments and in the soil (Lawyer, 1984). It colonizes pea straw on the surface and in the soil, and competes well as a saprophyte with other soil microflora. When temperatures are above freezing and sufficient moisture is available, old pycnidia mature and new pycnidia, perithecia develop, and their spores are released. The fungus is seed-borne. During wet weather, spores produced on the infected plants are transferred onto healthy plants by wind and rain splash. Early-sowing increases the likelihood of disease unless protection with chemical is planned.

Control Measures

Cultural: In many field pea-producing areas of Ethiopia, faba bean and field pea are grown in mixed cropping for weed suppression and physical support of field pea by faba bean. The major advantage, however, is suppression of foliar diseases (Dereje, 2000). Other advantages include higher grain yield and increased land productivity. Dereje (2000) reported the importance of mixed cropping of faba bean and field pea to control Ascochyta blight disease of field pea. After a three-year study at Holetta, the lowest disease pressure and maximum yield were obtained from a 2:1 faba bean to field pea mixture. Final disease score dropped from 93 to 70% as field pea proportion in the mixed cropping decreased from 100 to 32%.

Use of clean seed is also advisable, as infected seeds are important source of inoculum. In the absence of seed treatment however, seed should be held over at least for one year when known to be severely infected (Lawyer, 1984). Pea refuse should be disked and plowed under immediately after harvest before the fungus can be generally dispersed by wind and rain.

Host resistance: There was no single genotype with high level of resistance against black spot caused by *Mycosphaerella pinodes* after testing over 800 accessions (HARC, 2000). Ali Khan et al. (1974) screened 1200 introductions of peas from diverse origins, and none showed a high level of resistance, while 18 showed moderate resistance. Similarly, Ali et al. (1978) found only partial resistance in a screening of 155 diverse lines in Australia. Denbi has been suggested as a hot spot for Ascochyta blight disease, where the natural infection of the disease was reported to be as high as 85% (HARC, 1995). However, even when severely infected with *M. pinodes*, some cultivars yielded well in the presence of the disease, whereas others with an apparently equal level of infection produced poorly. Such differences in tolerance have been of practical value. Most existing cultivars are tolerant to the disease, and provide reasonable yield under heavy disease pressure.

Chemical: Fungicides Bravo 500, Benlate, Thiophanylmethyl and Redomyl control Ascochyta blight disease in field pea and increase seed yield (HARC, 1995). Chlorothalonil and metalaxyl should be sprayed at a rate of 2.5 kg a.i./ha and 1 kg a.i./ha , respectively. The report further recommended that the spraying should be done if the weather in the coming two weeks was expected to be wet and warm and when the crop is before or at flowering stages. Beyond this crop stage, the yield increase due to protection is very low. Seed treatment with flowable formulations of captan or thiram provides good seed coverage and protection (Lawyer, 1984).

2. Powdery Mildew:
Importance

Powdery mildew is the second most important disease of field pea in terms of distribution and damage to the crop (Dereje and Tesfaye, 1994a; HARC, 1995, 2002). Infected plants are covered with a white powdery film and severely affected foliage looks blue-white. Tissue below these infected areas may be purplish. In the heavily infected crop, clouds of spores can be shaken from the plants. The leaves, stems and pods may all become infected causing the whole plant to wither. Severe pod infection can result in a gray-brown discoloration of the seeds. These seeds may have an objectionable flavor that reduces the quality of the grain.

Control Measures

Powdery mildew is most damaging late in the season when dew formation is common, so early-sowing and/or harvesting may reduce effect of the disease. There are reports of major gene resistance to powdery mildew disease. In Ethiopia, however, there is little success in resistance breeding to this disease in spite of the fact that there is potential to achieve complete resistance from the immense gene pool. Preliminary reports indicated the possibility of achieving genotypes with such resistance to the disease from local and international collections (Dereje and Tesfaye, 1994a). Spraying benomyl at a rate of 2 kg a.i./ha every two weeks controls powdery mildew. The spraying should start when infection reaches about 5%.

3. Root Rot/Wilt Disease:
Importance

Root rot and wilt diseases are caused respectively by *F. solani* and *F. oxysporum*. Until recently, root rot disease was more common on field pea than wilt disease in Ethiopia. Dereje and Tesfaye (1994a) reported 70% mortality of field pea at Ghinchi, Inewari and Bichena due to root rot disease. Fusarium root rot is common early in the season on heavy black soil. In such cases, patchy fields are common when the disease is more serious resulting in poor stand and low yield. A recent survey in some parts of central Ethiopia to monitor disease situation indicated, however, that Fusarium wilt was also becoming important disease (HARC, 2002). As high as 75% incidence has been observed in some places of Wolmera, and Dagem with an overall average incidence of 15%. Unlike Fusarium root rot, wilt disease has been observed on any type of soils.

Control Measures

Biological: PPRC (1995a) have come up with similar results as in faba bean black root rot fungus (*F. solani*) by applying *T. viride* culture filtrate on growth media, which protected field pea infection by *F. oxysporum* (a root rot causing fungus in field pea).

Host resistance: Testing pea cultivars for resistance to *F. oxysporum* in the greenhouse using artificial inoculations and under field conditions indicated the resistance of Acc. No. 832781, 032801, 173/77 and 48/73 to the fungus in both environments (PPRC, 1995b).

4. Seed-Transmitted Viruses in Pea:
Survey

The incidence of seed-transmitted viruses was determined in 219 pea seed samples collected in 1998 and 1999 from farmers seed lots in central (Shoa and Arsi regions) and northern Ethiopia (Gojam, Gonder, and Wello region). The samples were tested by the tissue blot immunoassay (TBIA) (Makkouk and Comeau, 1994) for five seed-borne viruses reported to be seed-borne in pea: PSbMV, PEBV, BYMV, CMV and AMV, by using polyclonal antibodies produced against the respective viruses.

Serological (TBIA) results have shown that of the 219 pea seed samples tested for five seed-borne viruses, the great majority (212 out of 219) were found not to be infected with any of the viruses (Adane et al., 2000). Only seven samples were found to be infected with either BYMV or PEMV, both at very low rate. PSbMV, AMV and CMV were not detected in any of the samples tested. PSbMV incidence was also very low in pea germplasm resources. This result indicated that the incidence of seed-borne viruses in pea seeds grown by farmers was extremely low.

FUTURE RESEARCH DIRECTIONS

Future research on diseases of faba bean and field pea will focus on the following:

1. Survey will concentrate on quantitative observation in order to map the relative distribution and importance of faba bean and field pea diseases in different agro-ecological zones.
2. Search for resistance genes should continue for major diseases.
3. *Trichoderma viride* must be mass-produced and tested in farmers' fields where the incidence of *Fusarium solani* and *Fusarium oxysporum* are high.
4. Integrated root rot disease management should combine *T. viride*, host resistance and cultural control options to overcome the problems of *F. solani* and *F. oxysporum*.
5. Detailed surveys to monitor changes in virus incidence should be continued.
6. Proper field and laboratory screening techniques for powdery mildew and aschochyta diseases need also be established.

REFERENCES

Adane Abraham, Khalid M. Makkouk, Dereje Gorfu, Abashamo G. Lencho, Kemal Ali, Nigussie Tadesse, and Abdurazak Yusuf .2000. Survey of faba bean (*Vicia faba*) virus diseases in Ethiopia. *Phytopathol. Mediterr.* 39: 277-282.

Ali Khan, S.T., R.C. Zimmer, , and E.O. Kenaschuk. 1974. Reaction of pea introductions to *Ascochyta* foot rot and powdery mildew. *Canadian Plant Disease Survey* 53: 155-156.

Ali, S.M., L.F. Nitschke, A.J. Dube, M.R.Krause, and B. Cameron. 1978. Selection of pea lines for resistance to pathotypes of *Ascochyta pinodes, Ascochyta pisi,* and *Phoma medicaginis* var. *pinodella. Aust. J. Agric. Res.* 29: 841-849.

Amare Gizaw, and S.P.S. Beniwal. 1988. Faba bean and field pea research in Ethiopia: Development, achievements and future strategies. p. 189-228. *In* Proc. 19th National Crop Improvement Conference, 22-26 April 1987, IAR, Addis Ababa.

Dereje Gorfu. 1993. Studies in the epidemiology of chocolate spot (*Botrytis fabae* Sard.) of faba bean (*Vicia faba* L.). M. Sc. Thesis. Alemaya University of Agriculture.

Dereje Gorfu. 1994. Foot rot disease of faba bean in Ethiopia. *FABIS Newsletter* 34/35: 27-28.

Dereje Gorfu .1996a. Morphological, cultural and pathogenic variability among nine isolates of *Botrytis fabae* from Ethiopia. *FABIS Newsletter* 38/39: 37-41.

Dereje Gorfu.1996b. Effect of foot rot on faba bean. *Seed Sci. and Technol.* 25: 19-23.

Dereje Gorfu. 1999. Effects of mixed cropping of faba bean and field pea on disease development and yield. *Pest Management J. Ethiopia* 3(1&2): 61-67.

Dereje Gorfu. 2000. Yield loss of field pea due to Ascochyta blight in central Ethiopia. *Pest Management J. Ethiopia* 4 (1&2): 89-95.

Dereje Gorfu, and Tesfaye Beshir. 1994a. Field pea diseases in Ethiopia. p. 317-327. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia.

Dereje Gorfu, and Tesfaye Beshir. 1994b. Faba bean diseases in Ethiopia. p. 328-345. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia.* Proc. First National Coolseason Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia.

FAO. 1998. Production Yearbook. Rome, Italy, Volume 52. 96p.

Greenwood, N.H. 1959. Investigation into field beans at the National Institute of Agricultural Botany. *J. Royal Agricultural Society England* 120: 70-77.

Habtu Asefa, and Dereje Gorfu. 1986. Review of pulse disease research in Ethiopia. p. 347-401. *In* Tsedeke Abate (Ed.) *A Review of Crop Protection Research in Ethiopia.* Proc. First Ethiopian Crop Protection Symposium, 4-7 Feb. 1985, Addis Ababa, IAR, Ethiopia.

Harrison, J.G .1981. A laboratory technique for estimating the susceptibility of bean cultivars and its relation to disease in the field. *Annals Appl. Biol. Supplement, Tests of Agrochemicals and Cultivars* 2: 72-73.

Harrison, J.G. 1988. The biology of *Botrytis spp.* on Vicia beans and chocolate spot disease – a review. *Plant Pathology* 37: 168-201.

HARC. 1995. Research progress report. Plant Pathology Section, Holetta Agricultural Research Center (HARC), Holetta.

HARC. 2000. Field pea pathology research progress report. Holetta Agricultural Research Center (HARC), Holetta.

HARC. 2002. Faba bean and field pea pathology research progress report. Holetta Agricultural Research Center (HARC), Holetta.

Hughes, R.G., and J.F. Roebuck. 1969. Experiments, studies and surveys in arable crop production - southeast, 1968. p. 86-102. Her Majesty's Stationery Office, London.

Lawyer, A.S. 1984. Foliar diseases caused by fungi: Diseases caused by *Ascochyta* spp. *In* D.J. Hegdorn (Ed.) *Compendium of Pea Diseases.* The American Phytopathological Society. St. Paul, Minnesota.

Makkouk, K. M., and A. Comeau. 1994. Evaluation of various methods for the detection of barley yellow dwarf virus by the tissue-blot immunoassay and its use for virus detection in cereals inoculated at different growth stages. *European J. Plant Pathol.* 100: 71-80.

PPRC. 1994. Progress report for the period 1993/94. Plant Protection Research Center (PPRC), Ambo.

PPRC. 1995a. Evaluation of *Trichoderma* spp. for biological control of root rot caused by *Fusarium* spp. on field pea. p. 23-25. Progress report 1994/95. Plant Protection Research Center (PPRC), Ambo.

PPRC. 1995b. Progress report for the period 1994/95. Plant Protection Research Center (PPRC), Ambo.

PPRC. 1996a. Evaluation of the potential of *Trichoderma viride* in the biological control of root rot disease of faba bean. p. 11-13. Progress report 1995/96. Plant Protection Research Center (PPRC), Ambo.

PPRC. 1996b. Progress report for the period 1995/96. Plant Protection Research Center (PPRC), Ambo.

PPRC. 1997. Progress report for the period 1996/97. Plant Protection Research Center (PPRC), Ambo.

PPRC. 1998. Progress report for the period 1997/98. Plant Protection Research Center (PPRC), Ambo.

PPRC. 2003. Progress report for the period 2002/2003. Plant Protection Research Center (PPRC), Ambo.

Yitbarek Simaene. 1983. Build up of wilt on faba bean (*Vicia fabae*). *EPC Newsletter* 21: 3-4.

Lowland Pulses Disease Research in Ethiopia

Abiy Tilahun [1], Fekede Abebe [2] and Chemeda Fininsa [3]

[1]Ethiopian Agricultural Research Organization, P.O. Box 436, Nazareth, Ethiopia, [2]Bako Agricultural Research Center, P.O. Box 03,Bako, Ehtiopia, [3]Alemaya University, P.O. Box: 138, Dire Dawa, Ethiopia

ABSTRACT

Lowland pulses are important components of crop production systems in Ethiopia. This article reviews the status of the lowland pulse diseases research with a major emphasis on the achievements. Field surveys were conducted in the major bean growing areas of Ethiopia. Differences in disease severity between regions and seasons, cropping systems and diseases were characterized. Six fungal and two bacterial diseases are the major biotic production constraints in the common bean growing areas of the country. Bean cultivars were studied for components of partial resistance to an isolate of bean rust. The components included latent period, infectious period, infection efficiency, sporulation capacity and pustule size. Partial resistance of haricot bean genotypes to bean rust was studied and sources of host plant partial resistance were identified. The radial expansion of rust foci in mixtures of susceptible and resistant bean cultivars was studied at two sites. Actual yield losses due to rust (85%), anthracnose (67%) and common bacterial blight (CBB) (21%) were quantified on susceptible varieties. Research was also focused on identifying appropriate cultural practices, screening of effective fungicides, studying physiological races and multiple disease resistance varieties. Lower (< 25%) rust and CBB intensities were found associated with intercropping systems than with sole cropping. Promising results (reduced disease level and slowed disease progress rate) were obtained in intercropping and varietal mixtures as components for common bean integrated disease management (IDM). Need to integrate all relevant disciplines (agronomists, breeders, economists, entomologists, pathologists) is emphasized for proper management of diseases of lowland pulses.

INTRODUCTION

Lowland pulses including common bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna unguiculata* L. Walp.) constitute an important component of crop production system in Ethiopia. They are important components in various intercropping systems in eastern, southern, and southwestern parts of Ethiopia (Habtu et al., 1996). Common bean, grown for food and cash, is adapted to altitude ranges between 1200 and 2000 m asl (Ohlander, 1980), and is the most widely cultivated and used among lowland legumes in Ethiopia. Its production is concentrated in four regions: the Harerghe highlands (eastern), south and southwest, west, and the Rift Valley areas (Wortmann and Allen, 1994; Habtu et al., 1996). In Harerge highlands, 91% of common bean fields are under intercropping systems with maize, sorghum, vegetables and coffee (Fininsa and Yuen, 2002).

The national average yield of common bean under smallholder production is 823 kg/ha, which is far less than the attainable yield that could be obtained under good management conditions. Fungal and bacterial diseases are among the main production constraints in the major bean growing areas of the country (Habtu et al., 1996; Fininsa, 1996; Habtu et al, 1997; Fininsa and Yuen 2002; Fininsa, 2001). Disease management is a high priority for increasing bean productivity in Ethiopia. Various cropping systems, production situation, and disease management practices can influence the occurrence and development of diseases and their damage to crops. The effect of diseases may be restricted to certain production systems, locations and cropping seasons (Habtu et al., 1996; Fininsa and Yuen 2002). Management of bean diseases in mono-cropping and intercropping systems requires an understanding of the interrelated host, pathogen, and environmental factors leading to epidemics and yield loss. Surveys need to be conducted at regular intervals (Zadoks, 1961; James, 1969) to monitor changes in their relative importance and elucidate their epidemiology. Among the listed diseases of beans in Ethiopia, common bacterial blight, rust and anthracnose are economically important and widely distributed while angular leaf spot, web blight, halo blight, floury leaf spot, bean common mosaic virus and Ascochyta blight, though important, are much more restricted in some agro-ecologies (Habtu and Abiy, 1995). In the last 10 years, research endeavors have been made by research scientists in agricultural research centers and higher learning institutes in the country on the type, importance, and nature and occurrence of lowland pulses diseases, factors influencing the diseases, and control methods towards an integrated disease management (IDM). The major studies were mainly on major diseases of common bean and included: (i) occurrence, distribution, and relative importance in different agro-ecologies (Habtu et al., 1996; Fininsa and Yuen, 2002), (ii) association of bean diseases incidence and severity with cropping systems (mono-cropping and intercropping) and practices, (sowing date, variety type used, fertilizer use, weed management) in different geographical area, seasons and altitudes (Habtu et al., 1996; Fininsa and Yuen, 2002), (iii) effect of intercropping on temporal epidemics of bean common bacterial blight (CBB) caused by *Xanthomonas campestris* pv. *phaseoli* (Erw. Smith) Dowson, and rust caused by *Uromyces appendiculatus* Pers. Ung. (Fininsa, 1996; Fininsa and Yuen 2002), (iv) assessment of bean yield loss in monocropping and intercropping systems due to CBB (Fininsa, 2003), rust (Habtu et al., 1997) anthracnose caused by *Colletotrichum lindemuthianum* Sacc. &

Magn. Briosi & Cav. (Tesfaye, 1997), (v) epidemiology of bean rust at different locations (Habtu and Zadoks, 1995; Habtu et al., 1997); (vi) relative importance of CBB and anthracnose inoculum sources (Fininsa and Tadele, 2001), (vii) effect of bean varietal mixture on rust and CBB (Fikre, 1988), (viii) effects of micro climatic and weather factors on CBB, (ix) effect of partial resistance to bean rust, (x) analysis of the physiological races of *U. appendiculatus*, (xi) multiple disease resistant screening trials at multi-locations and other activities.

The objective of this article is, therefore, to review research activities on lowland pulses disease with due attention to common bean during the last 10 years. Brief summaries of important outputs of disease surveys and identification, pathogen biology, disease epidemiology, yield loss assessments, and cultural, host plant resistance and integrated disease management are highlighted. Research gaps and activities for future directions are indicated.

BASIC STUDIES

Disease Survey and Identification

Rust, anthracnose, angular leaf spot, floury leaf spot, brown spot, Ascochyta blight and web blight are the major fungal diseases on bean in major growing areas in Ethiopia. Economically, the major bacterial disease on bean is CBB. Halo blight (HB) (caused by *Psedomonas syringae* pv. *phaseolicola*) occurs less frequently (Habtu et al., 1996) (Table 1). These foliar diseases reduce biomass production by reducing the quality of radiation intercepted by the green portion of the bean plant as well as reducing the efficiency of the conversion of this radiation in asymptomatic areas of diseased plants. Root rots, vascular wilts, and bean common mosaic virus diseases occur in some areas and fields sporadically.

An extensive survey of haricot bean foliar diseases has been conducted to investigate the disease intensity, their relative importance and their association with bean production practices (sowing date, growth condition, plant density weediness, etc) in three of the four major bean growing areas of Ethiopia, the central Rift Valley (east and south Shoa), south and southwest (Sidamo), and west (Keffa) (Habtu, 1994). In these geographical areas, a field survey was conducted from 1990-1993 in 262 fields. Most data were collected around the pod filling stage when diseases were conspicuous at all canopy layers. A summary of the disease survey data over a four-year period indicated that differences were observed in prevalence and severity of diseases among areas, years and production practices (Table 2).

Prevalence and severities of bean diseases varied with cropping practices: In the Rift Valley and South low rust was associated with early sowing and high weeds. High levels of rust were associated with intermediate sowing date. The low presence of rust at early sowing date might be due to several factors. First, early sowing dates might have lead to escape the crop from late rust inoculum. Second, higher temperatures near the canopy and low rainfall early in the cropping season resulting in longer period of low leaf wetness made conducive microenvironment for rust infection to take place. An increase in leaf wetness duration is an important factor for rust infection (Harter et al., 1935). High severities of anthracnose and bacterial blight were associated with intermediate sowing dates.

Table 1. Economically important diseases of common bean in Ethiopia.

Disease	Causal agent	Occurrence/distribution	Importance
Anthracnose	Colletotrichum lindemuthianum	Wide	Major
Rust	*Uromyces appendiculatus*	Wide	Major
Common bacterial blight	*Xanthomonas campestris pv. Phaseoli*	Wide	Major
Web blight	*Rhizoctonia solani (=Thanatephorus cucumeris)*	Limited	Major
Angular leaf spot	*Phaeoisariopsis griseola*	Limited	Major
Ascochyta blight	*Phoma exigua var. diversispora*	Limited	Major
Halo blight	*Pseudomonas syringae pv. Phaseolicola*	Limited	Major
Floury leaf spot	Mycovellosiella phaseoli	Limited	Major
Bean common mosaic virus	*Bean common mosaic poty virus*	Limited	Intermediate
Root rots and wilts	*Rhizoctonia solani, Fusarium oxysporum, Sclerotium rolfsii*	Unknown	Minor

Table 2. Geographical distribution and severity of bean diseases in Ethiopia (1990-1993) expressed as percent of leaf area infected.

Area	Year	BR1	BA	BB	AL	FL	DT
Central	1990	2.28	3.39	6.07	0.00	0.00	0.86
	1991	2.96	6.60	8.01	0.00	0.00	3.14
	1992	2.23	4.27	6.43	0.00	0.00	3.53
	1993	5.09	3.94	5.42	0.00	0.00	2.05
Mean		3.14	4.30	6.48	0.00	0.00	2.39
South	1990	5.79	0.93	0.82	1.26	0.00	1.48
	1993	3.12	2.18	1.03	0.07	0.00	2.25
Mean		4.45	1.55	0.92	0.66	0.00	1.86
West	1990	1.30	2.15	0.14	2.46	1.45	-
	1992	1.99	2.37	3.32	4.63	3.17	0.49
	1993	2.95	3.68	3.14	10.26	8.20	0.00
Mean		2.08	2.73	2.20	5.78	4.27	0.24

[1] BR= bean rust; BA= anthracnose; BB= common bacterial blight; AL= angular leaf spot, FL= floury leaf spot; DT= dead tissue.

In the South, anthracnose and bacterial blight were nearly negligible during the survey period, where the bean production practices were characterized by light weeding, low plant density, and good crop rotation possibly by the use of healthy seeds. Low weediness was highly associated with low bacterial blight whereas medium and high weediness was strongly associated with high bacterial blight. The association between weediness and anthracnose was not significant. High plant density was associated with high levels of anthracnose, whereas low planting density with low levels of anthracnose.

The prevalence and severity of bean diseases in Ethiopia varied considerably with the environment, both by area and year. The central Rift Valley is characterized by high temperature and high variation in rainfall amount and intensity. Under such conditions the common bean diseases were bean common mosaic virus and common bacterial blight. In our study, CBB was dominant but rust and anthracnose were also observed. In the central Rift Valley, angular leaf spot and floury leaf spot were practically absent. The south is cooler than central Rift Valley and has dependable rains. Here rust was prominent probably due to optimum temperature and rainfall conditions, while differences within the regions were mostly due to cultural practices and surprisingly, anthracnose was insignificant. In the south beans were carefully weeded, plant densities were rather low, perhaps adversely influencing the microenvironment required for the development of anthracnose. In the west many diseases are present but the dominant ones were angular leaf spot (ALS) and floury leaf spot (FLS), with low level of rust and intermediate level of anthracnose. The west is characterized by high temperature, high rainfall and a humid climate. With regard to year, low rust intensity was found in 1990 and high rust intensity in 1993. In years 1991 and 1992 rust was about average, whereas anthracnose and CBB showed no clear associations with years.

Comparisons of rust prevalence on farmers' fields, state farms and research centers indicated that severity and prevalence were much on research centers, intermediate on state farms and slight in farmers' fields. On research centers, intensive production of bean in concentrated areas allowed gradual build up of the pathogen aggravated by the inclusion of susceptible lines in the trials. State farms grew bean on very large areas and used Mexican-142, which is susceptible to rust. Thus bean rust has become endemic and severity has been increasing. Farmers in Sidamo and Gamo Gofa grew different cultivars, sometimes with seeds of mixed color, size and shape. Farmers' bean fields were also rather scattered and in most cases associated with maize, enset or coffee. The value of associated cropping in pest management is well documented (Van Rheenen et al., 1981).

The study revealed the wide distribution of some bean diseases, the limited occurrence of others and the association of disease intensities with cropping systems. Obviously, not all bean diseases occurred everywhere, at the same intensity. Their prevalence and severity depended on area and season. Generally speaking, rust, CBB and anthracnose had wider distribution in Ethiopia than ALS and FLS. On worldwide basis, rust, anthracnose and ALS are reported to have wide distributions (Schwartz and Galvez, 1980). The study suggests that specific needs of areas with their own production situations must be considered in the process of developing strategies for the improvement of production and crop protection of beans. The results suggest priorities for strategies of control of ALS and FLS in the west and rust in the south. In the central Rift Valley, where rust, CBB and anthracnose occur simultaneously at different degrees, any control strategy designed to reduce the impacts of diseases must concurrently deal with these three diseases.

Similarly, surveys of rust and CBB diseases were conducted in the Habro, Chercher, and Wobera areas of the Hararge highlands during the 1998 and 1999 cropping seasons in 86 bean fields under sole and intercropping systems (Fininsa and Yuen 2002). On the average, CBB incidence was reduced from 54% in sole cropping to 29% in intercropping systems, and severity was reduced from 39% to 20%. Similarly, rust incidence was reduced by 25% and severity by 16% in intercropping. The associations of the CBB and rust incidence (percent number of plants infected) and severity index with eight independent variables (location, altitude, season, cropping system, crop proportion, sowing date, density, variety, and growth stage) were analyzed using logistic regression. The analysis indicated that cropping system, geographical area, altitude and season were important variables affecting both rust and CBB intensities. Lower (<25%) rust and CBB intensities were more associated with intercropping systems than the sole cropping.

Survey of diseases on major lowland pulse crops growing areas of West Shoa, Wollega and Illubabor zones were conducted from 1997 to 2000 in the main cropping season. More than 11 haricot bean foliar diseases on bushy type and three on climbing type were reported in the survey (Fekede and Kedir, 1998). Anthracnose, common bacterial blight, angular leaf spot and common bean mosaic virus were most wide spread and web blight, Ascochyta blight, halo blight, powdery mildew and white mold had limited distribution. Ascochyta blight, rust and common bacterial blight were limited on the climbing bean type. Bean anthracnose was a widespread destructive disease of haricot bean in western Ethiopia. In a series of screening trials for resistance of genotypes against the major foliar diseases of haricot bean more than 95% to total yield loss was recorded in varieties such as Pinto 650 (BARC, 2000). In seed multiplication program on farmers' fields the released variety, Roba-1 failed to produce any seed due to anthracnose in 2002 cropping season (BARC, 2002).

Mosaic in common bean caused by bean common mosaic potyvirus (BCMV) is the most common virus. Earlier, only serotype B strains (mosaic inducing strains) were identified (Agranovsky, 1985). Serotype A (bean common mosaic necrosis potyvirus) strain of BCMV causing systemic necrosis called black root was also recently isolated from infected plants at experimental sites (Alemu et al., 1998), possibly imported with infected seeds from other countries (Adane and Habtu, 2000). Soybean mosaic potyvirus (SBMV) in soybean (Adane and Albrechtsen, 1998) and peanut mottle potyvirus in cowpea were identified. However, no information on lowland pulses virus incidence and distribution, their epidemiology, estimate of their economic importance and control options is available.

BIOLOGY AND EPIDEMIOLOGY

Disease Epidemiology

The initiation of epidemics of anthracnose and CBB from primary inoculum sources (infected seed, infested debris and soil) and their effect on seed yield and quality were studied under Alemaya field conditions (Fininsa and Tefera, 2001). The inoculum sources had differential effect on levels of disease development, yields harvested and seed quality compared to treated seed planted plots. The primary inoculum from infested debris was relatively more damaging than other inoculum sources, causing early epidemic development and yield reduction. The management of primary inoculum is a key strategy in control of bean diseases (Hall and Nasser, 1996). Anthracnose and CBB management options should include components that reduce initial inoculum such as planting healthy seed, crop rotation whenever feasible, field sanitation, early incorporation of bean debris into soil. Burning of crop residues and effective seed treatment should be promoted in addition to developing resistant cultivars.

The effects of intercropping systems on temporal epidemics of CBB were studied under Alemaya field conditions (Fininsa & Yuen, 2002). CBB developed more rapidly in sole-cropped plots than intercropped ones. Intercropping delayed epidemic onset, reduced disease incidence (36%) and severity (20%), and the disease progress rate.

Radial expansion of foci in mixtures of susceptible and resistant bean cultivars was studied from 1990 to 1991 at two sites (Habtu, 1994). There were five treatments with the mixing proportions of 1:0 (twice, one treatment as a check without a focus and the other one with focus), 1:1, 1:2 and 1:4 susceptible (Mexican 142) to resistant (Negro Mecentral) plants. Seeds of the susceptible and resistant cultivars were mixed manually. From this mixture one seed at a time was drawn randomly and placed along the row. The foci expanded in a wave-like fashion. At Ambo (1990), radial expansion velocity ranged from 6 cm per day, in mixtures with 20% susceptible plants, to 15 cm per day in plots with the susceptible plants only. At Debre Zeit, the velocity ranged from 3 cm per day in a mixture with 20% susceptible plants to 16 cm per day in plots with 100% susceptible plants. At both sites, the radial expansion velocity of foci correlated linearly with the logarithm of the fraction of susceptible plants in the mixture. Velocities of focus expansion at Ambo and Debre Zeit were approximately equal in plots consisting of susceptible only. At lower proportions of susceptible plants the velocities at Debre Zeit were smaller at Ambo. Indications were given as to the environmental factors responsible for the observed differences between sites. At each site, variation between plots showed a clear spatial pattern.

Analysis of physiological races of *Uromyces appendiculatus* was studied in field and green house conditions using bean rust standard differentials and improved varieties. In the green house and field studies, variability in rust reactions occurred among isolates, indicating the presence of more than one isolate of the pathogen. The type and kind of races existing in the country would be identified in the future.

Yield Loss Assessment

Attempts have been made to assess the effect of some common bean diseases on actual yield. Presently, three important diseases of common bean have loss information under Ethiopian conditions. Habtu et al., 1996 analyzed yield losses due to bean rust in different cultivars across a range of environments in 1990, 1991 and 1993 using two genotypes, susceptible Mexican 142 and partially resistant 6R-395-08, and five spray treatments. The impact of bean rust on the attainable yield of beans was large. The impact differed with genotype, intensity of rust, location and year. The greatest impact was at Ambo, where the disease pressure was high. When rust severity reached its highest level, the yield was reduced by 85%. In an environment with a moderate disease pressure, as at Debre Zeit, the highest yield reduction was 43%. In the genotype with partial resistance the maximum yield loss was 30%. Yield loss in beans is mainly associated with reduction of pods per plant (Habtu and Zadoks, 1995). The experiment was conducted in research centers, with no external inputs but with relatively fertile soils. Farm operations are dynamic, and cropping practices and use of external inputs may change over time. Such dynamic changes will have an effect on the disease epidemic and subsequent impact on the damage to beans. To avoid serious losses, the use of partially resistant genotypes must be encouraged in any future rust management strategy (Parlevliet, 1978).

Loss assessment and severity damage relationship for rust was conducted at two locations, Ambo and Awassa (Habtu et al., 1998). The experiments were conducted using five varieties (Negro Mecentral, 6R-395-08, Red Wolaita, Mexican-142 and Nazareth small-03) and five spray treatments (unsprayed, sprays at 5, 10, 15 and 20-day- interval). Three weeks after emergence, each of the experimental plots was inoculated, and fungicide sprays were begun one week after inoculation to produce disease epidemic of varying intensity in each cultivar.

In 1988 and 1989, the experiments on bean rust on seed yields of haricot bean were studied using critical point models. In 1988 at Awassa, significant differences in rust severities were recorded among entries and the fungicide spray significantly reduced the disease reactions of the varieties (Table 3) except Negro Mecentral, which is resistant to rust. Yield losses were small for Negro Mecentral (0.3-4.1%) and 6R-395-08 (0-5.3%), and large for Nazareth Small-03 (19.2-27.6%), and intermediate for Mexican 142 (3.1-17.8%).

The results of 1989 at Awassa (Table 4) indicate the responses due to application of fungicide were larger. Losses ranged between 8.3 and 13.6 % in 6R-395-08, 15.2 and 35.1% in Nazareth small-03 and 4.1 and 23.3% in Mexican-142. In 1988, regressions of seed yield on the rust reactions for the individual entries (Table 5) showed that yields of Mexican-142 were reduced by 4.4% for each unit increase in disease reaction. For Nazareth small-03, this was 7.8%, for Red Wolaita it was 6.3% and for 6R-395-08, it was 3.9%. For Negro Mecentral (resistant), there was no relation ship between disease reaction and seed yield. In 1989, the yields of Mexican-142 decreased by 3.2% for each unit increase in disease reaction by 5.4% for Nazareth Small-03 and by 2.6% for 6R-395-08.

Table 3. Effect of bean varieties and fungicide sprays on rust disease and seed yield of haricot bean at Awassa in 1988.

Entry	Spray interval(in days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Percent change in yield
	5	1.5	1339	100.0	0
Mexican-142	10	2.3	1297	96.9	-3.1
	15	3.8	1275	95.2	-4.8
	20	4.5	1129	84.3	-15.7
	Control	5.3	1101	82.2	-17.8
	5	1.7	1781	100.0	0
	10	2.8	1344	75.5	-24.5
Nazareth Small-03	15	4.0	1320	74.1	-25.0
	20	4.0	1440	80.8	-19.2
	Control	5.5	1290	72.4	-27.6
	5	2.5	2894	100.0	0
	10	1.7	2914	100.7	+0.7
6-R-395-08	15	2.5	2741	94.7	-5.3
	20	2.5	2902	100.3	+0.3
	Control	3.0	2743	94.7	-5.3
	5	1.5	1518	100.0	0
	10	2.8	1389	91.5	-8.5
Red Wolaita	15	2.7	1344	88.5	-11.5
	20	3.3	1239	81.6	-18.4
	Control	5.3	1117	73.6	-26.4
Negro Mecentral	5	1.5	2441	100.0	0
	10	1.5	2449	100.3	+0.3
	15	1.5	2341	95.9	-4.1
	20	1.7	2439	99.9	-0.1
	Control	2.5	2434	99.7	-0.3

Table 4. Effect of bean varieties and fungicide sprays on rust disease and seed yield of haricot bean at Awassa in 1989.

Entry	Spray interval (in days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Percent change in yield
	5	1.0	1955	100.0	0
Mexican-142	10	1.6	1875	95.9	-4.1
	15	2.4	1550	79.3	-20.7
	20	3.2	1565	80.0	-20.0
	Control	5.4	1500	76.7	-23.3
	5	2.0	1740	100.0	0
	10	2.2	1760	101.1	+1.1
Nazareth small-03	15	3.8	1475	84.8	-15.2
	20	3.4	1360	78.2	-21.8
	Control	7.8	1130	64.9	-35.1
	5	1.4	1990	100.0	0
	10	2.0	1825	91.7	-8.3
6-R-395-08	15	2.0	1760	88.4	-11.6
	20	2.4	1825	91.7	-8.3
	Control	5.0	1720	86.4	-13.6

Table 5. Coefficients of regressions of seed yields on rust reactions and percentage yield losses due to bean rust at Awassa in 1988 and 1989.

	1988			1989		
Entry	Regression coefficient	r	% Loss	Regression coefficient	r	% Loss
Mexican-142	-63.3	0.86	4.4	-101.2	0.68	5.2
Nazareth Small-03	-127.0	0.71	7.8	-102.7	0.85	5.5
6-R-395	-123.9	0.43	3.9	-51.7	0.50	2.6
Red Wolaita	-103.5	0.93	6.3	NT	NT	NT
Negro Mecentral	+22.4	0.00	0	NT	NT	NT

In 1988 at Ambo natural infection of bean by rust in sprayed and unsprayed plots produced mean rust severities ranging between 3 and 5 (Table 6). Differences among treatments in rust reactions were not significant probably due to delays in spraying. Though, there were differences among treatments in seed yields, there were no consistent trends.

In 1989, there was high incidence of rust and the three entries showed moderate to high rust reaction related to their level of resistance. All spray schedules reduced disease reactions (Table 7); the least disease occurring with the most frequent sprays. The trend was consistent for all the three entries. Differences in seed yields were also observed. Assigning an index of 100 to the dried seed yield at lowest infection level, yield was reduced by 10-73% in Mexican 142, 9-67% in Nazareth small-03, and 3-15 % in 6R-395-08. Regressions of seed yield on rust reactions for the individual entries (Table 8) showed that yields of Mexican-142 were reduced by 203 g/plot (8.1%) for each unit increase in disease reaction. For Nazareth small-03, this was 127 g (6.5%), for Red Wolaita, it was 82 g per plot (6.1%). For Negro Mecentral (resistance), there was no relation ship between disease reaction and seed yield.

In 1989 (with Negro Mecentral and Red Wolaita omitted), the relation ship between seed yields and rust reactions were highly significant accounting for 83-96% of the variation in seed yields. Percent yield losses for every unit increase in disease reactions were 11% for Mexican-142, 8.7% for Nazareth Small-03 and 3.9% for 6R-395-08. Rust caused by very large reductions in yields of Mexican-142 in both seasons, followed by Nazareth Small-03 and 6R-395-08.

The use of different spray intervals produced good results. The most frequent sprays consistently produced the least disease reactions and the largest yields (index 100 %). Spray treatments affected seed yield, seed weight, seeds per pod and pods per plant. Obviously, variation in spray interval resulted in variation of disease pressure, which then resulted in differences in the magnitude of effects on yield components. Susceptible was always more sensitive to spray treatment than resistant, suggesting a large effect of sprays in susceptible cultivars. The study suggests the importance of rust in common bean, especially when a susceptible cultivar is attacked early. Rust is endemic in Ethiopia where an outbreak of rust in combination with wide spread cultivation of a susceptible cultivars can be devastating. The yield advantage obtained by applying fungicides frequently shows the damage potential of bean rust, but the experimental results also indicate that even one well timed treatment could produce economic benefits, but the use of chemical spray to the Ethiopian condition is influenced by the value of the crop (cash or consumption), availability and cost of chemicals, availability of sprayer and water. Critical point models estimate yield losses for any level of disease at a time when a specified level of disease is reached. So, future experiments should examine the role of initial infection and its subsequent development in yield loss.

Similarly, Fininsa (2003) calculated an actual yield loss of 21% for variety Red Wolaita due to CBB. In this study, a single-point regression model predicted that for each percent increase in CBB severity in broadcast and mixed intercropping, about 5.2 and 9.1 kg/ha seed yield loss, respectively, occurred at physiological maturity. In sole cropping for each percent increase in CBB, at an earlier growth stage, 73 days after planting, yield loss of 38.8 kg/ha occurred. In bean maize intercropping system, actual and predicted yield and 100–seed weight losses to CBB were, generally, less than in the sole cropping situation.

Loss assessment on haricot bean due to anthracnose was studied at Ambo station (Table 9), and at an on-farm site at Meki (Table 10) between 1992 and 1995 crop seasons, using the susceptible commercial bean genotype Mexican-142. Varying levels of disease severity and epidemic conditions were maintained in the experiment by spraying a systemic fungicide, benomyl at the rate of 0.4 kg/ha. Highly significant differences in disease level and yield were recorded between sprayed and unsprayed plots. Severity of anthracnose varied between 11.8% and 83.5% (Table 11) in the on-station, and between 17.2% and 76.6% in the on-farm trials. This high disease severity resulted in mean yield losses of 62.4% in on-station and 67.2% in on-farm trials. There was an estimated net gain of approximately Birr 2376/ha from on-station trial and Birr 1915/ha in the on-farm trial by controlling anthracnose with benomyl. The use of resistant varieties and producing pathogen-free seeds would be a cheap means of controlling the disease. Bean growers should be encouraged to use seed dressing against anthracnose when growing susceptible cultivars.

Table 6. Effect of bean varieties and fungicide sprays on rust disease and seed yield of haricot bean at Ambo in 1988.

Entries	Spray interval (in days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Percent change in yield
	5	3	1800	100.0	0
Mexican-142	10	4	1830	101.7	+1.7
	15	5	1600	88.9	-11.1
	20	5	1380	76.7	-23.3
	Control	5	1450	80.6	-19.4
	5	3	1315	100.0	0
	10	4	1630	123.9	+23.9
Nazareth Small-03	15	5	1240	94.3	-5.7
	20	5	1660	126.0	+26.0
	Control	5	1110	84.4	-15.6
	5	4	1865	100.0	0
	10	4	2090	112.0	+12.0
6-R-395-08	15	4	1920	103.0	+3.0
	20	5	1830	98.1	-1.9
	Control	5	1390	74.5	-25.5
	5	3	1065	100.0	0
	10	4	1135	106.5	+6.5
Red Wolaita	15	4	975	62.3	-37.7
	20	4	1070	91.5	-8.5
	Control	5	900	84.5	-15.5
Negro Mecentral	5	4	1100	100.0	0
	10	4	1315	120.0	+20.0
	15	4	1375	125.0	+25.0
	20	4	1130	103.0	+30.0
	Control	5	1250	114.0	+14.0

Table 7. Effect of bean varieties and fungicide sprays on rust disease and seed yield of haricot beans at Ambo in 1989.

Entry	Spray interval (in days)	Disease severity (1-9)	Seed yield (g/plot)	Index	Percent change in yield
	5	1.8	1267	100.0	0
Mexican-142	10	3.3	1144	90.3	-9.7
	15	3.8	1108	87.5	-12.5
	20	4.2	1071	84.5	-15.5
	Control	6.8	341	26.9	-73.1
	5	1.6	1246	100.0	0
	10	3.2	1145	91.2	-8.8
Nazareth small-03	15	4.0	1016	81.5	-18.5
	20	4.6	1007	80.8	-19.2
	Control	8.0	417	33.5	-66.5
	5	1.4	1496	100.0	0
	10	2.8	1447	96.7	-3.3
6-R-395-08	15	3.2	1359	90.8	-9.2
	20	3.8	1352	90.4	-9.6
	Control	5.2	1271	85.0	-15.0

Table 8. Coefficients of regressions of seed yields on rust reactions and percentage yield losses due to bean rust at Ambo in 1988 and 1989.

	1988			1989		
Entry	Regression coefficient	r	% Loss	Regression coefficient	R	% Loss
Mexican-142	-203.3	0.30	8.1	-191.0	0.90	11.0
Nazareth Small-03	-127.3	0.08	6.5	-133.5	0.96	9.7
6-R-395	-131.7	0.65	5.4	-60.7	0.83	3.9
Red Wolaita	-82.5	0.40	6.1	NT	NT	NT
Negro Mecentral	+20.0	0.01	0	NT	NT	NT

Table 9. Effect of anthracnose on yield and yield components of haricot bean at Ambo (1992-1995).

Treatment	Severity (%)	Pods/plant	Seeds/pod	Seed wt. (g)	Loss in seed (%)	Yield (kg/ha)	Loss in seed yield (%)
7 days	11.8	18.9	5.8	15.8	-	2024	-
14 days	17.9	13.3	4.5	11.1	29.8	1385	31.6
21 days	25.1	13.3	4.3	10.4	32.9	1251	38.2
28 days	27.4	13.6	4.2	9.8	38.0	1189	41.3
Seed treat	16.1	14.9	5.1	13.5	14.6	1647	18.6
Control	83.5	8.7	3.5	8.0	43.4	756	62.6
$LSD_{0.01}$	2.6	0.7	0.2	0.6	7	-	
CV	9.03	5.64	4.98	5.31	5.14	-	

Table 10. Anthracnose disease development, seed yield, seed weight and yield loss of haricot bean in the on-farm trial at Meki, 1994-95.

		Anthracnose development (%)					Yield/plot		Seed wt.	
Crop Season	Treatment	V4	R5	R6	R7	R8	Gram	Loss (%)	Gram	Loss (%)
1994	P	9.3	13.4	16.1	19.7	19.3	1508.9		157.1	
	UP	15.3	35.3	45.9	55.5	67.8	522.2	65.4	111.8	28.8
1995	P	10.2	17.2	19.5	21.1	15.1	1680.5		146.9	
	UP	25.0	35.0	47.9	65.1	85.4	522.5	68.9	94.4	35.7
Mean	P	9.8	15.3	17.8	20.4	17.2	1594.7		152.0	
	UP	20.2	35.2	46.9	60.3	76.6	522.4	67.2	103.1	32.2

V4= 3rd trifoliate leaves; R5= Pre-flowering; R7= Pod formation; R8= Pod filling; P= protected; UP= unprotected

Table 11. Effect of anthracnose on yield and yield components of haricot bean at Ambo (1992-1995).

Treatment	Severity (%)	Pods/plant	Seeds/pod	Seed wt. (g)	Loss (%) in seed weight	Yield kg/ha	Loss (%) in seed yield
7 days	11.8	18.9	5.8	15.8	-	2024	-
14 days	17.9	13.3	4.5	11.1	29.8	1385	31.6
21 days	25.1	13.3	4.3	10.4	32.9	1251	38.2
28 days	27.4	13.6	4.2	9.8	38.0	1189	41.3
Seed treatment	16.1	14.9	5.1	13.5	14.6	1647	18.6
Control	83.5	8.7	3.5	8.0	43.4	756	62.6
$LSD_{0.01}$	2.6	0.7	0.2	0.6		7	
CV	9.03	5.64	4.98	5.31		5.14	

Such yield losses are important to take appropriate production policy and management. More than 98% of the land devoted to legumes gives primitive yield that is modern inputs such as improved seeds, mechanized tillage, irrigation and crop protection are not applied. The yields recorded are fairly low (Dereje and Yaynu, 2001).

Economic Importance

Research findings on some major diseases affecting common bean, their prevalence and severity, their economic importance, and geographical distribution are discussed in this review. Although a large number of diseases have been identified and recorded, only a few of them are of economic importance (Table 1) that needs human intervention to reduce crop losses.

CONTROL MEASURES

Cultural Control

Cultural practices will be employed as long as crops are cultivated. At Nazareth, the effect of plant densities and weeding practices (Table 12) were studied to determine their effect on common bacterial blight (CBB) and halo blight both on haricot bean and mung bean. Though both practices seem to have a limited effect on the spread of CBB and halo blight, high plant densities and weeding early in the morning when the leaves are still wet favored the spread of the bacterial diseases though the effect on yield was not significant

Table 12. Effect of population densities and weeding time on the development of CBB.

	Dry weeding			Wet weeding		
Spacing	5	10	20	5	10	20
20	7.0	6.5	6.0	6.6	5.1	5.2
40	6.3	6.0	5.1	7.0	5.5	5.6
60	6.1	5.5	4.8	6.3	6.3	4.6
Mean	6.3	6.0	5.3	6.6	5.6	4.9

Host Plant Resistance

Multiple disease resistance: Haricot bean productivity under farmers' conditions is not exceeding 800 kg/ha. In Ethiopia, under good management conditions beans can produce up to 2500-3000 kg/ha (Amare, 1988). The wide gap in yield in beans is due to a wide range of production constraints among which diseases that include anthracnose, rust, common bacterial blight, web blight and angular leaf spot. Many of the commercial and local varieties (Mexican 142, Awash-1, Red Wolaita, Brown speckled) are susceptible to many of these major diseases. Identifying multiple disease resistance genotypes would be quite useful to increase yield, which is quite low in the country. Hence, the main purpose of host plant resistance is to reduce losses in haricot bean due to diseases by using disease-resistant varieties.

Evaluation of haricot bean lines for multiple disease resistance was started in 1996. For this, hot spot areas were selected, which included Melkassa (representing the arid climate for CBB); Ambo (representing cooler temperatures for anthracnose and rust); Jimma (representing sub-humid climate for angular leaf spot); and Pawe (representing hot humid climate for web blight).

From our previous studies we have identified varieties, which have got multiple disease resistance, and these were included in the breeding program. These resistant varieties identified across locations include: HAL-5, Roba-1 (though it becomes susceptible to anthracnose, CBB and angular leaf spot), Atndaba, Awash Melka, Pan-173, A-197, TY-3396-1, and Zebra. Genotypes that possess multiple disease resistance for three major diseases (CBB, rust and anthracnose) were identified. These include A-409, Bat-73, Bat 24, Bonita nigra, Red lands pioneer, Xan-175, Emp-87, Emp-110, Hal-5, Pvad-1022, Pan 173, Pva-1145, Xan-41, Pan-64, Ica-15541, Icapijas, Xan-162, Zaa-84057, TY-3396-16 and Bat-1629.

Also, genotypes that possess multiple disease resistance for five diseases (CBB, anthracnose, rust, angular leaf spot and web blight) were identified. These are EAP-4, EMP-236, FEB-147, ENT-5, G-19833, PAN-173, PAN-164, and TY- 3396-1. The results reported here indicate that there is a good possibility of identifying genotypes with resistance to one or more diseases. Sources of resistant genotypes are now identified, and should either include in the breeding program or directly tested for yield and other traits in order to release them.

Partial resistance: For a variable pathogen in terms of pathogenicity, such as rust of bean, selection for higher levels of partial resistance (PR) is a good alternative than selection for specific resistance. For a better understanding of the interaction between host and pathogen it is essential to evaluate components of partial resistance. Thus, a study was conducted to determine the components disease screening program and to detect differences in the level of resistance in bean cultivars.

Common bean cultivars were tested in a greenhouse for five components of partial resistance to bean rust (Table 13). The components examined included latent period (LP_{50}), infection efficiency (IE), sporulation capacity (SC), infectious period (IP), and pustule size (PS). Differences in responses of cultivars were found for all the five components of partial resistance tested. Differences were largest, however, for IE and SC. Cultivars exerico-23, A-176, Veracruz-10 and Bat 1198 had a high level of PR to the bean rust isolate. M-142, a widely grown cultivar in Ethiopia, was intermediate whereas Red Wolaita, an important cultivar in the south, showed a low level of PR. Linear correlations between LP_{50} and IE and between SC and PS were high. Linear correlations between IE, SC and PS with IP were not significant. Though differences in cultivar response were found for all components, any one parameter may not suffice to explain the PR potential of a particular cultivar. The study suggests using latent period, infection efficiency and pustule size in the selection for PR. For the evaluation of large numbers of bean cultivars in the greenhouse, IE and PS are preferable to minimize labor requirements. Using this methodology (LP_{50}, IE and PS), a total of 132 genotypes were tested for partial resistance to bean rust in greenhouse conditions. Of these, 52 were found to be promising for bean rust. These materials again were investigated to the other major diseases including bean rust in field conditions at three locations. Finally, genotypes that possessed resistance for the major diseases were identified. These included varieties G-3124, G-11044, G-19428 and G-19792

Chemical Control

To control bean anthracnose, common bacterial blight (CBB) and halo blight (HB), various chemicals were tested both as seed treatment and foliar sprays. For anthracnose, seed infections were controlled by benomyl seed treatment, and spraying fungicides such as captafol and mancozeb reduced the disease severity and increased bean yield. Seed treatments followed by spraying proved effective but the economics of this treatment might limit the use to only seed treatments. For CBB and HB, seed treatments and foliar protectant chemicals did not appear to be effective.

PRIORITIES FOR FUTURE DIRECTION

Emphasis should be given for the effect of cultural control methods (planting density, sowing date, varietal mixtures, and species mixture), effect of weeding and effect of available nutrients against major diseases in different ecologies.

Research on lowland pulses diseases has so far focused on haricot bean. Hence, future attempts have to be made to avert crop losses due to diseases on cow pea, pigeon pea and soybean.

Most of past attempts were concentrated on the epidemiology and control of fungal and bacterial diseases. Research efforts must also be directed to the assessment of the distribution, their epidemiology, economic importance and control option of viral diseases.

The epidemiological studies being undertaken thus far were on rust, CBB, and anthracnose. The same studies need to reflect on the other major lowland pulse diseases. Identification of physiological races of bean rust was studied. In the greenhouse and field studies, variability in rust reaction occurred among isolates, indicating the presence of different races of the pathogen. However, there is a need to clearly identify the type and kind of races of bean rust as well as other pathogen races based on many years of data which are available.

Table 13. Latent period (LP_{50}), infection efficiency (IE), sporulation capacity (SC), infectious period (IP) and pustule size (PS) of primary leaves of 14 cultivars, inoculated with a bean rust isolate from Ambo.

Cultivar	LP_{50}	IE	SC	IP	PS
ICA 15541	9.4a	2.5d	0.34ef	27.6a	4.0c
Jalisco 33	9.6a	3.1bcd	1.12a	14.6d	6.0a
Red Wolaita	9.6a	3.5bc	0.76cd	15.2d	5.0b
Brown speckled	9.7a	3.9b	0.38ef	15.2d	5.0b
KY Wonder 765	9.7a	5.4a	0.44de	24.3b	5.0b
Diacol Calima	9.9ab	2.4d	0.58cd	27.3a	4.0c
Mexican 142	9.9ab	2.9cd	0.53de	23.6b	3.5cd
US # 3	9.9ab	3.4bc	0.50de	21.5bc	3.5cd
Mexico 6	10.1ab	2.4d	0.51de	21.5bc	4.0c
CSW	10.2ab	3.6bc	0.47de	15.5d	3.5cd
BAT 1198	10.7ab	0.8ef	0.04g	19.6c	2.5e
Veracruz 10	11.4b	1.2e	0.19fg	22.4b	3.0de
Exrico 23 (Awash)	17.0c	0.2f	0.04g	14.4d	2.5e
A 176 (Roba)	18.6c	0.1f	0.04g	15.0d	2.5e

Cultivars means within each component followed by the same letter are not significantly different at $p \leq 0.05$.

There is a collapse of host plant resistance due to the existence of new races or strains. Many of the released commercial and local varieties (Mexican-142, Awash-1, Red Wolaita, Brown speckled and Roba-1) are found to be susceptible to many of the major bean foliar diseases. Hence, breeding program should be initiated to improve these varieties. Some points which need future consideration are:

1. Biological disease control
2. Biotechnology involving gene transfer to develop disease-resistant genotypes.
3. Integrated disease-management practices.
4. Seed pathology to reduce seed-born diseases.
5. Development of information on disease dynamics through conduct of surveys in major lowland pulses growing areas.

REFERENCES

Adane Abraham, and Habtu Assefa. 2000. Virus and virus like diseases of plants in Ethiopia. *Pest Mgt.J. Eth.* 4: 1-10.

Adane Abraham, and S.E. Albrechtsen. 1998. Seed borne viruses infecting some important crops in Ethiopia. *Pest Mgt.J. Eth.* 2: 294-101.

Agranovsky, A.A. 1985. Identification of viruses infecting pulses crops in Ethiopia. p. 73-80. *In* Proc. 10th Annual Meeting of the Ethiopian Phytopathology Committee. Addis Ababa, Ethiopia, 31 January-1 February 1985. Ethiopian Phytopathology Committee, Addis Ababa.

Alemu Lencho, Adane Abraham, and A. M. Matias. 1998. Necrotic strain of bean common mosaic virus in Ethiopia. *Pest Mgt.J. Eth.* 1: 110-112.

Amare, A. 1988. Haricot bean (*Phaseolus vulgaris* L.) varieties performance and recommended methods of production. p. 229-251. *In* Proc. 19th National Crop Improvement Conference, 22-26, April 1987. Institute of Agricultural Research, Addis Ababa.

BARC. 2000. Bako Research Center; Crop Protection Division progress report for 1999/2000. Bako Agricultural Research Center (BARC), Bako Ethiopia.

BARC, 2002. Bako Research Center; Crop Protection Division Progress Report for 2001/2002. Bako Agricultural Research Center (BARC), Bako Ethiopia.

Dereje Gorfu, and Yaynu Hiskias. 2001. Yield losses of crops due to plant diseases in Ethiopia. *Pest Mgt. J. Eth.* 5: 55-67.

Fekede Abebe, and Kedir Wako. 1998. Disease and pest recommendations for western Ethiopia. p. 145-150. *In* Beyene Seboka and Aberra Deressa (Eds.) *Agricultural Research and Technology Transfer Attempts and Achievements in Western Ethiopia.* Proc. Third Technology Generation Transfer and Gap Analysis Workshop, 12-14 November 1996, Nekemt, Ethiopia.

Fikire Lemessa. 1988. Effect of bean (*Phaseolus vulgaris* L.) cultivars mixtures on development of bean rust and common bacterial blight. M. Sc. Thesis, Alemaya University of Agriculture. 95 pp.

Fininsa, C. 1996. Effect of intercropping bean with maize on bean common bacterial blight and rust diseases. *International J. Pest Mgt.* 42: 51-54.

Fininsa, C. 2001. Epidemiology of bean common bacterial blight, and maize rust in intercropping system. Ph. D. Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Habtu Assefa, and Abiy Tilahun, 1995. Disease management in lowland pulses: Progress and possibilities for an integrated approach. p. 141. *In Proc. 25th Anniversary Conference of Nazareth Agricultural Research Center: 25 Years of Experience in Lowland Crops Research.* Nazareth/Melkassa, Ethiopia, 20-23 September 1995.

Fininsa, C., and T. Tefera. 2001. Effect of primary inoculum sources of bean common bacterial blight on early epidemics, seed yield and quality aspects. *International J. Pest Mgt.47: 221-225.*

Fininsa, C., and J. Yuen. 2002. Temporal progression of bean common bacterial blight (*Xanthomonas campestris* pv. *phasseoli*) in sole and intercropping systems. *European J. Plant Pathology* 108: 485-492.

Habtu, A., 1994. Epidemiology of bean rust in Ethiopia. Wageningen Agricultural University. Department of Phytopathology, Wageningen, The Netherlands. 118 pp.

Habtu Assefa, and Abiy Tilahun, 1995. Disease management in lowland pulses: Progress and possibilities for an integrated approach. p. 141. *In* Proc. 25th Anniversary Conference of Nazareth Agricultural Research Center: 25 Years of Experience in Lowland Crops Research. Nazareth/Melkassa, Ethiopia, 20-23 September 1995.

Habtu Assefa, and J.C. Zadoks. 1995. Crop growth, disease and yield components of rusted phaseolus beans in Ethiopia. Journal of Phytopathology 143: 391-401

Habtu, A., I. Sache, and J. C. Zadoks. 1996. A survey of cropping practices and foliar diseases of common bean in Ethiopia. *Crop Protection* 15: 179-188.

Habtu, A., T. Abiye, and J.C. Zadoks. 1997. Analyzing crop loss in bean pathosystem: Disease progress, crop growth and yield loss. Pest Management J. Ethiopia 1(1&2): 9-18.

Habtu, A., J.C, Zadoks, and T. Abiye. 1998. Analyzing crop loss in a bean rust pathosystem. II. Severity-damage relationship. Pest Mgt.J. Eth. 2(1&2): 1-13.

Hall. R., and L. C. B. Nasser. 1996. Practices and percepts in cultural management of bean diseases. *Canadian J. Plant Pathology* 18: 176-185.

Harter, L. L., Andrus, C.F., and W.J. Zaumeyer. 1935. Studies on bean rust caused by *Uromyces phaseoli* typical. *Journal of Agricultural Research* 50: 737-759.

James, W.C.1969. A survey of foliar diseases of spring barley in England and Wales in 1967. Annuals Appl. Biol. 63: 253-263.

Ohlander, L.J.R. 1980. Research on haricot bean production in Ethiopia 1972-1976. Swedish University of Agricultural Sciences, Department of Plant Husbandry, Report 82, Uppsala. 288 pp.

Parlevliet, J.E. 1978. Further evidence of polygenic inheritance of partial resistance in barley to leaf rust, Puccinia hordei. *Euphytica* 27: 369-379.

Schwartz, H.F., and Galvez, G.E. 1980. Bean production problems: Disease, pest, soil and climatic constraints of Phaseolus vulgaris. CIAT, Cali, Colombia. 424 pp.

Tesfaye Beshir, 1997. Loss assessment study on haricot bean due to anthracnose. Pest Mgt. J. Eth. 1(1&2): 69-72.

Van Rheenen, H.A., Hasselbach, O.E., and S.G.S. Muigai. 1981. The effect of growing beans together with maize on the incidence of bean diseases and pests. *Netherlands J. Plant Pathology* 87: 193-199.

Wortmann, C. W., and D. J. Allen. 1994. African bean production environments: Their definitions, characteristics and constraints, network on bean research in Africa. Occasional Paper Series No. 11. Dare Salaam, Tanzania: CIAT. 47 pp.

Zadoks, J.C. 1961. Yellow rust on wheat studies in epidemiology and physiologic specialization. *Tijdshr. Piziekten* 67: 69-256.

Research Needs in Pest Management for Improved Productivity and Sustainability of Food Legume Crops in Eastern Africa

S. Sithanantham[1] and G. V. Ranga Rao[2]

[1]*International Center for Insect Physiology and Ecology (ICIPE), P. O. Box 30772, Nairobi, Kenya,* [2]*International Crops Research Institute for the Semi- Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, 502324, India*

ABSTRACT

Insect-pests constitute a major constraint to sustainable production of the commonly grown food legume crops (pigeonpea, cowpea, chickpea, groundnut, lentil, mungbean, beans, pea, and grass pea) in Eastern Africa. Pest-caused losses in yield are often substantial enough, and farmers find it difficult to cope with investment demands for ensuring adequate pest control. The important insect-pest problems on food legume crops include soil pests (e.g. white grubs, termites), seedling pests (e.g. stem maggot), sap feeders (e.g. aphids, white flies), defoliators (e.g. beetles, caterpillars) and, most importantly, those affecting the reproductive parts (e.g. caterpillars, bugs and flies). Since pest control based on sole dependence on chemical pesticides is found to be not sustainable, National Agricultural Research and Extension Systems (NARES) are required to avail the legume farmers' safer and affordable pest control technology options. There is, therefore, an increasing keenness in promoting sustainable crop protection practices through adoption of the Integrated Pest Management (IPM) approach. IPM researchers are seeking to develop more holistic 'menu' of options that constitute compatible components of Integrated Crop Management (ICM). The priority is to provide the food legume farmers with affordable and safer pest control options, so to wean them away from indiscriminate and inappropriate pesticide use. Research should evolve simple pest monitoring scouting systems, backed up with dependable 'action thresholds' for local decision-making, based on the economic injury levels. Attention should be paid to fine-tune the promising eco-friendly technologies like conservation/augmentation of bio-control agents, botanicals, 'pest-tolerant' cultivars and habitat-management, involving the beneficial role of companion and rotation crops. For polyphagous pests like *Helicoverpa*, research should be so strategized to evolve an ecosystem approach for managing them across the major target crops and their alternate hosts. Farmer-participatory IPM development should become a regular feature of research-extension linkages, so as to guide in developing and delivering appropriate technologies that match with farmers' perceived needs. Promotion of multi-disciplinary and multi-organizational approach to IPM research would greatly enhance the soundness and impact potential of the IPM technologies on food legume crops. IPM-ICM integration, with high priority on human resource development in research and extension could contribute significantly to enhance the productivity and sustain the production of food legumes in the region.

INTRODUCTION

Food legumes constitute the major source of affordable protein to the rural population in Eastern Africa. Insect-pests constitute a major biotic constraint to the sustainable production of most food legume crops. Insect-pests are known to often cause over 20% yield loss, while more severe crop losses are not uncommon. It is difficult to predict and take up preventive crop protection interventions, due to the largely rain-fed and subsistence nature of the legume crops production and to the largely sporadic nature of several major insect-pests in these crops. Recent progress in international and national research has enabled the farmers to also grow some of the legumes round the year to cater to market opportunities, through supplementary irrigation, while they were only seasonal in the past. This also brought significant shift in the insect-pest population dynamics, and some times resulted in change in the pest status of some insects on the food legume crops. The major challenge for crop protection researchers is to develop and disseminate ecologically compatible and economically viable pest control options for these crops, so to be widely adoptable by the smallholder farmers. This paper focuses on promising themes for future pest management research on food legumes, based on recent and upcoming scenario of concerns and opportunities for developing and adopting more sustainable pest management options in the region.

THE PEST SPECTRUM SCENARIO

The food legume crops are grown in a range of agro-ecological zones and include lowland crops like haricot bean (*Phaseolus vulgaris*), groundnut (*Arachis hypogaea*), pigeonpea (*Cajanus cajan*) and cowpea (*Vigna unguiculata*), as well as highland crops such as lentil (*Lens culinaris*), grass pea (*Lathyrus sativus*), field pea (*Pisum sativum*), faba bean (*Vicia faba*) and chickpea (*Cicer arietinum*). They are mostly subject to substantial pest–caused losses, the extent varying with regions and seasons. The insect-pests affecting the commonly grown food legume crops in Eastern Africa include soil pests (e.g. white grubs, termites), seedling pests (e.g. stem maggot), sap feeders (e.g. aphids, whiteflies, leafhoppers), defoliators (e.g. beetles, caterpillars) and more importantly, those affecting the reproductive parts like flowers/pods/seeds (e.g. caterpillars, bugs, flies). An indicative (not exhaustive) list of the known pests on these crops in the region is provided in Table 1.

The pest situation in the region is largely comparable to the scenario in Asia, as reported by Ranga Rao et al. (2002). It should be noted that economic thresholds are included as an integral part of the pest-related basic information by food legumes IPM researchers in Asia.

In some legume crops like cowpea and pigeon pea, the pest problems are often complex. Cowpea is indeed regarded a paradise for insect-pests, right from germination to harvest. In pigeon pea, as illustrated in

Kenya, *Maruca* occurs at early phase on short-duration varieties and is followed by *Helicoverpa*, pod flies and pod-sucking bugs at maturity phase (Minja et al., 1996a). Hence it is necessary to develop strategies for tackling all the key pest groups including pod flies, for successful pest management in the crop. It is seen that short-duration pigeon pea varieties are mostly heavily damaged by *Maruca* and *Helicoverpa*, while medium- and long-duration types are severely attacked by pod fly (Minja et al., 2000b). In a given location or region, the climate tends to influence the abundance and relative severity of infestation by the different pest species. Therefore, it is important to establish benchmark sites, which represent the major production ecologies for the target food legume crops, and so to relate to the research to the local pest situation.

QUANTIFYING THE YIELD LOSSES DUE TO KEY PESTS

Information on the quantity and value of yield loss caused by pests has been relatively limited and scattered across the research centers in the region. Very often these estimates represent the 'overall loss' caused by a group of pests feeding in the same niche (e.g. sucking pests, soil pests, flower pests, pod/seed feeders). Nevertheless, there is need to quantify the contribution by individual key pests and estimate the extent of loss caused at different severities/levels of pest infestation (Sithanantham et al., 1983b). This information would assist in prioritizing the pests for research resource allocation as well as in cost - benefit analyses. The on-farm yield loss assessments made on pigeon pea in Eastern Africa (Minja, 1997; Minja et al., 1996a) could provide a basis for pursuing this approach. In Ethiopia, the relative economic importance of pests of food legume crops has been reviewed by Abate (1995), Abate et al. (1985a), Ali and Habtewald (1994) and Wale et al. (2000). Filling in knowledge gaps on the relative yield losses by key pests should receive attention, both nationally and across the region.

STORAGE PESTS OF FOOD LEGUMES

For all the food legumes, storage beetles are an important source of loss in the storage and they are mostly Bruchids, *Callosobruchus chinensis (L.)* and, *Callosobruchus maculatus* (Fabricius). In stored groundnut, *Caryedon serratus* (Olivier) and *Tribolium castaneum* (Herbst) are economically important (Ranga Rao et al., 2002). These stored-produce insects are cosmopolitan and emphasis should be placed on more objective and accurate estimates of the losses they cause. The initative made in this direction in Uganda (Silim Nahdy and Agona, 2001) and Ethiopia (Ferede, 1994) is worth pursuing. Since seed material is of prime importance for legume farmers, we must consider providing affordable control options to minimize pest damage to seed stocks at farm and storage level.

Table 1. Indicative list of insect-pests on some common food legume crops in Eastern Africa*.

	Known extent of importance*						
Pest	Pigeon pea	Chick pea	Haricot bean	Cowpea	Groundnut	Field pea	Lentil
1. Soil pests							
1.1. White grubs	E	E	E	E	B/C	E	E
1.2. Termites	E	E	E	E	B/C	E	E
2. Seedling pests							
2.1. Stem maggot	-	-	A/B-	C/D	-	-	-
3. Sucking pests							
3.1. Aphids	B	B	C	B/A	B/C	B/C	B/C
3.2. Jassids	D	-	D	C	B/C	C/D	C/D
3.3. Thrips	C	-	C	C	B/C	B/C	B/C
3.4. Whiteflies	D	-	B	C	B/C	B/C	B/C
4. Defoliators							
4.1. Spodoptera	-	-	D	D	A/B	C/D	E
4.2. Leaf miners	D	C	C	C/D	A/B	C/D	E
4.3. Beetles	D	-	D	C/D	B/C	C/D	C/D
4.4. Grasshoppers	D	-	D	C/D	B/C	C/D	E
5.Bud/flower/pod/seed feeders							
5.1. Flower thrips	B	D	A	A	C/D	C/D	C/D
5.2. Flower beetles	D	D	D	B/C	C/D	C/D	C/D
5.3. *Helicoverpa*	A	A	C	C/D	C/D	C/D	E
5.4. Maruca	A	-	C	A/B	-	C/D	-
5.5. Etiella	C	-	B	B/C	-	B/C	-
5.6. Pod fly	A	-	-	-	-	-	-
5.7. Pod sucking bugs	A	-	C	A/B	-	-	-
6. Storage pests							
6.1. Bruchids	A	A	A	A	A	A	A
6.2. Red flour beetles	-	-	-	-	C	-	-

*A = Key pest; B = Common pest; C = Minor pest; D = Occasional pest; E = Not ascertained; -= Not known/reported.

PEST MONITORING AND THRESHOLDS DEVELOPMENT

Local information on biology and ecology of pests is generally available in national research centers, especially on the seasonality of the different pests in the major target crops. Examples of national research contributions to bio-ecology of key pests in food legume crops in Ethiopia are available for the pea aphid, *Acyrthosiphon pisum* (Wale et al., 2000; Wale, 2002) and bean stem maggot, *Ophiomyia* spp (Abate et al., 1985a). There is need and scope to collate all such information and synthesize it, so to identify gaps in critical knowledge areas. It is desirable to establish a network of on-station and on-farm monitoring plots for major legume crops so to provide baseline information on year-to-year pattern of dynamics and relative severity of incidence pests. The development and use of simple traps to continuously monitor the mobile stages of key pests, as undertaken at ICRISAT (Pawar et al., 1984) may provide a basis for appropriate incorporation of this component in IPM research themes of the national legume research programs. A modest yet continuing resource input for such network monitoring would be highly valuable, to keep track of the patterns of relative importance among key pests as well as of any changing scenarios in overall pest spectrum. Such benchmark network should represent the major agro ecological zones where the major food legumes grown.

Since most of the food legume crops are grown under a range of climatic conditions, there is advantage in developing ETLs (Economic Threshold Levels) to match the specific crop-pest situation in different agro-ecologies. Development of 'empirical' action thresholds should be given high priority, since it is useful in minimizing the overuse misuse of chemical pesticides by farmers. Examples of ETLs developed at ICRISAT for some of the important pest species are illustrated by Ranga Rao et al. (2002). The results obtained ETL for pea aphids in Ethiopia (Ali, 1997) could provide the basis for further research on the other key pests in food legumes. There is interest to evolve economic thresholds or action thresholds for the key pests. It is important that simple and thumb-rule based thresholds are first developed for pests which require need-based control, so to motivate farmers to undertake scouting as a routine practice for pest management. However, the lack of laboratory mass rearing facilities for artificial infestation of the target pest and the inadequate priority assigned for this research activity by national programs constitute a major limitation. Besides selecting research centers within and across counties in the region and equipping them with the physical facilities and trained human resource to undertake the needed insect mass rearing, methodological inputs could be availed from the expertise available from International agricultural research centers like ICRISAT, ICARDA, CIAT, IITA, and ICIPE.

BIOLOGICAL CONTROL

Biological control offers considerable scope for sustainable crop protection in Africa (Sithanantham and Maniania, 2001). To enable maximizing the potential for biological control, a baseline should be built on the range of natural enemies that occur as well as their relative impact on the key pests in the local crop ecosystems. The ICRISAT-NARS linked database for *H. armigera* natural enemies in India (Manjunath et.al., 1989) can provide an example of crop-wise listing of known natural enemies. Food legume IPM researchers have so far tended to limit their role to recording the commonly occurring natural enemies, as by Okeyo-Owuor et al. (1991) while very little efforts have been made to systematically assess their potential impact on the pest, over time and space. Networking within and between countries in the region for coordinated surveys (both on- station and on-farm) to assess the range of native natural enemies and their incidence/impact levels is needed. Expertise in identification of parasitoids and predators could be availed in the region, through participation by national museums and taxonomy experts in biodiversity networks.

Microbial Control

There are several naturally occurring disease causing organisms, including nematodes, fungi, bacteria and viruses that are known to infect and kill key pest insects on the food legume crops. Some of them are amenable mass production and can be commercially produced and made available to farmers in the region. Among them are *Bacillus thuringiensis* (*B.t*) and *Helicoverpa* nuclear polyhedrosis virus (HaNPV), which are popularly used elsewhere in food legumes for plant protection. There have also been some promising results from efforts to utilize fungal pathogens (e.g. *Metarhizium*) for flower thrips in cowpea (Sithanantham and Maniania, 2001). Bacterial pathogens like *B.t.* are found effective for controlling defoliating/pod-boring caterpillars, while baculoviruses are commonly used for *H. armigera.* Local surveys for assembling native diversity in virulence among *Helicoverpa* NPV have been undertaken by ICIPE, Kenya, which has shown the occurrence of the SNPV (single nucleocapsid) subtype of NPV in the region (Baya et al., 2001). One of the Kenyan native NPV strains has been evaluated at ICRISAT and it has also been found promising for field control of *H. armigera* on pigeon pea in Kenya (Minja et al., 2003). Future research should include the identification of virulent native strains, exploring for potential manipulations to enhance their field persistence and/or efficacy of the formulated products, besides promotion of local mass production/commercialization of the promising pathogens. A recently concluded ICRISAT-led legumes IPM project in Asia has promoted village-level NPV production units, which could produce over 171,500 LE (level equivalents) during the first cropping season.

With occasional guidance and initial training, such units could empower the farmers to locally produce good quality NPV product at local-level. In Ethiopia, there have been records of local occurrence of NPV and recent evaluation of *Bt* product for *H. armigera* biocontrol. These provide a good starting point to pursue further research towards their improved utilization in the region.

SCOPE FOR ARTHROPOD PREDATORS

Surveys for naturally occurring predators of key pests in the region have been very limited (Sithanantham and Reddy, 1990; Duffield and Reddy, 1997). There is potential for minimizing the chemical pesticide use and so conserve arthropod predators such as coccinellids (lady bird beetles) and syrphids (hover flies) for managing the sucking pests like aphids, besides ants/spiders which feed on eggs/young larvae of caterpillar pests. Augmentation of biocontrol with mass-produced predators like *Chrysopa* holds promise in high value legume crops, such as peas, for being deployed against caterpillars and aphids. Establishing perches for predatory birds has been shown by ICRISAT studies as a useful practice that may be validated/ demonstrated for externally visible caterpillar pests as with *H. armigera* in chickpea and with *Spodoptera* spp. on groundnut.

Assessment of locally occurring predators has to be also pursued, as only scanty reports such as ants, chrysopids, and spiders are available in the region. As in Ethiopia, only limited information is available on predators of legume pests and there is need to be fill in the gaps on knowledge of the locally occurring predators and their relative importance in natural suppression of key pests at national and regional level.

SCOPE FOR CONSERVING AND AUGMENTING PARASITOIDS

Food legume crops are known to host a vast number of parasitoids such as larval parasitoids on stem maggot in beans and on pod fly in pigeonpea, besides egg parasitoids (*Trichogramma*) on caterpillar pests (Sithanantham et al., 1987; Sithanantham and Reddy, 1990; Shanower et al., 1996). For augmentative control, Trichogrammatids have been found to be not useful in chickpea, while in pigeonpea there appears to be species/varietal difference in compatibility among Trichogrammatids. Otherwise, most of them are suitable targets for conservation biocontrol. Chickpea is not a compatible crop, while pigeonpea genotypes differ in their suitability.

ICRISAT studies in Asia have shown that natural parasitism of *H. armigera* eggs by *T. chilonis* in short-duration pigeonpea is enhanced (19-58%) when grown as companion crop with sorghum through transfer from the preceding generation bred on the same pest on sorghum, (Duffield, 1994), compared to negligible parasitism levels (mostly below one per cent) occurring on other cultivars /sole pigeon pea crop (Pawar et al., 1986). Such approaches towards *in situ* conservation could be explored in Eastern Africa, as well.

Recent research by national/network programs in the region along with ICRISAT, CIAT and ICIPE have recorded a range of parasitoids occurring on pests of pigeon pea, groundnut, and haricot bean. There is need to assemble local information on the common parasitoid species occurring in the target food legume crop ecosystems, so to plan suitable conservation and/or augmentation biocontrol strategies. The studies undertaken by van den Berg (1993) on natural enemies of *H. armigera* in Kenya provide a good model for planning similar studies on other key pests of food legume crops.

CHOICE OF PEST-TOLERANT CULTIVARS

More than 14000 germplasm accessions of both pigeonpea and chickpea have been evaluated for pest resistance/tolerance in collaboration with ICRISAT at several research stations over many years. A number of genotypes with different levels and mechanisms of resistance to several pest species have been identified, as illustrated for pod flies by Sithanantham et al. (1981b). Significant progress has been made in identifying stable source of resistance to specific pests like borers and pod flies in pigeon pea and to borers/aphids in chickpea. Considerable progress has also been made in identifying resistance sources in groundnut against foliar insects such as jassids, aphids, thrips, leafminer and *Spodoptera* through research led by ICRISAT. Minja et al. (2000b) demonstrated the potential for host plant tolerance to pod fly among some long duration genotypes of pigeonpea. Recent research efforts in Ethiopia on chickpea (Damte and Chichaybelu, 2002) and field pea (Goftishu, 2001) pointed to the potential for such methods as an IPM component. Future thrust in the region should also focus on utilizing tolerance to key pests among adapted landraces/cultivars.

PROMOTING CULTURAL PRACTICES AND BENEFICIAL HABITAT MANAGEMENT STRATEGIES

Several cultural practices have been evaluated for their potential contribution to pest suppression, which include intercropping, trap crop deployment, adjusting planting pattern/timing, besides crop rotation. Intercropping has been shown to be beneficial in pest suppression in groundnut, pigeonpea and chickpea in ICRISAT led research. In Ethiopia, Abate (1988) demonstrated the potential for trap cropping for *H. armigera*, a major pod-borer on legume crops. The benefit of maize intercropping in reducing the pest pressure by *Maruca* on cowpeas has also been well documented in the region (Kyamanywa and Ampofo, 1988). Further research on the scope of cultural practices for managing other key pests should be encouraged, as this is generally cost effective and less disruptive to the beneficials in the crop ecosystem.

Where possible, it is important to avoid cross-season build up of pests, such as by rotation and avoiding the pest breeding sources in volunteers/weeds. Where the food legume crops are grown in farms with a field margin, it may be useful to explore the growing of flowering plants there so that they can provide supplementary nutrition for some of the beneficials like parasitoids. In farms with shrubs in the boundaries as live fence or as demarcation, it may be worth promoting their role as 'refugia' for predators like spiders.

UTILIZING BOTANICALS AND OTHER ORGANIC PRODUCTS

Presently, *neem* products are being actively evaluated and/or promoted on food legume in Asia. Given the resource constraints of food legume farmers, the use of local plants or organic products should receive due attention. In Ethiopia, this option has received some attention, as in recent studies by Teshome (1993), Damte and Chichyabelu (2001) and Mulatu and Gebremedhin (2000). To facilitate quality control among botanical products, the recent ICRISAT-led legumes IPM project in Asia concentrated on village-based production of *neem* in pilot units. It would be useful to extend attention to utilizing these and such other additional local plants, which have not yet been included in research evaluations adequately, but are thought to be promising.

USE OF FARMERS' KNOWLEDGE AND INDIGENOUS PRACTICES

Adequate understanding of the farmers' knowledge, attitude and practices is an important yet often neglected area of research. Food legume farmers should not be treated simply as recipients of IPM technology, but also as resource persons, who can contribute through indigenous knowledge as well. Chichyabelu and Bejiga (1999) have studied the perception of farmers in relation to pod-borer control on chickpea as part of on-farm survey to assess pest damage on chickpea in Ethiopia. It is important that the knowledge resource of African smallholder farmers do not continue to be neglected in IPM development and application.

For comparison, it may be pointed out that pigeon pea farmers in southern India have been known to protect their crops from insect-pests, particularly pod-borers, in several ways, one of which is to shake the plants at peak pest activity to dislodge and so make it easy to destroy the larvae. With their past experience in pest management, they have refined the technology to some extent so as to tide over any high infestations.

To get rid of the larvae that are partially embedded (feeding) in the pods, some farmers apply *neem* kernel suspension in the early hours and later start shaking during afternoon time, which has proved even more effective. The ICRISAT legumes IPM project collected data (ICRISAT 2000) that showed that there was very high (97%) larval drop while only limited drop of flowers and pods occurred.

This technology has also allowed natural enemies, particularly birds to settle in this area keeping the pod-borer away from the adjoining chickpea crops and saving 3-4 sprays of insecticides. Thus, these simple traditional practices helped in not only saving the pigeon pea crop, but the spillover effects on the subsequent crops like chickpea were evident.

EVOLVING INTEGRATED PEST MANAGEMENT (IPM) AND INTEGRATED CROP MANAGEMENT (ICM) APPROACHES

The importance of linking IPM development and implementation as an integral part of overall crop management should also receive continuing attention. There is need to evaluate the compatibility of IPM components (Reed et al., 1989), involve approaches that differ with planting season (Sithanantham et al., 1981b) and evolve crop-focus IPM strategies (Reed et al., 1987; Shanower et al., 1997). As a case study, we could cite here that the IPM options developed and implemented in food legume crops in Asia recently through an ICRISAT-led IPM project have resulted in significant change in the farmers' attitude to pesticide usage (ICRISAT, 2000). The need to strengthen IPM development and application, is mainly to help over come the three evils caused by pesticide misuse, namely, resistance to insecticides, resurgence of pests, and residues of chemicals. In Ethiopia, there has been emphasis on IPM development for food legume crops (Abate, 1995; Ali, 1997, 1999, 2002) and this should be extended to all major target pests. In addition, the concept of IPM implementation should be built into the overall crop management under Integrated Crop Management (ICM) approach. Legume IPM scientists should endeavor to link up closely with crop production experts to ensure that IPM becomes a compatible component of the overall production package. The vision for such approach could be developed from crop focus packages developed by food legume researchers in Ethiopia (Bejiga et al., 1996a, b).

As a means of developing the IPM components, a field experiment was conducted during 1998-99 at ICRISAT, Patancheru to assess the relative efficacy of spraying a *neem* product (AZA) 0.006 %, HNPV @ 250 LE ha^{-1}, endosulfan 0.07%, erecting bird perches and the combination of the four treatments (as IPM package). The system of combining pest damage and crop yield assessments (Fig. 1), has led to their economic analysis (Fig. 2) was adopted to validate the overall benefit of IPM package.

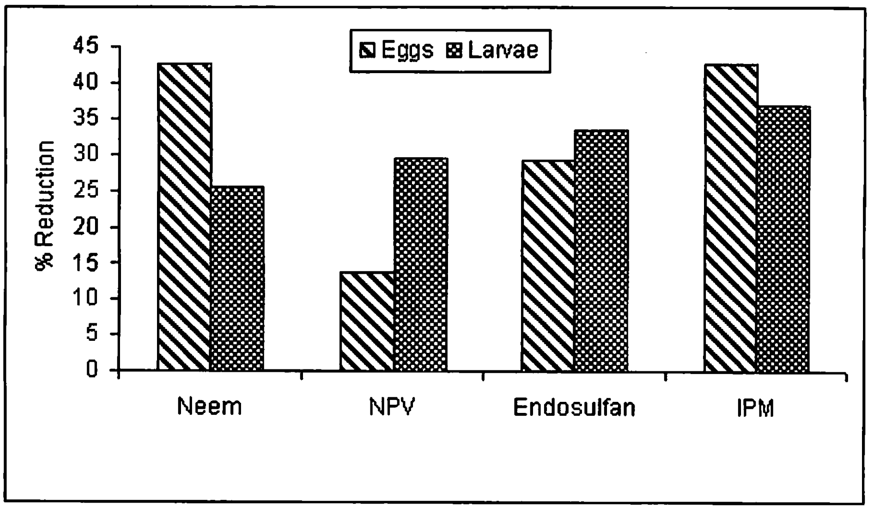


Fig. 1. Extent of reduction in egg and larvae of *H. armigera* under different treatments including IPM module on chickpea, ICRISAT, Patancheru, 1999-2000.

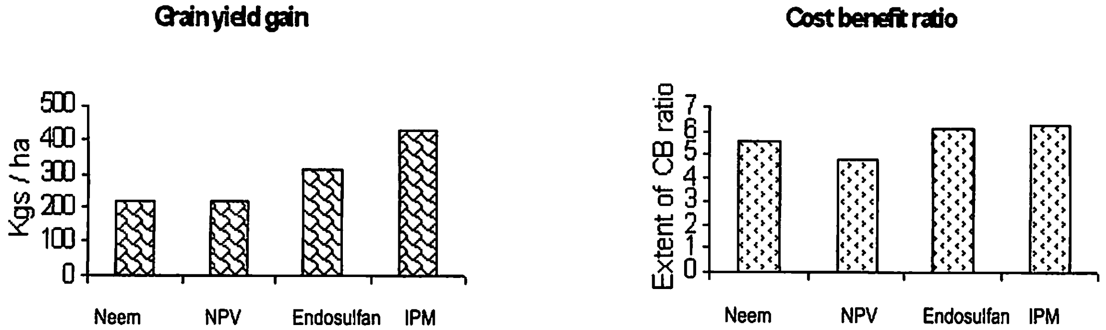


Fig. 2. Extent of gain in grain yield and cost: benefit ratio of different treatments and IPM module on chickpea, ICRISAT, Patancheru.

To validate the ecological benefits, suitable quantification of abundance/activity of key natural enemies like insect predators (Coccinellids, Chrysopids and spiders) should also to be undertaken, as illustrated by the multi-village observations made under the ICRISAT – legumes IPM project in Asia (ICRISAT, 2000).

IMPACT ON REDUCTION IN CHEMICAL PESTICIDE USE

In Eastern Africa, surveys by Minja et al. (1996b) have shown that pigeonpea farmers tended to apply high frequency of chemical pesticides, but often been applying the wrong chemical, wrong dose and /or at the wrong time, ending up in ineffective control of the key pests. Rationalizing the use of chemical pesticides is therefore an important component in evolving and adopting IPM approach. Minja et al. (2000a) have pointed out the relative efficacy of the commonly used chemical pesticides for control of the three major pest groups on pigeonpea-borers, bugs and podfly. The example of ICRISAT-led legumes IPM popularization in Asia has shown that participatory IPM activities in food legume crops resulted in reduction in pesticide use in pigeonpea at village level by 6-93%, within one season of IPM implementation without sacrificing yields (ICRISAT 2000). Thus, it has been shown that food legume IPM farmers made better profits not only through reduction in inputs on plant protection, but also through improved yields due to effective management of the pod-borer.

STAKEHOLDERS INVOLVEMENT AND FARMER PARTICIPATORY MODELS

In order to respond continuously to the changing needs and perceptions of the stakeholders, the IPM researchers in food legume crops should ensure the constant consultation with and involvement of stakeholders, which include mostly extensionists, private enterprise, NGOs/ CBOs and farmers groups themselves. Such interactions should be periodical, since IPM issues/options/ perceptions may well be influenced by the changing scenario in relative criticality of the pest caused losses, the need for alternative options and the investment worthiness of the crop, as influenced by crop production risks and market forces.

IPM researchers in food legumes should therefore remain in continuously contact with legume farmers' groups located near to their research centers, so to better understand the perceptions, priorities and preferences among the end users relating to the type of

IPM options that would be needed and so stand better chance of being adopted. Such model IPM farmers groups could be utilized for confidence building as well as training of farmers' cadre trainers at grassroots level for promoting legumes IPM technologies. In addition, they could also serve as farmer –to- farmer extension/communication means that could promote multiplier effects in awareness and adoption.

FUTURE THRUSTS FOR FOOD LEGUMES IPM RESEARCH

The future thrust and focuses of food legumes IPM research in the region should be on the following themes/outputs:

1. Strengthen pest monitoring by effective means such as pheromones and weather based advisory systems.
2. Periodic pest surveys to update their incidence, distribution, extent of losses.
3. Crop varieties with resistance/tolerance to important pests to be identified.
4. Economic thresholds for key pests to be generated, for promoting need-based control.
5. Beneficial cultural practices and augmentation/conservation of natural enemies to be identified
6. Use of safer/selective pesticides so to minimize adverse effects on the natural enemies
7. Use of bio-rationals and indigenous technologies as alternative to over dependence on chemical pesticides.
8. Periodic monitoring of insecticide resistance in key pests like *Helicoverpa*, *Spodoptera* and white fly.
9. Encourage farmers' participation in identifying the adoptable remedies.
10. Systems-based (ecosystem and area-based) approach rather than pest or crop based approach.

For impact making in IPM research on food legumes, it is important to initially judge the potential affordability/accessibility of the technologies in the context of Integrated Crop Management (ICM). Linking with crop improvement and crop production scientists, besides experts in socio-economic and extension is critical. Further linkages with stakeholders could strengthen both the scientific as well as the practical bias and holistic approach to develop appropriate IPM options. There is need for enhancing the level of scientific collaboration with International centers, especially those mandated for improvement in food legume crops (ICRISAT, ICARDA, IITA, CIAT). ICIPE being the Pan African lead center for advanced training and collaborative research in insect science and IPM is well endowed to provide the partnership in training and in joint research/development initiatives for IPM-ICM promotion in food legumes in Eastern Africa. The existing linkages of ICIPE, ICRISAT, ICARDA and CIAT in IPM networks and linking with the national research programs/institutions/scientists could be strengthened for such a partnership to be further developed for promotion of food legumes IPM-ICM in the region.

REFERENCES

Abate, T. 1988. Experiments with trap crops against African bollworm, *Heliothis armigera* in Ethiopia. *Entomologia. Experimentalis et Applicata* 48:135-140.

Abate, T. 1995. Pest management in lowland pulses: progress and prospects. p. 181-194. *In* Proc. 25th Anniversary of Nazareth Research Center, 22-23 September 1995, Melkassa, Ethiopia.

Abate, T., N. Ferede, and A. Kemal. 1985. A review of grain legume pest management research in Ethiopia. p. 327-44. *In* T. Abate (Ed.) *A Review of Crop Protection Research in Ethiopia.* Institute of Agricultural Research, Addis Ababa.

Abate, T., A. Gashawbeza, and G. Amannual. 1985a. Ecology of bean stem maggots in Ethiopia. Presented at the 2nd International Crop Science Conference, eastern and southern Africa, Malawi, Feb. 19-24, 1995.

Ali, K. 1997. Economic threshold for pea aphid. *Pest Mgt. J.Eth.* 1-2: 63-68.

Ali, K. 1999. Population dynamics of Acyrthosiphon pisum (Homoptera: Aphididae) and its natural enemies on Pisum sativum. Pest Mgt. J. Eth. 1-2: 23-29.

Ali, K. 2002. An integrated approach to pest management in field pea, *Pisum sativum* (L.), with emphasis on pea aphid, *Acyrthosiphon pisum* (Harris). Ph. D. Thesis. University of the Free State, Bloemfontein, South Africa.

Ali, K., and T. Habtewold. 1994. Research on insect pests of cool-season food legumes. p. 367-396. *In* Asfaw Telaye et al. (Eds.) *Cool-sSeason Food legumes of Ethiopia.* Proc. First National Coolseason Food Legumes Review Conference. Addis Ababa, Ethiopia.

Baya, J., S. Sithanantham, J. Mueke, C. Kariuki, G.V.R. Rao, E. Osir, and J. Baumgaertner. 2001. Natural occurrence, characterization and biological potential evaluation of nuclear polyhedrosis virus (NPV) on *Helicoverpa armigera* in Kenya. p. 6-7. *In* Proc.13th Entomological Congress, 2 – 5 July 2001, Pietermaritzburg, South Africa.

Bejiga, G., M. Eshete, and Y. Anbesa. 1996a. Improved cultivars and production technology of chickpea in Ethiopia. Research Bulletin No. 2. DZARC, AUA, Debre Zeit, Ethiopia.

Bejiga, G., M. Eshete, and Y. Anbesa. 1996b. Improved cultivars and production technology of lentil in Ethiopia. Research Bulletin No. 3. DZARC, AUA, Debre Zeit, Ethiopia.

Chichaybelu, M., and G. Bejiga. 1999. Farmers' perception of the importance and management of chickpea insect pests in Ethiopia. *NVRSRP Newsletter* 2: 35-37.

Damte,T., and M. Chichaybelu. 2001. Pea aphid (*Acyrthosiphon pisum,* Homoptera: Aphididae) management in lentil (*Lens culinaries).* Paper Presented at the Nile Valley and Red Sea Regional Program Regional Coordination Meeting, Food Legume Research Program, 23-27 September, Cairo, Egypt: ICARDA.

Damte, T., and M. Chichaybelu. 2002. The efficacy of some botanicals in controlling Adzuki Bean Beetle (*Callosobruchus chinensis)* in stored chickpea. *Tropical Sciences* 42: 192-195.

Duffield, S. J. 1994. *Trichogramma* egg parasitism of *Helicoverpa armigera* on short duration pigeonpea intercultured with sorghum. *Entomol. Exp. Appl.* 71: 289-96.

Duffield, S. J., and Y.V.R. Reddy. 1997. Distribution and movement of predators of *Helicoverpa armigera* in intercropped sorghum and short-duration pigeonpea. *Crop Research* 14: 315-35.

Ferede, N. 1994. Studies on the economic importance of and control of bean bruchids in haricot bean. M. Sc. Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia. 103 pp.

Goftishu., M. 2001. Advanced screening of field pea lines for their resistance/tolerance to pea aphid (*Acyrthosiphon pisum*). Entomology progress report for the period of 2001. Sinana Agricultural Research Centre, EARO, Addis Ababa, Ethiopia.

ICRISAT (International Crops Research Institute for Semi Arid Tropics). 2000. ICRISAT–IFAD, TAG 330 Special Asia Legumes IPM Project 2000. Final Technical Report.

Kyamanywa, S., and J.K.O. Ampofo. 1988. Effect of cowpea/maize mixed cropping on the incidence light at the cowpea canopy and flower thrips *Megalurothrips sjostedti* (Tryboomn) (Thripidae). *Insect Science and its Application* 9: 255-259.

Manjunath, T. M., V.S. Bhatnagar, C.S. Pawar, and S. Sithanantham. 1989. Economic importance of *Heliothis* spp. in India and an assessment of their natural enemies and host plants. p. 197-228. *In* E. G. King et al. (Eds.) Proceedings of Workshop on Biological Control of Heliothis: Increasing the effectiveness of Natural enemies.New Delhi: Far East, Reg. Res. Off., US Dep. Agric.

Minja, E. M. 1997. Insect pests of pigeonpea in Kenya, Malawi, Tanzania and Uganda; and grain yield losses in Kenya – a consultant's report. Bulawayo, Zimbabwe: International Crops Research Institute of Semi-Arid Tropics (South East Africa Reg.). 65p.

Minja, E. M., T.G. Shanower, J.M. Songa, J.M. Ong'aro, P. Mviha, F.A. Mayaka, and H.I. Okurut-Akol. 1996a. Pigeonpea seed damage from insect pests on farmers' field in Kenya, Malawi, Tanzania and Uganda. *International Chickpea and Pigeonpea Newsletter* 3: 97-98.

Minja, E.M., T.G. Shanower, J.M. Songa, and J.M. Ong'aro. 1996b. Pigeonpea farmers in southern and eastern Africa: Do they spray their crop? *International Chickpea and Pigeonpea Newsletter* 3: 98-100.

Minja, E.M., T.G. Shanower, S.N. Silim, and O. Karuru. 2000a. Efficacy of different insecticides for pigeonpea pest management in Kenya. *International Chickpea and Pigeonpea Newsletter* 7: 53-55.

Minja, E.M., S.N. Silim, and O. Karuru. 2000b. Insect pest incidence on long-duration Uganda pigeonpea lines at Kabete in Kenya. *International Chickpea and Pigeonpea Newsletter* 7: 56-57.

Minja E., S. Sithanantham, J.M. Baya, J.M. Songa, O. Karuru, and T. Chole. 2003. Field evaluation of nucleopolyhedrosis virus for control of *Helicoverpa armigera* on pigeon pea in Kenya. Paper presented at the 15th Biennial Conference of African Association of Insect Scientists (AAIS), 4 - 13 June 2003, ICIPE, Nairobi - Kenya.

Mulatu, B., and T. Gebremedhin. 2000. Oviposition-deterrent and toxic effects of various botanicals on the adzuki bean beetle, *Callosobruchus chinensis* L. *Insect Science and its Application* 20: 33-38.

Okeyo-Owour, J. B., G.W. Oloo, and P.O. Agwaro. 1991. Natural enemies of legumes pod borer, *Maruca testulalis* Geyer (Lepidoptera: Pyralidae) in small scale farming systems of western Kenya. *Insect Science and its Applications* 12: 35-42.

Pawar, C. S., Y.S. Bhatnagar, and D.R. Jadhav. 1986. *Heliothis* species and their natural enemies, with their potential for biological control. *Proc. Indian Academy of Sciences (A.S.)* 95: 695-703.

Pawar, C.S., S. Sithanantham, H.C. Sharma, S.L. Taneja, P.W. Amin, K. Leuschner, and W. Reed. 1984. Use and development of insect traps at ICRISAT. p. 133-150. *In* Proc. National Seminar on Use of Traps in Pests/Vector Research and Control, 10-11 March 1984, Kalyani, West Bengal, India.

Ranga Rao, G.V., S. Pande, Y.V.R. Reddy, Narayana Rao, and V. Rameshwar Rao. 2002. Insect pests and diseases of agricultural importance and their management in India. p. 85-103. *In* Proc. National Seminar on Resources Management in Plant Protection Volume 1, Plant Protection Association of India, NPPTI Campus 14-15th November 2002, Rajendra Nagar, Hyderabad-500030, Andhra Pradesh, India.

Reed, W., C. Cardona, S. Sithanantham, and S.S. Lateef. 1987. Chickpea insect pests and their control. p. 283-318. *In* M.C. Saxena and K.B. Singh (Eds.) *The Chickpea.* Wallingford: CAB International.

Reed, W., S.S. Lateef, and S. Sithanantham. 1989. Compatibility of host plant resistance and biological control of *Heliothis* spp. p. 529-535. *In* Proc. International Workshop on Biological Control of *Heliothis*, 11-15 November, 1985, New Delhi, India: U.S.D.A.

Shanower, T. G., V. Anita, V.R. Bhagwat, and H. Dreyer. 1996. Parasitism of *Clavigralla* spp. (Hemiptera: Coreidae) eggs by *Gryon clavigrallae* Mineo (Hymenoptera: Scelionidae). *J. Biological Control* (In press).

Shanower, T. G. T.G. Kelley, and S.E. Cowgill. 1997. Development of effective and environmentally sound strategies to control *Helicoverpa armigera* in pigeonpea and chickpea production systems. p. 255-76. *In* R. K. Saini (Ed.) *Tropical Entomology*. Proc. Third International Conference of Tropical Entomology, Nairobi, Kenya: ICIPE Science Press.

Silim-Nahdy, M., and J.A. Agona. 2001. Integrated management of post harvest pests of pigeonpea: Status and potential. p. 174-180. *In* S.N. Silim et al. (Eds.) *Status and Potential of Pigeonpea in Eastern and Southern Africa.* Proc. Regional Workshop, 12-15 Sep 2000, Nairobi, Kenya. B.5030, Gembloux,Belgium: Gembloux Agricultural University and Patancheru 502324, Andhra Pradesh, India: International Crops Research Institute for the Semi-arid Tropics.

Sithanantham, S., and N.K. Maniania. 2001. Augmentation Biocontrol: Recent Progress and Emerging Opportunities. p. 63-73. *In* S.P. Singh *et al.* (Eds.) *Biological Control.* Project Directorate for Biological Control, Bangalore, India.

Sithanantham, S., O. Tahhan, G. Hariri, and W. Reed. 1981a. The impact of winter sown chickpeas on insect pests and their management. *In* Proc. International Workshop on *Ascochyta* Blight and Winter Sowing of Chickpeas, ICARDA, 4-7 May, 1981, Aleppo, Syria: ICARDA.

Sithanantham, S., S.S. Lateef, and W. Reed. 1981b. Pod fly susceptibility in pigeonpea: some aspects of oviposition preference. p. 329-335. *In* Y. L. Nene and V. Kumble (Eds.) Proc. International Workshop on Pigeonpea. Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-arid Tropics.

Sithanantham, S., S.S. Lateef, and W. Reed. 1983a. Survey of pigeonpea pod fly parasites in India. *International Pigeonpea Newsletter* 2: 66-68.

Sithanantham, S., V. Rameshwar Rao, and M.A. Ghaffar. 1983b. International review of crops losses caused by insects on Chickpea. Crop losses due to insect pests. *Indian J. Entomology, Special Issue* 2: 269-283.

Sithanantham, S., V. Rameshwar Rao, and W. Reed. 1987. Parasites of the pigeonpea podfly, *Melanagromyza obtuse* (Malloch), in India. *J. Biological Control* 1: 10-16.

Sithanantham, S. and Y.V.R. Reddy. 1990. Arthropods associated with pigeonpea in Kenya, Malawi and Zambia. *International Pigeonpea Newsletter* 11: 17-18.

Teshome, L. 1993. Evaluation of neem (*Azadirachta indica*) and vegetable oils against the adzuki bean beetle (*Callosobruchus chinensis*) (Abstract). p. 31. *In* Proc. Joint EPC//CEE Conference. Crop Protection Society of Ethiopia, Addis Ababa.

Van den Berg, H. 1993. Natural control of *Helicoverpa armigera* in smallholder crops in East Africa. Ph. D. Thesis. Wageningen Agricultural Univeristy, Wageningen. 233 pp.

Wale, M. 2002. Population dynamics of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae) on field pea (*Pisum sativum* L.) in northern Ethiopia. *Insect Science and its Application* 22: 131-137.

Wale, M., B. Jembere, and B. Seyoum. 2000. Biology of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae) on cool season food legumes. *Insect Science and its applications* 20: 171-180.

Insect-Pest Management Research of Faba Bean and Field Pea in Ethiopia

Kemal Ali

Ethiopian Agricultural Research Organization
P.O. Box 2003, Addis Ababa, Ethiopia

ABSTRACT

Field pea and faba bean are two of the most important pulse crops in Ethiopia. The productions of these crops have been very low, and one major limiting factor has been susceptibility to insect-pests that adversely affect yield. The crops are damaged by > 12 insect species, of which pea aphid (*Acyrthosiphon pisum*), pea weevil (*Bruchus pisorum*), black bean aphid (*Aphis fabae*), groundnut aphid (*Aphis craccivora*), African bollworm (*Helicoverpa armigera*), cutworm (*Agrotis segetum*) and adzuki bean beetle (*Callosobruchus chinensis*) are the major pests. The severity of infestation of different pests varies depending on the location and season. Although it is possible to control these pests by agricultural chemicals, economic and environmental concerns limit their use in resource-poor farmers' fields. So for, limited efforts have been made on the integrated control of these pests. Research and development approaches that have contributed to integration of host plant resistance, cultural and chemical controls have been discussed. Recent research results on biology and population dynamics of key insect-pests are also reviewed. Future research must focus on environmentally sound pest management strategies that are compatible with the needs and limitations of field pea and faba bean farmers.

INTRODUCTION

Field pea and faba bean are important grain legume crops in Ethiopia, providing high quality vegetable protein. They also play an important role in sustaining the productivity of the farming systems. Their high protein concentration makes them a valuable yet cheap substitute for meat and other high-protein animal products in the developing countries. They are cultivated by resource-poor farmers as subsistence crops, mainly for self-consumption, in low input agriculture where sustainability is a major concern. Yield of these pulses vary considerably among locations, cultivars, seasons, and cropping systems.

In most areas, insect-pests are the most important yield constraint and the greatest cause of yield variation. More than a dozen species of insects have been found feeding on these two crops, although only a few of these cause significant and consistent damage to the crops. Of these, aphids (*Acyrthosiphon pisum* Harris, *Aphis craccivora* Koch, *A. fabae* Scopoli), pod borer (*Helicoverpa armigera* Hübner), and cutworms (*Agrotis segetum* Sch.) in the field and seed beetles (*Callosobruchus chinensis* L. & *C. maculates* F.) in the store are most damaging. Research on these pests has been reviewed by Kemal and Tibebu (1994). Pea aphid and the recently reported pea weevil (*Bruchus pisorum* L.), are the main pests occurring in mid-altitude areas in high densities causing substantial yield losses (Birhane et al., 2001).

Research has focused on these two pests because other pests, i.e., cutworms and pod borer are sporadic in nature. This paper attempts to summarize our current knowledge of the key insect-pest constraints facing field pea and faba beans. Priorities for research are also suggested. This review by no means is complete. Nevertheless, it is believed that such a compilation will provide useful information in setting priorities for research and development in the major production regions of these crops.

INSECT-PEST SURVEYS

Field pea and faba bean are grown over a wide range of environments and are subject to insect-pest attack. However, few of these can completely destroy or greatly reduce the quantity and quality of their products. There is great variation in the occurrence of these pests, both between and within the crop species and across time and space. Insect-pests that are known to severely reduce yields are given in Table 1.

Pod borer is sporadically active causing widespread damage and loss of pods and grains. Black bean aphid is also a sporadic pest in some regions where the crops are grown. The infestation causes severe distortion of the apical leaves and pods, but their development is greatly influenced by environmental conditions.

In pea, pea aphid (*A. pisum*) is very commonly found in crops grown in mid-altitude areas (1800–2200 m asl) and remains the most damaging by direct feeding. The seriousness of the pest depends on agro-climatic (mostly temperature & rain fall) conditions that prevail during the cropping season. Their incidence diminishes to insignificance at higher altitudes, with cool temperatures and high rainfall since its development and spread is arrested. Pea weevil, *Bruchus pisorum,* is the only pest added to the list of the previous survey report. The surveys conducted in the Amhara region have revealed the occurrence of pea weevil with usually wide distribution and often-high incidence (Birhane et al., 2001). The pest was reported in 1988 in western Amhara regional state around Ebinat, Belesa, Wegera and Jan Amora woredas of northern Gonder. Lately, it invaded western and eastern Gojam, southern Gonder and southern Wello resulting in severe damage on field pea with substantial yield losses. Very recently, the pest was found on field pea seeds collected around Debre Zeit areas. This new pest is slowly spreading throughout the country that could threaten the future production of field pea in Shoa and Arsi. The spread of the pest with seed materials is likely to be more rapid and difficult to control. The larvae of this weevil reduce yield and quality by feeding on the developing seeds. Only one larva develops to maturity in an individual seed, but consumes a large portion of that seed. This pest can be devastating to developing and maturing seed if adequate management precautions are not taken.

Table 1. Insect-pests affecting faba bean and field pea in Ethiopia.

Crop	Common Name	Scientific name
Field pea	Pea aphid	Acyrthosiphon pisum
	Pea weevil	*Bruchus pisorum*
	African bollworm	*Helicoverpa armigera*
	Common cutworm	*Agrotis segetum*
	Adzuki bean beetle	*Callosobruchus chinensis*
	Bean bruchid	*C. maculates*
Faba bean	Groundnut aphid	*Aphis craccivora*
	Black bean aphid	*Aphis fabae*
	African bollworm	*H. armigera*
	Common cutworm	*S. segetum*
	Adzuki bean beetle	*C. chinensis*
	Bean bruchid	*C. maculatus*
	Thrips	*Caliothrips impusus*
	Shiny Cereal Weevil	*Nematocerus brachyderes*

INSECT-PESTS OF FIELD PEA

Biology

Pea aphid (*Acyrthosiphon pisum*): Recently, Kemal (2002), Melaku et al. (2000), Tebekew (1999) and several others provided a detailed account of different aspects of *A. pisum* biology. The pre-reproductive period of pea aphid reared on faba bean in greenhouse at 20±0.5^{0}C and 70-80% RH varied from 7.6 days (Frazer 1972) to 8.9 days (Cartier, 1960) in Canada. Sandstrom (1994) reported a similar pre-reproductive period on pea cultivars. A parthenogenic female produces between 83.7 nymphs (Siddiqui et al., 1973) on field pea at 20^{0}C and 60± 10RH to 101 on alfalfa at 14.8^{0}C, and 50-70% RH (Campell and Mackauer, 1977), although individuals may produce as many as 128 on pea at 20^{0}C (Markkula and Roukka, 1971).

Maximum mean daily fecundity of pea aphid on peas ranged between 8 nymphs (Siddiqui et al., 1973) and 12 nymphs per day at 20^{0}C and 60-70± 10 RH (Murdie 1969), while it was only 5.3 to 6.8 nymphs under the same environment (Sandstrom, 1994). The life cycle was completed in 9.4 days with total life span and adult longevity of 24.4 and 18.0 days, respectively.

The Biology of pea aphid under Ethiopian conditions was studied in some detail (Kemal, 2002). The study was carried out in an insectary under natural photoperiod with mean temperature during the experiment of 22.7^{0}C (day) and 15.5^{0}C (night) and relative humidity of 70-94%. The pre-emergence period ranged between 10.1 to 11.1 days. A parthenogenic female produces between 74.9 to 95.4 nymphs with an average of 84.7. The adult reproductive and post-reproductive periods of 15.5 and 10.6 days, respectively, were recorded. Average maximum and mean daily fecundity were 10.9 and 5.5 respectively. The life span of the pea aphid ranged from 30.7 to 32.4 days with a generation time of 14.2.

Melaku et al. (2000) studied the biology of pea aphid on faba bean, field pea, lentil and grass pea under minimum and maximum temperatures of 6.3^{0}C and 25.3^{0}C. They reported mean nymphal period of 9.4 days on faba bean), 9.4 days on field pea and lentil, and 9.3 days on grass pea. Mean total fecundity was significantly different among the legumes used in the experiment (Melaku et al., 2000). Average total fecundity was 78.9 nymphs (range 35 to 145). The highest was on lentil (115 nymphs) and the lowest was on field pea (58 nymphs). Mean reproductive period ranged between 9.8 days (faba bean) and 17.4 days on lentil. The life span was between 20-35 days with mean generation time of 14.3 days to 18.1 on faba bean and lentil, respectively.

It is clear from these studies that the growth and development of pea aphid is temperature dependent. According to Morgan et al. (2001), the optimum temperature for rapid development ranged from 12^{0}C to 20^{0}C.

In another study, Melaku et al. (2003) investigated the effect of aphid density on fecundity and survival under greenhouse. The environment in which the experiment was carried out was not presented, especially temperature and relative humidly. Reproductive capacity and survival of four levels of aphid density (2, 6, 10, and 14 nymphs/seedling) were tested on faba bean, field pea, lentil and grass pea. The results showed that the number of nymphs produced per female decreased with increasing aphid density. At the lowest density of two aphids/plant, they produced significantly more nymphs per aphid (37.3) than at 6, 10 and 14 aphids/plant. Aphids fed on faba bean produced the lowest number of nymphs than the remaining host plants. Data on the survival indicated that decreasing survival with increasing aphid density was similar to that of nymphiposition.

Pea weevil: The biology of the pea weevil was studied at Ebinat and Adet in 1999 and 2000 by Birhane (2003). The eggs are cigar-shaped and yellowish in color. The young is small about 1 cm and is cream white, while the older instar is legless, curled, cream grub, which grows about 5 mm. The pupa is described as an exarate form, with the appendages free and not glued to the body, usually not covered by cocoon.

The preliminary biology study in the field have shown that a female can lay up to 60 eggs on a single pod and the young larvae hatched within a week of entry into the seed. Four larval instars were reported and the adult weevil emerged from the seed after ten days. Only one adult was emerged from a single seed.

Population Dynamics

Pea aphid (*A. pisum*): Since 1990, the pea aphid has become widely distributed over the country and is a pest of field pea, lentil and grass pea. The abundance of pea aphid has been studied in pea at Denbi and Kulumsa for three consecutive years (Kemal 1999). The author reported two peaks in population, one in late-august and the other in mid-September. The study describes seasonal changes in abundance of pea aphid in field pea. Such information is essential for designing an effective pest management program.

Flowering of pea peaked at the beginning of September, in about 45-50 days after emergence. Pods were formed, elongated, and filled in the first three weeks of October and matured and dried in the last week of November and first half of December. Each year, aphids first appeared in early-August, and their densities remained low through July and then increased to a peak in the latter half of August or first week of September. This pattern was observed at both locations and in all the three years. However, the population of aphids are influenced primarily by climatic differences in temperature and rainfall seasonality. The period of increase in aphid density in September (40-50 days after crop emergence) coincided with the period when the crop was flowering and producing pods. The population decline coincided with the period when the leaves on the last 25% of the nodes were senescing and pods were beginning to dry. In another study carried out at Adet and Zema, Melaku (2002) showed that pea aphid population peaked in August at Adet, and mostly in September at Zema. The author also reported a positive correlation with maximum temperatures and negative correlation with weekly rainfall although level of significance was not shown.

Economic Importance

Insect-pests attack field pea in the field and in storage, causing considerable losses. Field pea is grown under very variable conditions in the country, being cultivated in mid-altitude areas (1800-2200m asl) with average rainfall of 740 mm, and high altitude areas (> 2200 m asl) with average rainfall of 900 mm entirely under rain-fed. The crop is dependent on the rainy season (June – September) for initial growth and subsequent flowering. Early stoppage of rain during flowering, coupled with poor moisture conditions, render the plants extremely susceptible to attack and damage by aphids. The pest has been of considerable economic importance in the production of field pea, lentil and grass pea throughout many areas of Ethiopia. Since 1980, aphid infestation of varying intensity, particularly in the mid-altitude areas, has been present each year. Pea aphids feed in aggregation in the upper canopy of the plants on the growth tips of leaves, where they cause yellowing, stunting and even plant death.

In Ethiopia, avoidable yield loss in field pea reaches up to 70%, with an average of 37% in different regions and under different farming systems (Kemal, 1997; Lemma et al., 1996; Shambel et al., 1998). From yield loss assessments for four cultvars in Bale region, Lemma et al. (1996) reported a mean yield loss averaged over two locations of 29.7% (Dadimos), 32.7% (Tulushenen), 50.0% (G22763-2C) and 52.9% (Farmers' variety). The yield losses estimated by Shambel et al. (1998) are much lower than those of Lemma et al. (1996). The 1998 results from the same authors showed that the location mean of cv. G22763-2C and farmers' variety had the losses of 23.1% and 26.0%, respectively. Cultivars Tullushenen (4.8%) and Dadimos (16.1%) recorded the lowest losses compared to the above two cultivars.

Pea weevil is becoming a serious pest of pea. It was first observed in Sokota during 1994 and has since become one of the most destructive pests with recorded yield losses of up to 85% (Worku, 1998). An infestation level of 85% was recorded in Sokota in 2002 (PPRC, 2002).

Control Measures

Cultural: The use of cultural control practices is another important method that has tremendous scope in IPM. A cultural practice, as a pest management tool, is a neglected area of research that needs to be explored. Cultural practices employed within crop habitats can affect pest species and biological control agents directly by minimizing crop damage or indirectly by altering microclimatic conditions within the crop habitat. Activities that produce such microenvironment modifications include irrigation, fertilizer application, row spacing, seeding rate, planting time, intercropping and tillage. These practices may lead to substantial improvement in benefits of biological control, especially in cases where changes are more favourable towards natural enemy populations than the pest populations.

The cultivation of more than one crop in a field commonly referred to as mixed cropping or intercropping, is a popular cultural practice in virtually all subsistence agriculture. Multiple cropping systems have been suggested as a possible mechanism for the management of pest species. There are several types of multiple cropping systems, which are defined as the simultaneous cultivation of two or more crops in the same field. Although many intercropping systems may have evolved to take advantage of a beneficial plant-to-plant interaction (e.g. nitrogen fixation), some intercropping systems are being investigated and recommended for the reduction of insect pest load. Mixed cropping has been reported to promote natural biological control and reduce pest populations in certain crop combinations.

Field trials have also been conducted to manage various aphid species by intercropping. A mixture of cereals with grain legumes has been the most preferred combination by small-scale farmers in tropics. The effect of mixed cropping of field pea with faba bean, wheat, and Ethiopian mustard on the population dynamics of pea aphid and its natural enemies was studied at three locations (Kemal, 2002). Pure stands of field pea, faba bean, wheat and mustard, respectively, were established at a seedling rate of 150, 200, and 15 kg ha^{-1}. There were three mixed stands: field pea + faba bean at 112.5:50 kg ha^{-1}, field pea + wheat (112.5:37.5 kg ha^{-1}), and field pea + mustard (112.5:3.75 kg ha^{-1}). Overall and at all three locations, incidence and size of aphid colonies were the highest in monoculture field pea than was the case in the other three mixtures. At Holetta, average aphid densities per plant on monoculture field pea were significantly different compared with other mixed cropping. At Denbi, there were significantly more aphids per plant in sole field pea plots than in mixtures with wheat and mustard. The number of pests per plant was not affected by the cropping system at Kulumsa. However, the number of aphids per plant in the field pea/mustard mixture was smaller compared to other treatments, but the difference was not significant. The pea aphid densities were different between locations, with lower values for the cool, high rainfall site (Holetta). The cropping system had no impact on the degree of parasitization by *Apidius* spp. (Braconidae), which were not significantly different at all experimental sites. The population of numbers of predators were too low to be assessed.

There were significant differences regarding field pea grain yield at all locations, in particular reflecting reduced yield when mixed with mustard (Table 2). Mixed crops produced mean grain yield of 2108 kg/ha (ranging from 1354 to 3221 kg/ha), 1891 kg/ha (range of 911 to 3853 kg/ha), and 2046 kg/ha (range of 1432 to 3081 kg/ha) at Holetta, Denbi and Kulumsa, respectively.

Land equivalent values (LER) calculated from grain yield was higher than that of field pea/mustard mixed intercropping at all locations, whilst only a minor advantage was obtained from mixed cropping of field pea/wheat at Kulumsa. Field pea intercropped with mustard gave higher LERs of 1.72 at Holetta followed by Kulumsa (1.3) (Table 3).

In terms of economic return, the highest net benefit of 10042, 12966 and 9431 birr ha^{-1} was obtained when field pea was mixed-cropped with mustard at Holetta, Denbi and Kulumsa, respectively (Table 3). The potential of mixed cropping, especially as a component of an integrated pest management system in Ethiopia, is promising and deserves to be investigated further. This study presented some evidence that mixed cropping might provide some yield stability under adverse pest conditions. If the above results are confirmed under field conditions, intercropping with mustard could contribute towards controlling pea aphid population build up in an IPM program.

Adjusting planting time and fertilizer application to escape pest damage is the most important means of keeping pest damage below economic level. For example, early- planting is perhaps the most effective means of controlling stem borers on sorghum and maize in many parts of Africa and is widely practiced by farmers. Early- planting is a means of reducing damage of pea aphid on field pea. Effect of variation in planting date, fertilizer and cultivars on damage of to plants was studied in field trials over three locations (Kemal, 2002). A field trial was carried out to investigate the effect of sowing date and fertilizer application (18 kg N and 46 kg P_2O_5 per ha) on pea aphid infestation levels using three cultivars at three locations. The experiments were carried out at Holetta (2400 m asl), Denbi (1900 m asl) and Kulumsa (2200 m asl). The experimental units were established on fields where wheat (at Kulumsa and Denbi) or potato (at Holetta) had been grown in the previous year. All treatment combinations were arranged factorially within a randomised complete block design and replicated four times. Analysis of variance on stand count at emergence was initially performed separately for each location, but the test for homogeneity of variance showed non-significant χ^2 values at Denbi and Kulumsa. Therefore, the data for all variables for the two locations were pooled and analysed and subsequently interpretations were based on the combined analysis.

The probability values for the partial ANOVA indicated that fertilizer application significantly influenced the density of pea aphid population at Holetta. Fertilizer, sowing date and field pea variety interactions were non-significant, indicating that the three factors had little or no effect on each other. Pea aphid population density was not significantly affected by either fertilizer application or by sowing date, both at Denbi and Kulumsa. However, fertilizer x sowing was significant for aphid infestation. Significant differences were found among fertilizer application, varieties and location.

There was a significant effect resulting from fertilizer application on most of attributes under study at Holetta. The grain yield, pods per plant and 100-seed weight increased significantly in the fertilized plots versus the non-fertilized ones. The use of fertilizer significantly increased pods per plant, biomass and seed yield by 12, 21 and 28%, respectively, over the control at Holetta. Neither the fertilizer, nor the sowing date had any statistically significant effect on the number of pods per plant, seeds per pod, biomass and grain yields for the three varieties of field pea used in the study at Denbi and Kulumsa.

A field experiment to identify appropriate planting time in relation to pea aphid populations was carried out at Adet and Zema, northwestern Ethiopia, for three years. At Adet, grain yield of field pea was observed to increase as planting was delayed from mid-May to late-June (Melaku, 2002). The highest grain yield of 0.63 t/ha was obtained from June 30 planting. A mean of 0.32 t/ha more yield was recorded from planting at the end of June compared with May and up to the second week of June, indicating that the best time for planting field pea at Adet was from mid- to late-June. Unlike at Adet, grain yield generally decreased with delay in planting at Zema. Planting during the first two weeks of June gave the highest yield of 1.07 t/ha (Melaku 2002). According to the author, planting at Zema could be advanced for about one week than at Adet.

Table 2. Effect of different intercropping combinations on biomass and grain yields (kg/ha) of field pea,faba bean, wheat and Ethiopian mustard at Holetta, Denbi and Kulumsa, 2000.

	Biomass yield (kg/ha)			Grain yield (kg/ha)			
Crop treatment	Fp	Fb	W	Fp	Fb	W	M
Holetta							
Field pea pure stand (Fp)	4325a	-	-	1640a*	-	-	
Faba bean pure stand (Fb)	-	3377a	-	-	1722a	-	
Wheat pure stand (W)	-	-	9887a	-	-	2010a	
Mustard pure stand (M)	-	-	-	-	-	-	3087a
Fp+Fb	3450b	1209b	-	1236b	118b	-	
Fp+M	1525c	-	-	496c	-		2725a
Fp+W	3637a	-	2062b	1337b	-	411b	
Denbi							
Crop treatment							
Field pea pure stand (Fp)	2112ab	-	-	395a	-	-	-
Faba bean pure stand (Fb)	-	7587a	-	-	3310a	-	-
Wheat pure stand (W)	-	-	8425a	-	-	3236a	-
Mustard pure stand (M)	-	-	-	-	-	-	3925a
Fp+Fb	2450a	2150b	-	211b	699b	-	-
Fp+M	1750b	-	-	91c	-	-	3762a
Fp+W	2350a	-	2425b	160bc	-	751b	-
Kulumsa							
Crop treatment							
Field pea pure stand (Fp)	5362a	-	-	1231a	-	-	-
Faba bean pure stand (Fb)	-	10,312a	-	-	5662a	-	-
Wheat pure stand (W)	-	-	6687a	-	-	2377a	-
Mustard pure stand (M)	-	-	-	-	-	-	3712a
Fp+Fb	4850a	1125b	-	930b	695b	-	-
Fp+M	3737b	-	-	917b	-	-	2162b
Fp+W	4512ab	-	437b	1126ab	-	306b	-

*Means within column, without letters in common, differ significantly at p<0.05 (LSD). Source: Kemal (2002).

Table 3. Land Equivalent Ratio (LER) and net economic benefit (birr, 1US$ = 8.50 birr) of different intercropping patterns and in pure stand for field pea, faba bean, wheat and Ethiopian mustard based on the mean grain yield at Holetta, Denbi and Kulumsa, 2000.

Crop treatment	Fp	Fb	W	M	Total	Net benefit (birr/ha)*
Holetta						
Field pea (Fp)	1.00 a	-	-	-	1.00	3530
Faba bean (Fb)	-	1.00 a	-	-	1.00	2728
Wheat (W)	-	-	1.00 a	-	1.00	3251
Mustard (M)	-	-	-	1.00 a	1.00	10750
Fp+Fb	0.76 b	0.07 b	-	-	0.83	2720
Fp+W	0.31c	-	0.20 b		0.51	3563
Fp+M	0.83b	-	-	0.89 a	1.72	10042
Denbi						
Field pea (Fp)	1.00 a	-	-	-	1.00	417
Faba bean (Fb)	-	1.00 a	-	-	1.00	5904
Wheat (W)	-	-	1.00 a	-	1.00	5457
Mustard (M)	-	-	-	1.00a	1.00	13683
Fp+Fb	0.58b	0.21 b	-	-	0.79	1329
Fp+W	0.41 bc	-	0.13 b	-	0.54	1233
Fp+M	0.25 c	-	-	0.98a	1.23	12966
Kulumsa						
Field pea (Fp)	1.00 a	-	-	-	1.00	2507
Faba bean (Fb)	-	1.00 a	-	-	1.00	10608
Wheat (W)	-	-	1.00 a	-	1.00	3912
Mustard (M)	-	-	-	1.00a	1.00	12938
Fp+Fb	0.76b	0.13 b	-	-	0.89	3109
Fp+W	0.95 a	-	0.23 b	-	1.18	2847
Fp+M	0.75 b	-	-	0.59 b	1.34	9431

* Market price of field pea @ Ethiopian birr 2.50/kg, faba bean @ 2.00/kg, wheat 1.80/kg and mustard @ 3.50/kg; birr 8.50 = approx. US$ 1, April 2001. Source: Kemal (2002).

Biological: Progress and achievements in biological control of insect-pests of tropical crops clearly show that the use of predators, parasitoids and pathogens for pest control, either by introduction from other sources or by exploiting those already in the area, has proven effective and economically beneficial. Perhaps the most effective natural control agents for the control of explosive pest populations in annual crops are entomopathogens. Entomopathogenic fungi constitute a unique group of insect pathogens. Some success with *Beauveria bassiana* and *Metarhizium anisopliae* against pea aphid has been reported elsewhere. Coocinellids also play an important role in aphid population regulation and are known to have the strongest impact on all aphidophagus insects.

The effective predator, *Hippodamia variegata* (Coccinelidae), and an entomopathogenic fungus, *B. bassiana* in regulating pea aphid populations on field pea cv. Mohanderfer were evaluated in field cages (Kemal, 2002). Caged plants were inoculated with the same initial density of aphids (one aphid/plant), and the predator or fungus bio-control agents were introduced after the population had reached 10-12 aphids/plant. After three weeks of coccinellid introduction aphid incidence was significantly lower in the *H. variegata* treatments than in the *Beauveria* and infested control treatments. Weekly pea aphid population trend averaged across replication for live aphids in the presence of and absence of natural enemies is shown in Fig. 1. Coccinellid-treated plots had fewer aphids (52/sampling unit) in comparison to fungus-treated (102/sampling unit) and infested control (108) plots (Table 4). The results indicated that coccinellid applied at one adult per 200 pea aphids provided the best control and optimum grain yield. The grain yield in the fungus-treated plots was comparable to the infested untreated plots.

Table 4. Yield of field pea and yield loss due to pea aphid infestation in plants treated with *Hippodamia variegata* and *Beauveria bassiana* in 2001.

	Yield (kg/ha)		
Treatment	Biological*	Grain	Yield loss (%)
CI (infested control)	5390c	1700c	22.0
CII (uninfested control)	6630a	2180a	-
A (*H. variegata*)	6370ab	2000b	8.3
B (*B. bassiana*)	5870bc	1830c	16.0
CV (%)	6.48	7.14	

*Means followed by the same letter are not significantly different at P =0.005 (LSD). Source: Kemal (2002).

Host Plant Resistance

Plant resistance to pea aphid may be especially important control measure in crops with a narrow profit margin, such as field pea. It is the least expensive method of crop protection and perhaps the only one available to resource-poor, small-scale farmers in the developing world. The use of resistant pea varieties may reduce economic loss for *A. pisum*, and it may reduce the economic and environmental costs associated with the use of insecticides.

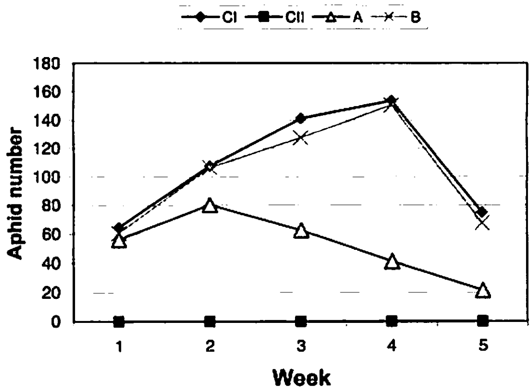


Fig. 1. Average number of aphids per 0.25 m² cardboard treated with *Hippodamia variegata* and *Beauveria bassiana*. CI = infested control; CII = uninfested control; A = treated with *H. variegata;* B = treated with *B. bassiana*.

Extensive screening for resistance to pea aphid has been carried out at Kulumsa, Denbi, Adet and Sinana Agricultural Research Centres. Despite intensive screening efforts, it is difficult to find substantial levels of host plant resistance. However, progress in finding tolerant lines has been made. At present no insect resistance cultivars of this crop have been released to growers. However, efficient field and greenhouse procedures to evaluate field pea lines for resistance to pea aphid have been developed. Screening of large number of germplasm accessions is more efficiently accomplished in the field where the pest pressure is reliable. Evaluation of host plant resistance to pea aphid is largely based on number of aphids per plant.

Muluken (2001) screened 131 field pea genotypes in a field naturally infested with pea aphid. All the genotypes were susceptible in terms of mean aphid population. From the evaluation of more than 600 germplasm accessions and breeding lines evaluated from 1990-2000 under field conditions, 16 pea aphid resistant lines were identified. These selected lines together with released cultivars from Ethiopia and South Africa were further tested under greenhouse conditions. Genotypes differed significantly in terms of pea aphid incidence at individual scoring dates and averaged overall scoring dates (Table 5). By the third week, most of the plants had scores of 6, and were thus all within the susceptible range, indicating that the length of time of the test was sufficient to detect damage. Furthermore, none of the 30 genotypes investigated in this study showed a high level of resistance. However, Six lines, viz., Holetta Local-90, 305ps210689, 061K-2P-2/9/2, 061K-2P-14/7/1, JI898 and 304WA1101937 and one susceptible line, NEP874UK, were selected from screening test based on their performance and subjected to more intensive tests to ascertain their resistance traits. Components and mechanisms of resistance in these lines to pea aphid were investigated in a greenhouse under natural photoperiod with mean temperature during the experiment of 22.7°C (day) and 15.8°C (night) and relative humidity of 70-94% (Kemal, 2002).

Antibiosis: Studies on antibiosis involved rearing cohorts of apterae aphid on these cultivars and comparing them in respect of the number of aphids surviving to reproduce, the fecundity, the duration of nymphiposition, the net reproductive rate, the intrinsic rate of increase, the finite rate of increase and doubling time. Nymph production on field pea lines is presented in Table 6. The results indicated that lines 061K-2P-2/9/2 and 304WA1101937 had significantly lower antibiosis than Holetta Local-90, 305ps210689 and 061K-2P-14/7/1. The number of nymphs produced ranged from an average of 95.4±9.1 nymphs from adults fed on line 304WA1101937 to 74.9±9.0 nymphs from adults fed on line Holetta Local-90, with an overall mean of 84.7±7.5.

The r_m (intrinsic rate of increase) of *A. pisum* on all lines was not significant, indicating that separation of lines having the various combinations of antibiosis is not possible. Mean generation and doubling time were similar among aphids reared on the seven genotypes (Table 7).

Antixenosis: The antixenosis (non-preference) properties of the field pea genotypes were also examined by Kemal (2000). There were significant differences among the seven entries for antixenosis. The results showed that the line 304WA1101937 consistently sustained the highest number of aphids for settling and development. This shows the involvement of antixenosis (non-preference) as a mechanism of resistance to the pest in field pea.

Tolerance: The seven field pea entries were studied for their tolerance properties in a pot study. Significant differences were noted between uninfested tolerant test entries in plant growth, number of leaves, fresh and dry plant mass at the end of the test, indicating that the genotypes were not similar in these parameters. In infested plants, lines 061-2P-2/9/2, 061K 2P11/7/1 and JI 898 had significantly more growth than the remaining lines, indicating genotypic differences. Significant differences were also observed in number of leaves, fresh plant weight and dry plant weight (Table 8), indicating the presence of genotypic differences in tolerance to the aphid infestation.

Resistance Index: Normalized indices for antibiosis, tolerance and antixenosis for pea aphid populations are presented in Table 9. The resistance index (RI) ranks the lines in terms of the combination of their resistance components and does not indicate any statistical differences. A plant resistance index was calculated for each entry using the following equation: 1/(xyz), where x is the antibiosis index, y is the antixenosis and z is tolerance indices (Inayatullah et al., 1990). The use of resistance index in Table 9 is a simplified way to simultaneously present and evaluate all three-resistance mechanisms, and provides a single value to aid in determining appropriate resistant lines for crossing. In this case, all mechanisms were weighted equally, but if particular component was to be deemed more important in a breeding program, it could be weighted accordingly.

The normalized indices for the three components of resistance are shown in Table 10. The data indicate that lines Holetta Local-90, 305PS 210687 and NEP 874 UK are more resistant than the remaining lines. The most susceptible lines appeared to be 061K-2P-2/9/2, 061K-2P-14/7/1, JI-898 and 305PS 210687, albeit that these lines were not as resistant in these tests as they were in the field. In part, this lack of resistance appears to have been the result of their low antibiosis.

Combining multiple categories of resistance in a single cultivar may prolong the resistance to *A. pisum* in adapted cultivars. The lack of high levels of reproductive antibiosis should negate or delay the development of *A. pisum* biotypes, and the tolerance response of these resistant sources should enable the aphids to survive on plants that will support predators and parasitoid populations. Although these reductions may not be great, they may be important under light to moderate field infestation levels when they are combined with the effects of pea aphid biological control agents. Host plant resistance at the levels discussed in this study may become an important component of an IPM system because of its compatibility with the use of natural enemies.

Pea weevil (Bruchus pisorum): Melaku et al. (2002) screened 336 field pea genotypes against pea weevil under field conditions at Ebinat under natural infestation. Variations in infestation level among tested entries were noted. However, most of the genotypes were susceptible and only 13 were found to be less susceptible with fewer than 10 eggs/5 plants. Three of the 336 genotypes had 100 to 200 eggs/5 plants while the majority had 30 to 40.

Chemical and Physical Control

Pea aphid: Although insecticides have been used as an important method of pest control, economic and environmental conditions would lead to a significant reduction in their use to control pests in legumes especially in developing countries. The pea aphid can be controlled by insecticides, but their widespread use in the largely subsistence farming systems, where the crop is grown, is not a viable option. Field trials for six consecutive years related to infestation levels with yield losses to establish economic threshold level using improved and farmers' variety were conducted at Kulumsa. Insecticide applications of pirimicarb were carried out at different infestation levels. Yields were maximum in fully protected plots for both cultivars. Considering the economics of pesticide application, the highest benefit was obtained from one spray at 35% level for cv. Mohanderfer. Therefore, optimum threshold levels for improved variety (Mohanderfer) and farmers' variety were about 30-35% infested leaflets coinciding with one or two applications, averaged over three years for each (Table 11) (Kemal, 1997).

Chemical control of pea aphid with selective insecticides and *neem* seed extract in field pea was carried out at Denbi for two years (1996-1997). The experimental seeds were treated with different rates of aqueous solutions of Gaucho 70% ws and promet 400cs and planted in furrows. Pirimicarb 50% wp (the standard check) gave the best aphid control with a mean number of aphids/plant of 5.7 and 3.1 in 1996 and 1997, respectively (Kemal 1998a, b). The highest rate of Gaucho (300g/100kg seed) significantly reduced the pest populations compared with *neem* and promet treatments. The seed-dressing chemicals failed to control aphids that appeared in high densities late in the season when the crop is at flowering and early-pod setting stages.

Grain yields were also statistically different at 5% significance level. Pirimicarb (2 sprays) resulted in the highest grain yield, 809 kg ha^{-1}, and 779 kg ha^{-1} in the two years, respectively (Table 12), followed by the highest rate of Gaucho.

In the greenhouse studies, the effect of *neem* seed kernel extract aqueous solution and commercial *neem* product, Multineem® on metamorphosis, longevity, and fecundity of pea aphid exposed as young nymphs and adults to treated plants and topical spray were determined (Kemal, 2002). The studies reported here were conducted by setting four different experiments. The insecticide was Multineem® 0.03% EC that is a natural insecticide derived from the *neem* tree that contains 3g/l azadirachtin. The results indicated reduced rate of increase of *A. pisum*, comprised of nymphs and adults, at 10 days after treatment on plants applied with ≥ 20 ppm Multineem® and seed extract (SE) than was observed on control plants. At a concentration equivalent to 100 mg liter^{-1} of azadirachtin, population increase was 37% lower than the control while the 10% aqueous seed extract was 62%. The exposure of the nymphs to Multineem® treated field pea plants significantly reduced the number of molts, longevity and fecundity that had been reared on treated field pea plants. The molting process was completely disrupted at the two levels of SE, averaging less than one molt. The average number of offspring that produced a female over a lifetime was 69.8 in the control group and only 3.4 in the group exposed to 100 ppm Multineem® from birth.

Table 5. ***Acyrthosiphon pisum*** **population level scores and percentage of dead plants for 30 field pea genotypes in the greenhouse, scored 7, 14 and 21 days after infestation.**

Entry	Aphid rating score (on 1-6), days after infestation*				% dead seedlings
	7	14	21	Mean	
Adi	2.7	5.0	6.0	4.6	33
Green Feast	2.7	5.0	6.0	4.6	33
G22763-2C	3.3	5.0	6.0	4.8	33
Hassabe	3.0	4.3	6.0	4.4	66
Holetta Local-90	2.3	4.3	5.7	4.1	0
Markos	3.0	4.7	6.0	4.6	66
Milky	2.7	5.7	6.0	4.8	100
Mohanderfer	4.0	5.0	6.0	5.0	33
NC 95 Haik	3.0	4.3	6.0	4.4	66
Oregon Sugar Pod II	3.3	5.3	6.0	4.9	66
Shield	5.7	6.0	6.0	5.9	100
Sugar Queen	3.7	5.7	6.0	5.1	66
EXDZ	2.7	5.0	6.0	4.5	33
G22763X305ps210736-2	2.3	4.7	6.0	4.3	33
HI-7	3.0	5.3	5.3	4.6	33
HI-21	3.7	5.0	6.0	4.9	66
JI-91	3.0	4.3	6.0	4.4	66
JI-116	2.7	5.0	5.7	4.4	33
JI-898	3.3	4.7	6.0	4.7	66
KFP-103	2.3	5.0	6.0	4.5	33
Kyondo	4.0	5.7	6.0	5.2	66
NEP 874 UK	3.3	6.0	6.0	5.1	100
Nur 74B x Filby	3.7	5.7	6.0	5.1	33
304 WA 1101937	3.7	5.7	5.7	5.0	66
305PS 210025	3.7	6.0	6.0	5.2	100
305PS 210572	2.7	4.3	5.3	4.1	33
305PS 210687	2.7	4.7	5.3	4.2	0
305PS 210900	3.0	5.0	6.0	4.7	33
061K-2P-2/9/2	2.3	3.7	4.3	3.4	0
061K-2P-14/7/1	3.0	5.3	6.0	4.8	66
LSD (0.05)	1.32	1.55	0.55	0.86	
CV (%)	25.5	18.9	5.7	11.1	

* Score data are mean scores from 3 replicated blocks. Source: Kemal (2002).

Table 6. Mean fecundity, daily nymphal production, nymphipositional period, longevity, maximum daily nymphal production and pre-nymphipositional period for *Acyrthosiphon pisum* on seven lines of field pea from Holetta. (abc means without letters in common differ significantly).

Entry	Fecundity*	DNP	NP	Longevity	MDNP	PNP
Holetta Local-90	74.9±9.0d	5.2±1.1	15.0±3.1	30.9±2.6	10.9±1.9	10.6±0.7
305PS 210687	77.4±14.9bcd	5.4±1.0	14.5±1.8	31.0±1.2	10.0±1.7	10.7±0.4
061K-2P-2/9/2	93.6±9.2a	5.5±0.7	16.7±1.9	32.0±3.0	11.6±2.3	10.5±0.9
NEP 874 UK	86.7±11.7abcd	5.5±0.7	15.6±1.2	31.7±2.4	10.7±2.1	11.1±0.6
061K-2P-14/7/1	76.6±12.0cd	5.1±0.8	15.9±1.8	32.4±2.0	10.4±1.5	10.9±0.8
JI-898	88.1±8.7abc	5.8±0.6	15.2±1.9	32.0±2.5	11.2±1.0	10.5±0.7
304 WA 1101937	95.4±9.1a	6.2±0.7	15.6±2.1	30.7±2.0	11.4±1.0	10.1±0.3
Mean	84.7±7.5	5.5±0.3	15.5±0.6	31.5±2.1	10.9±0.5	10.6±0.3
CV (%)	13.6	15.0	14.3	8.2	16.4	6.5

*Fecundity is the number of nymphs produced per female; DNP, number of nymphs produced per female per day; NP, number of days in nymphipositional period; Longevity, number of days adult aphid lived; MDNP, maximum number of nymphs produced per female during a 24-h period; PNP, number of days before female began producing nymphs. Source: Kemal (2002).

Table 7. Demographic statistics derived from the life table study of individual pea aphids confined on seven lines of field pea from Holetta, 2000.

Entry	r_m[a]	λ[b]	T[c]	DT[d]
Holetta Local-90	0.292	1.24	14.3	2.4
305PS 210687	0.291	1.34	14.3	2.4
061K-2P-2/9/2	0.304	1.35	14.0	2.3
NEP 874 UK	0.284	1.33	14.8	2.4
061K-2P-14/7/1	0.293	1.32	14.5	2.5
JI-898	0.305	1.35	14.0	2.3
304 WA 1101937	0.318	1.38	13.5	2.2
Mean	0.300			
CV (%)	8.21			

[a] Intrinsic rate of increase, [b] Rate of increase per female per day (finite rate of increase), [c] Mean generation time, days, [d] Doubling time. Source: Kemal (2002).

Table 8. Tolerance component of resistance of field pea entries to pea aphid at Holetta, 2000 (abc means without letters in common differ significantly).

Entry	No. leaf infested	% Non-infested	Fresh plant weight (g) infested	% Non-infested	Dry plant weight (g) infested	% Non-infested
Holetta Local-90	14.4c	43.7bc	0.43de	25.6b	0.04c	27.8b
305PS 210687	14.0c	39.2c	0.59de	29.0b	0.06c	35.6ab
061K-2P-2/9/2	30.6a	80.1a	1.55a	54.2a	0.16a	58.5a
NEP 874 UK	21.4bc	59.8abc	0.59de	30.5b	0.06c	32.1b
061K-2P-14/7/1	25.0ab	69.5a	1.36ab	36.4ab	0.13ab	38.6ab
JI-898	24.8ab	62.4ab	1.00bc	28.0b	0.11b	34.1b
304 WA 1101937	28.8ab	60.7ab	0.94cd	25.4b	0.14ab	34.6b
Mean	22.7	59.4	0.92	32.7	0.10	37.3
CV (%)	25.6	27.2	31.7	45.5	33.8	43.7

Source: Kemal (2002).

Table 9. Antibiosis, antixenosis and tolerance components of resistance of field pea lines to *Acyrthosiphon pisum* at Holetta, 2000.

Entry	Antibiosis (nymphs/adult)	Antixenosis (adults/plant)	Tolerance (% of non-infested plant height)
Holetta Local-90	74.9	4.9	27.5
305PS 210687	77.4	6.7	27.4
061K-2P-2/9/2	93.6	5.3	41.5
NEP 874 UK	86.7	7.1	26.1
061K-2P-14/7/1	76.6	7.6	35.9
JI-898	88.1	7.5	34.6
304 WA 1101937	95.4	9.0	27.4
Mean	84.7	6.9	31.7

Source: Kemal (2002).

Table 10. Normalized indices and overall resistance index (RI) based on components of resistance to *Acyrthosiphon pisum* in eight field pea lines at Holetta, 2000.

Entry Code #	Normalized indices			
	Antibiosis (x)	Antixenosis (y)	Tolerance (z)	PRI*
Holetta Local-90	0.78	0.54	0.66	3.6
305PS 210687	0.81	0.74	0.66	2.5
061K-2P-2/9/2	0.98	0.59	1.00	1.7
NEP 874 UK	0.91	0.79	0.63	2.2
061K-2P-14/7/1	0.80	0.84	0.86	1.7
JI-898	0.92	0.83	0.83	1.6
304 WA 1101937	1.00	1.00	0.66	1.5

*PRI = 1/(xyz) (Inayatullah *et al.* 1990); indices calculated using x, y and z indices. Source: Kemal (2002).

Table 11. Mean grain yield of field pea (cvs. Arsi local and Improved Mohanderfer) and economic return of pirimicarb application against *A. pisum* at Kulumsa (averaged over three years).

	Grain yield (kg/ha)		% Yield loss		Benefit over control (birr/ha)		
Treatment application	Mohanderfer	Local	Mohanderfer	Local	Mohanderfer	local	No. of sprays
15% infestation	1297	719	12.0	13.8	946	548	5
20% infestation	1267	696	14.0	16.5	750	508	4
25% infestation	1189	653	19.2	21.7	784	443	2
30% infestation	1163	687	21.0	17.6	706	494	1
35% infestation	1210	657	17.8	21.2	816	450	1
40% infestation	923	610	37.3	26.8	672	373	1
45% infestation	910	585	38.2	29.8	635	325	1
50% infestation	908	377	38.3	54.8	576	347	1
Full protection	1472	834	-	-	1158	749	7
Untreated control	667	397	54.7	52.4	-	-	-
CV (%)	13.6	18.9					
LSD (0.05)	181.7	142.5					

Source: Kemal (1997).

Table 12. Effect of seed dressing insecticides and neem seed extract on pea aphid damage and grain yield, Denbi, 1996 and 1997.

		1996		1997	
Treatment	Rate	No. of aphids/plant[1]	Grain yield (kg/ha)	No. of Aphids/plant	Grain yield (kg/ha)
Gaucho 70% ws	100g/100kg seed	19.2	502	8.1	645
Gaucho 70% ws	200g " "	19.4	552	6.2	750
Gaucho 70% ws	300g " "	17.8	632	5.0	770
Promet 400 cs	400 ml " "	20.0	483	8.0	673
Promet 400 cs	500 ml " "	19.3	591	9.4	679
Neem seed extract	1 kg/10 L water	16.8	379	6.7	754
Pirimor 50% wp	1 kg/ha	5.7	779	3.1	809
Control (Check)	-	21.0	437	9.2	558
CV (%)		14.7	13.5	16.2	19.9
LSD (0.05)		3.17	145	1.4	207

[1] Mean of six counts. Source: Kemal (1998a, b).

When adult aphids were exposed to plants treated with different concentrations of the *neem* formulations, the survival and fecundity declined with increasing dosage. The longevity ranged between 16.8 and 24.0 days in treatments, while it was 24 days in control. In the 20 ppm or less treatments, minor effects were found on survival of adults. Their number of offspring also declined in response to pesticide exposure in the population exposed as adults. Significantly fewer offspring were produced at the highest concentration of Multineem® (80 and 100 ppm) and SE than other treatments. However, the reduction in progeny number was much less dramatic than aphids exposed to treated plants from birth (Figure 2).

When applied topically, the neem formulations significantly reduced longevity and fecundity of adult aphids. Life spans of individuals treated with 100 ppm and 10 % SE were, respectively, 29 and 40% shorter than those in control (Table 13). The mean fecundity over the lifespan of an adult was 81.1 nymphs for control aphids, compared with 44.8 nymphs for 100 ppm and 25.1 for aphids sprayed with 10% SE (Table 13). The 12 day LC_{50} for individuals exposed from birth was 49.29 mg azadirachtin liter^{-1} while the 12-day LC_{50} for adults was 440.94 mg liter^{-1}. The LC_{50} value for adults topically sprayed was 60.20 mg (Table 14).

Pea weevil: On-farm and on-station trials at Ebinat were carried out to determine critical time of insecticide application in relation to crop growth stages against pea weevil using trichlorfon 85% wp at a rate of 1.5 kg/ha (Melaku et al., 2002). Their results of the two years experimentations showed that the insecticide failed to control both the adults and eggs of the pest. They suggested screening several other potential insecticides with ovicidal property to kill eggs laid on pods.

Table 13. Effects of *neem* insecticide formulations on adult *Acyrthosiphon pisum* treated topically.

Treatment	Longevity (± SEM) [a] (days)	Number of offspring (± SEM) [b]
0 mg azadirachtin/l	23.7 ± 1.9 ab	81.8 ± 9.2 a
10 " "	25.1 ± 3.1 a	79.9 ± 11.9 ab
20 " "	24.1 ± 3.6 ab	69.6 ± 5.7 bc
40 " "	22.6 ± 2.7 ab	70.6 ± 10.6 bc
60 " "	21.0 ± 4.2 bc	68.8 ± 13.5 c
80 " "	18.6 ± 3.6 cd	58 ± 11.3 d
100 " "	17.0 ± 4.9 de	44.8 ± 15.1 e
5 % SKE	17.4 ± 4.5 de	41.5 ± 9.3 e
10 % SKE	13.7 ± 3.2 e	25.1 ± 7.3 f
CV (%)	18.14	18.66

a Aphids were treated with 0.68 µ l of solution, b means with out letters in common differ significantly, (P= 0.05. Source: Kemal (2002).

Table 14. Toxicity of Multineem® to Acyrthosiphon pisum reared on field pea as newborn nymphs or adults or applied topically.

Stage initially Exposed	Day	Slope (SE)	LC50 (95% FL) mg azadirachtin/l
Exposed to treated plants			
Nymphs	12	1.85 (0.21)	49.29 (31.58 - 81.60)
Adults	20	1.33 (0.31)	55.54 (28.39 - 125.60
Adults (topically applied)	20	2.14 (0.31)	60.2 (39.8 - 102.5)

Source: Kemal (2002).

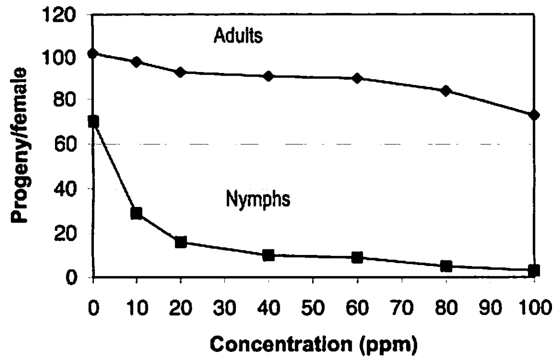


Fig. 2. Fecundity of *A. pisum* exposed to different concentrations of Multineem® from birth and as adults. Source: Kemal (2002).

An attempt was also made to control the pea weevil with solar heat using polyethylene sheet at regular intervals after threshing (Melaku et al., 2002). The results showed that there was no significant difference among the treatments. However, the immediate heating after threshing was better in terms of larval penetration sites and total windows. The heating and pirimiphos-methyl 2% dust had no effect on adult weevil.

Integrated Pest Management

Insecticides have played an important role in increasing yields of many crops, including pulses. However, cost and environmental concerns have prompted reaction against their liberal use, and stimulated research on alternatives. The majority of resource-poor farmers hardly use any control measures. Consequently, pea crop in this sector sustain extensive damage from pea aphid and pea weevil. The widespread recognition of IPM is relatively recent. Pesticides will continue to have an important role in IPM. The first step in most successful IPM initiatives has been the realization that insecticides should be used according to need rather than as routine. For IPM to become effective, suitable components of pest control to be used will have to be developed. Major emphasis needs to be centred on host-plant resistance and cultural methods.

The most important considerations in small-scale agriculture are tackling a number of multifaceted problems i.e. economic, human and sustainability. Thus, any strategy on IPM must provide satisfactory answers to these considerations. Therefore, one has to strive to develop IPM strategies that are effective, economical, safe, and compatible with other crop management practices. For the IPM to become effective, suitable components of pest control to be used will have to be developed.

INSECT-PESTS OF FABA BEAN

Faba bean has relatively few insect-pest problems compared with field pea. Hence research was focused on bean bruchid in store. Interest in botanical pesticides is on the rise because they provide third world farmers with inexpensive pesticides and they are also sources of novel pesticides, some of which have commercial potential.

Laboratory tests have been conducted on botanicals with insecticidal properties for the control of this pest. The result showed that the three rates of pyrethrum (*Chrysanthemum cineraraefolium*) flower powder were the most effective among the treatments when adult mortality, progeny emergence and egg laying are considered (Bayeh and Tadesse, 2000). This botanical pesticide gave comparable results to the synthetic insecticide primiphos-methyl (2% dust) in controlling the pest (Bayeh and Tadesse, 2000). The oil extracts of *Azadirachta indica*, *Melletia ferruginea* and *Chrysanthemum cineraraefolium* seeds were reported to be the most effective in preventing egg laying, no adult bruchids emerged from few eggs laid under laboratory conditions. The authors suggested that further study was required to identify the optimum doses for the effective botanical pesticides.

FUTURE DIRECTIONS

Insect-pests are a major constraint to field pea and faba bean production, yet there has been relatively little research investment, particularly outside of the developed countries, into the ecology and management of the pests and their natural enemies. To some extent research has concentrated on host plant resistance, cultural and chemical control. Chemical control of the pea aphid has been the only option for many growers and will remain so for some time. Knowledge of the impact, dynamics and ecology of the pest and its natural enemies is essential before effective control strategies can be developed. It should be stressed that understanding plant-pest-natural enemy interactions is essential to the successful integration of plant resistance with biological control for optimal IPM results. The integration must focus on cropping systems as a whole, as the crop in question is just one component of a complex farming system. In the short-term, the greatest impact may come from improving pesticide application and developing safe alternatives that have potential to replace the toxic pesticides. The incompatibility between chemical and biological control has in fact been the main force behind the evolution of IPM. Strategy for medium-term should concentrate on developing improved cultivars that combine high yield, disease and insect-resistance with good agronomic characters. A longer-term solution to insect-pest problem in field pea must focus on ways to enhance natural control processes by enhancing the effectiveness of endemic species.

Exploitation of underutilized natural enemies, development of novel bio-pesticides and management of resistance are all tactical options to enrich IPM strategies. All the aforementioned control tactics yield the best results when they are a component of the IPM strategy. IPM should be given the highest priority as a pest management strategy for developing countries, including Ethiopia. How it should be developed accentuates the need for focussed research on all components of IPM.

The gaps in our knowledge of different methods needed for effective IPM in field pea have been indicated above. Future research efforts should address these gaps. The need for technology development has been emphasized in this paper. To achieve this, the national capabilities for research on integrated control aspects will need strengthening. Developing national networks will have to be thought of, and a general awareness has to be developed among farmers and agricultural personnel in the country. And, finally, a group action will be required at the national level to coordinate the research activities in IPM.

References

Bayeh Mulatu, and Tadesse Gebremedhin. 2000. Oviposition-deterrent and toxiceffects of various botanicals on the adzuki bean beetle, *Callosobruchus chinensis* L. *Insect Science and its Applications* 20: 33-38.

Birhane Assayehegne. 2003. The biology and ecology of pea weevil (beetle) (*Bruchus pisorum* L.), Coleoptera: Bruchidae. Paper presented during the pea weevil workshop, 25-27 November 2003, Bahir Dar, Ethiopia.

Birhane Assayehegne, Awgechew Kidane, and Libawit Haile Michael. 2001. Abundance and distribution of pea weevil (*Bruchus pisorum*) in field pea growing areas of west Amhara region. Paper presented in the 14th African Association of Insect Scientists and the 9th Crop Protection Society of Ethiopia Joint Conference, June 4-8, 2001, Addis Ababa, Ethiopia.

Campbell, A., and M. Mackaur. 1977. Reproduction and population growth of the pea aphid (Homoptera: Aphididae) under laboratory and field conditions. *Canadian Entomologist* 109: 277-284.

Cartier, J.J. 1960. Reproduction and longevity in one biotype of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae). *Canadian Entomologist* 92: 762-764.

Frazer, B.D. 1972. Population dynamics and recognition of biotypes in the pea aphid (Homoptera: Aphididae). *Canadian Entomologist* 104: 1729-1733.

Inayatullah, C., Webster, J.A., and W.S. Fargo. 1990. Index for measuring plant resistance to insects. *Entomologist* 109: 146-152.

Kemal Ali. 1997. Economic threshold for pea aphid. *Pest Mgt. J. Eth.* 1-2: 63-68.

Kemal Ali. 1998a. Chemical control of pea aphid with selective insecticides and neem seed extract in field pea. *In* Nile Valley and Red Sea Regional Program on Cool Season Food Legumes and Cereals Annual Report 1995/96. ICARDA/NVRSRP, Cairo, Egypt.

Kemal Ali. 1998b. Chemical control of pea aphid with selective insecticides and neem seed extract in field pea. *In* Nile Valley and Red Sea Regional Program on Cool Season Food Legumes and Cereals Annual Report 1996/97. ICARDA/NVRSRP, Cairo, Egypt.

Kemal Ali. 1999. Population dynamics of *Acyrthosiphon pisum* (Homoptera: Aphididae) and its natural enemies on *Pisum sativum. Pest Mgt. J. Eth.* 1-2: 23-29.

Kemal Ali. 2002. An integrated approach to pest management in field pea, *Pisum sativum* (L.), with emphasis on pea aphid, *Acyrthosiphon pisum* (Harris). Ph.D. Thesis. University of the Free State, Bloemfontein, South Africa.

Kemal Ali, and Tibebu Habtewold. 1994. Research on insect pests of cool-season food legumes. p. 367-396. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. 1st National Cool-season Food Legumes Review Conference. Addis Ababa, Ethiopia.

Lemma Ebsa, Asrat Kelbesa, and Arfasa Kiros. 1996. Yield loss assessment of field pea due to pea aphid in Bale region. Sinana Agricultural Research Centre Progress Report for the period of 1996, Sinana, Ethiopia.

Markkula, M., and K. Roukka. 1971. Resistance of plants to the pea aphid *Acyrthosiphon pisum* Harris (Homoptera: Aphididae). III. Fecundity on different pea varieties. *Annales Agriculturae Fenniae* 10: 33-37.

Melaku Wale. 2002. Population dynamics of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae) on field pea (*Pisum sativum* L.) in northern Ethiopia. *Insect Science and its Applications* 22: 131-137.

Melaku Wale, Bekele Jembere, Emiru Seyoum. 2000. Biology of the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae) on cool season food legumes. *Insect Science and its Applications* 20: 171-180.

Melaku Wale, Birhane Assayehegne, Dereje Ashagre. 2002. Research attempts on the management of pea weevil (*Bruchus pisorum* L.) on field pea. Paper presented during the pea weevil workshop, 25-27 November 2003, Bahir Dar, Ethiopia.

Melaku Wale, Bekele Jembere, and Emiru Seyoum. 2003. Effect of density on reproduction and survival of pea aphid on cool season food legumes. *Pest Mgt. J. Eth.* 7: 63-69.

Morgan, D., K.F.A Walters, and J.N. Aegerter. 2001. Effect of temperature and cultivar on pea aphid, *Acyrthosiphon pisum* (Hemiptera: Aphididae) life history. *Bulletin of Entomological Research* 91: 47-52.

Muluken Goftishu. 2001. Advanced screening of field pea lines for their resistance/tolerance to pea aphid (*Acyrthosiphon pisum*). Entomology progress report for the period of 2001. Sinana Agricultural Research Centre, Sinana, Ethiopia.

Murdie, G. 1969. The biological consequences of decreased size caused by crowding or rearing temperatures in apterae of the pea aphid, *Acyrthosiphon pisum* Harris. *Transactions of Royal Entomological Society of London* 121: 423-442.

PPRC. 2002. Progress report for the period of 2001. Plant Protection Research Centre (PPRC), Ethiopia.

Sandström, J. 1994. High variation in host adaptation among clones of the pea aphid, *Acyrthosiphon pisum* on peas, *Pisum sativum. Entomologia Experimentalis et-Applicata* 71 : 245-256.

Shambel Kumbi, Lema Ebsa, and Asrat Kelbesa. 1998. Yield loss assessment trial of field pea to pea aphid. Entomology progress report for the period of 1998. Sinana Agricultural Research Centre, Sinana, Ethiopia.

Siddiqui, W.H., C.A. Barlow, and P.A. Randolf. 1973. Effects of some constant and alternating temperatures on population growth of pea aphid, *Acyrthosiphon pisum* (Homoptera: Aphididae). *Canadian Entomologist* 105: 145-156.

Tebekew Damte. 1999. Influence of different cultivars of lentil, *Lens culinaris*, on life history traits of pea aphid, *Acyrthosiphon pisum* (Homoptera: Aphididae). M.Sc. Thesis. George August Universitaet, Goettingen, Germany.

Worku Teka. 1998. New insect pest on field pea. p.13-14. *In Gibrinachen* (in Amharic). Vol. 1. Bureau of Agriculture, Bahir Dar, Ethiopia.

Chickpea, Lentil and Grass Pea Insect-Pest Research in Ethiopia: A Review

Tebkew Damte[1] and Mohamed Dawd[2]

[1]*Debre Zeit Agricultural Research Center, P.O. Box 32, Debre Zeit,* [2] *Plant Protection Research Center, P.O. Box 37, Ambo*

ABSTRACT

The insect-pests of chickpea, lentil and grass pea in Ethiopia are few in number. However, the insect-pest problem and complexity particularly on lentil and grass pea is generally of the same nature. The degree of infestation and damage intensity varies depending on region, season and cultural practices. Thus, the pod-borer *(Helicoverpa armigera)* on chickpea and the pea aphid *(Acyrthosiphon pisum)* both on lentil and grass pea are the major yield limiting insect-pests under field conditions. Moreover, these crops are attacked by Adzuki bean beetle (*Callosobruchus chinensis*) in storage. As a result, major emphasis was given to study and devise sound control methods for the management of these insect-pests under the existing chickpea, lentil and grass pea production systems in Ethiopia. Compared to the 1980s when research work focused mainly on chemical control of insect-pests on lentil and chickpea, the current research efforts have been geared towards pesticide alternatives and generating baseline information on biology and seasonal abundance of key pests. Therefore, this article summarizes research activities and achievements on the survey/monitoring, cultural control methods, host-plant resistance and biology/life history of the key pests of the three legume crops in the past 10 years (1993-2003). Finally, future research needs and directions are indicated.

INTRODUCTION

Chickpea (*Cicer arietinum*), lentil (*Lens culinaris*) and grass pea (*Lathyrus sativus*) are important pulse crops grown in different agro-ecological zones of Ethiopia. They account for about 32.3 % of the total area under pulse production and 30.41% of the total annual grain production of pulses (CSA, 2002). Although these crops are widely cultivated, their yields per unit area have remained low due to biotic and abiotic constraints. Among the biotic constraints, insect-pests are the major hindrance that limits their production. The insect-pest spectrum of chickpea, lentil and grass pea is indicated in Table 1. As shown, the insect-pest problem and complexity on these crops particularly on lentil and grass pea is generally of the same nature. However, the degree of infestation and damage intensity vary depending on the region, season and cultural practices. Besides the direct damage caused by these pests, particularly aphids, the yield loss caused by insect-transmitted viral diseases is also of paramount importance. *Acyrthosiphon pisum* and *Aphis craccivora,* for instance, are known to transmit faba bean necrotic yellow nanovirus (FBNYV) from infected grass pea to healthy grass pea and lentil. But FBNYV can't be transmitted to chickpea, as the aphid does not feed long enough on this plant species to inoculate virus (Adane and Alemu, 2000). Similarly, chickpea stunt virus is transmitted to chickpea by several aphid vectors including *A. craccivora* (Adane and Habtu, 2000). Although pea seed-borne mosaic virus (PsbMV), a potyvirus, in lentil is seed-borne, it is further spread by *A. pisum* to healthier lentil plants (Taddese et al., 1999; Adane and Habtu, 2000). Taddese et al. (1999) speculated that chickpea was infected by migratory viruliferous aphids other than *A. pisum* that are involved in the transmission of luteoviruses.

Research attempts and achievements on insect-pests of major cool season food legume crops except grass pea have been reviewed up to 1993 by Kemal and Tibebu (1994). Since then, entomological research activities were carried out on pests of chickpea, lentil and to some extent on grass pea. This article, thus, summarizes the results of different entomological research work undertaken in the past 10 years to alleviate the insect-pest problems on the above-mentioned legume crops.

LENTIL

Survey of Insect-Pests of Lentil

Lentil fields were surveyed in different lentil growing areas in Shoa Administrative Region between 1991 and 1994. Pea aphid (*A. pisum*) was found to be the major insect-pest in various locations and it was more important in eastern Shoa than in western or northern Shoa. The largest number of aphid was recorded from lentil fields around Debre Zeit, Dukem and Akaki (Table 2). Although Chefe Donsa is located in eastern Shoa, the aphid was of minor importance. Also pod-borer, (*H. armigera*) was recorded in 1991/92 and 1992/93 seasons causing heavy damage on lentil pods particularly in eastern and western Shoa (Table 2). Other pests of minor importance in lentil crop like flower thrips *(Taenothrips sp.)* particularly in Sheno area in northern Shoa, black aphid *(Aphis sp.),* unidentified lepidopterous larvae attacking leaves, flower and young green pods of lentil in Tefki area in western Shoa, and unidentified snout beetle at Debre Zeit were recorded (DZARC, 1993, 1996, 1997). Very few farmers in the surveyed area particularly in eastern Shoa spray their field with insecticide (dimethoate 35% EC) to control pea aphid. In the storage, Adzuki bean beetle *(C. chinensis)* was the only species found attacking stored lentil. To reduce the level of infestation and to allow proper ventilation during storage time some farmers store their lentil on verandas while farmers in Tefki area store their lentil after mixing with *tef.* Very few of them use insecticides such as malathion 50% EC to treat their seeds (DZARC, 1993, 1996).

Natural Enemies and Alternate Hosts

Although comprehensive survey was not done, parasitoids of pea aphid in the family Encytridae associated with lentil in Geregera area of Wello and red mites during early October, when the weather is dry and cooler, and entomopathogenic fungus (probably entomophtrales) during September, when the weather is dumpy, have been recorded at Debre Zeit. In Akaki area, vetch *(Vicia dasycarpa)* and clover *(Trifolium spp)* were found hosting pea aphid (unpublished data).

Seasonal Abundance of Pea Aphid

***Pea aphid population*:** The seasonal population dynamics of pea aphid was studied at Debre Zeit Center between 1993/94 to 1996 (Fig. 1a-c). The population curves were plotted on the total number of individuals in all stages. Although the aphid infested the crop both in the lentil growing and non-growing periods, peak incidence of this aphid was variable from one year to the other. In 1993/94 season, for instance, the population reached its maximum of 19.5 aphids/130cm^2 in the last week of May. Normally during this period farmers do not grow lentil in any part of the country. In 1995, the highest number of pea aphid, an average of 41.79-47.44 aphids/ 130cm^2, was recorded throughout October after which the population declined. This period coincides with active growth stage of lentil and as a consequence local outbreak of pea aphid in different parts of the central Ethiopia was recorded. In 1996, the aphid population peaked, 16.00 to 27.33 aphids/130cm^2, throughout the month of May (DZARC 1996; 1997; 1998a). The economic threshold level for spraying against this aphid on lentil is 25-50 aphids/130cm^2 (DZARC, 1993; Kemal and Tibebu, 1994). Thus, the population density surpassed this threshold level in 1995 and 1996, even though the 1996 peak period was non-lentil growing time. Moreover, the incidence of the aphid throughout the year might suggest that the aphid over-seasons in live form on alternate hosts or volunteer plants. But, despite the presence of aphid throughout the year, the occurrence of their natural enemy *(Coccinella spp.)* was lower to cause any significant reduction on aphid population (unpublished data).

Table 1. Insect-pests recorded on chickpea, lentil and grass pea in Ethiopia.

Crop Species	Common name of the insect	Scientific name	Status	Reference(s)
Chickpea	African bollworm (pod borer)	*Helicoverpa armigera*	Major	Tsedeke et al. (1982); Kemal & Tibebu (1994); AdARC (2002a)
	Cutworm	Agrotis sp.	Minor	Kemal & Tibebu (1994); AdARC (2002a)
	Mendi termites	Macrotermes subhualinus	Undetermined	Abraham & Adane (1998)
	Unidentified thrips	?	Undetermined	Unpublished data
	Adzuki bean beetle	Callosobruchus chinensis	Major	Geletu et al.(1996a)
	?	Delia cilicrura	Minor	Tsedeke et al. (1982)
	?	Gonocephalum simplex	Minor	Tsedeke et al. (1982)
	Lesser armyworm	Spodoptera sp	Undetermined	DZARC (2004)
	Pea aphid	Acyrthosiphon pisum	Minor	DZARC (2002)
Lentil	Pea aphid	*A. pisum*	Major	Geletu et al. (1996b); AdARC (2002a)
	Thrips	*Caliothrips impurus*	Minor	AdARC (2002a)
	Bean flower thrips	*Taeniothrips spp*	Undetermined	Kemal & Tibebu (1994)
	African bollworm	*H. armigera*	Minor	DZARC (1999); AdARC (2002a)
	Adzuki bean beetle	*C. chinensis*	Major	Geletu et al. (1996b)
	Epilachna	*Epilachna spp*	Minor	Kemal & Tibebu (1994)
	Cow pea aphid	*Aphis craccivora*	Minor	DZARC (2002)
Grass pea	Pea aphid	A. pisum	Major	AdARC (2002a)
	Thrips	*C. impurus*	Minor	AdRC (2002a)
	African bollworm	*H. armigera*	Minor	DZARC (1999); AdARC (2002a)
	Blue butterfly	Lampides boetucus	Undetermined	Unpublished data

Table 2. Occurrence of *A. pisum* and percent pod damage due to *H. armigera* on lentil in the former Shoa Administrative Region.

		Aphid populations per 10X13 cm^2		Percent pod damage	
Zone	Location	1991/92	1992/93	1991/92	1992/93
East Shoa	Akaki	192	220	32.42	11.50
	Dukem	320	270	60.76	42.2
	Chefe Donsa	25	18	8.09	NR
	Debre Zeit	183	320	NR	5.4
	Mojo	184	90	-	-
	Ejere	118	73	-	-
	Shenkora	44	66	-	-
West Shoa	Sebeta	23	20	NR	6.3
	Tefki	9	15	16.23	60.00
	Tullu Bollo	17	32	12.15	10.50

NR= Not Recorded., Source: DZARC (1993).

Effect of weather variables: Although different weather variables are inter-correlated to some extent and their joint effects differ, pea aphid population peaks were associated with rainfall periods that were followed by dry spells or periods of very low rainfall. Moreover, at Debre Zeit in all years the temperature, except for one or two weeks in a year, was above the minimum threshold (5.56°C), and on the average 34 to 36 weeks in a year had mean minimum temperature of 10C° and above. On the contrary, the experimental period, 40 weeks per year, had a mean maximum temperature above 25°C (up to 32.2°C). This might suggest that pea aphid under Ethiopian conditions either had acclimatized to high temperature conditions or its population growth is less influenced by daily maximum temperature. Although air humidity from meteorological station does not accurately represent the humidity in crops, the relative humidity during peak incidence of 1993/94, 1995 and 1996 was 25%, 29-35% and 56.2%, respectively. Similarly, sunshine duration during high reproductive periods of pea aphid was 7hr and above though the intensity is not known (re-summarized from DZARC, 1996).

Biology of Pea Aphid

Melaku et al. (2000) studied the biology of pea aphid on four cool season food legumes, namely, faba bean (variety CS-20DK), field pea (variety Mohanderfer), lentil (variety EL-142) and grass pea (Accession LS-8246) under variable temperatures (minimum range 4-10.5c° and maximum range 23-27c°). They found that the number of molts and the nymphal period required by each nymph to reach adulthood were similar on all crop species. However, there were some variations in the other life table traits. For instance, aphids reared on lentil had the longest reproductive period, post-reproductive period, and longest lifespan than those aphids raised on the other three crop species. The second longest lifespan was recorded on aphids reared on grass pea. Similarly, the survival curve of the aphid was different from one crop species to the other. Because of the extended reproductive periods and longer total lifespan of the aphids raised on lentil, nymphs per day and the total reproduction of the aphids were higher on lentil than on the other three crop species. Thus, based on net reproductive rate of pea aphid, the crop species are ranked (in descending order) as lentil, grass pea, field pea and faba bean. Mean generation time follows a similar pattern. However, the intrinsic rate of increase was greater on faba bean and followed by grass pea, lentil and field pea. Melaku et al. (2000) also speculated that lentil was not a good choice of crop in places where the pea aphid was a problem. However, for mass rearing of the aphid for screening purpose or for rearing natural enemies of pea aphid, lentil is a suitable host. Later, Melaku et al. (2003) studied the influence of density on reproduction and survival of pea aphid on aforementioned crop species and found that pea aphid reproduction and survival decreased with increase in pea aphid density per plant, although the magnitude of the effect was variable among the tested crop species.

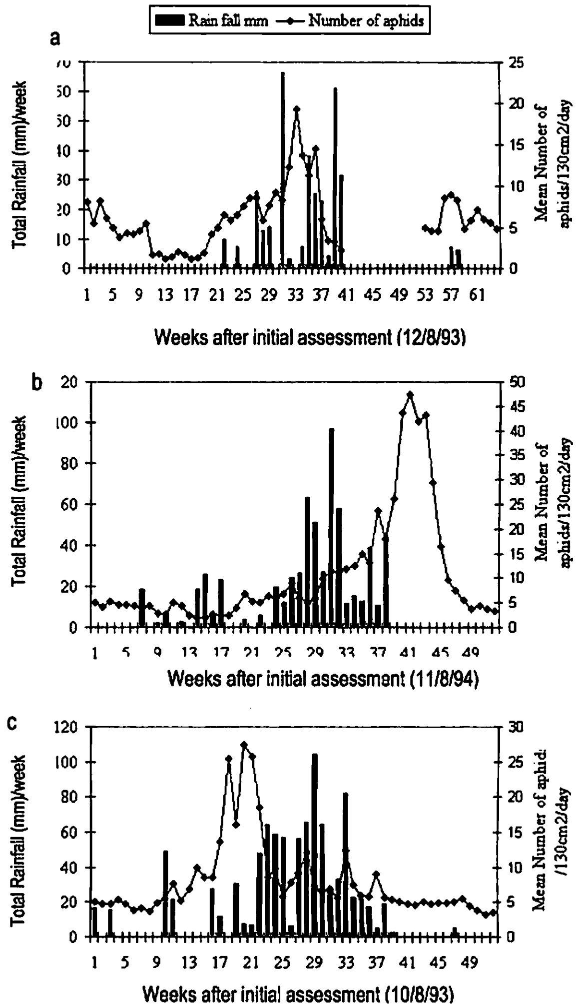


Fig 1. (a) Seasonal distribution of pea aphid at Debre Zeit during 1993, (b) Seasonal distribution of pea aphid at Debre Zeit during 1994, (c) Seasonal distribution of pea aphid at Debre Zeit during 1995.

Similarly, using four lentil genotypes Tebkew et al. (2002) studied the biology of two strains of pea aphid, Debre Zeit (DZ) strain from Ethiopia, and Goettingen (GOE) strain from Germany, at a constant temperature of 21C° and relative humidity of 50-70%. On the average, the GOE strain required relatively longer developmental period to reach adulthood and at the same time had longer post-reproductive period than the DZ strain. However, the commencement of reproduction was not affected by different lentil genotypes due to the ability of the aphids to compensate for the delay in reproduction by shortening the pre-reproductive period or compensate for pre-maturity by extending the pre-reproductive period. In terms of reproduction, however, there was interaction between strains and lentil genotypes. Thus, the DZ strain highly reproduced on FLIP-88-12L and Chalew, whereas the GOE strain performed better on ILL-8006 and FLIP-88-12L than on other genotypes. In contrast to this, the DZ strain raised on ILL-8006 and the GOE strain raised on Chalew produced the least number of nymphs. The net reproduction of both strains was closer to the total reproduction on Chalew and FLIP-88-12L. On the contrary, the net reproduction of the strains was lower on Alemaya and ILL-8006. However, based on intrinsic rate of increase (r_m) there was no variation among genotypes or strains. The mean r_m of DZ strain was 0.33 compared to 0.32 of the GOE strain.

Economic Threshold Level

Insecticide Pirimicarb (pirimor) was sprayed at nine different pea aphid population levels on lentil variety EL-142 sown at its recommended seed rate at Debre Zeit and Akaki. The net benefit (Birr/ha) obtained at Akaki due to insecticide spraying at different aphid population level is indicated in Table 3. The relation between net benefit and the incidence of the pest *per se* were not consistent over years. In 1992/93 and 1994/95 crop seasons, the net benefits decreased as the aphid population level increased. The highest net return was obtained at two to three sprays at a population level of <25 aphids per 10X13cm^2 white board (DZARC, 1993, 1997). Whereas, in the succeeding years the net benefit obtained varied from one season to the other and in some seasons the aphid population did not reach all the desired levels partly because of the incidence of rust *(Uromyces fabae)* on the test variety, and partly due to water-logging problem that affected stand establishment. At Debre Zeit, no conclusive results were obtained due to the above-mentioned problems (DZARC, 1998a, 1998b, 1999, 2000, 2001).

Host Plant Resistance

Lentil germplasm accessions were screened for their resistance or tolerance to pea aphid in various seasons. In 1992/93 and 1995/96, genotypes were tested at Akaki, and there after screening activities were carried out at Debre Zeit Center. Despite the genetic variation among the tested genotypes and the difference in location, no lentil genotype was found free of aphid infestation. However, there was difference in the level of infestations. Thus, in 1992/93 and 1995/96 crop seasons about 25 and 32 genotypes, respectively, were found promising and promoted for further evaluation. Unfortunately, the 25 genotypes were not further evaluated. Out of the 32 genotypes tested, 12 gave better yield at maximum of 8.78 and 6.00 aphids/130 cm^2 in 2000/01 and 2001/02 cropping seasons, respectively. Only these genotypes were further tested as insecticide-treated and -untreated. But other materials like NEL-2612 with low level of aphid infestation at different phenological stages but poor in yield were not promoted (DZARC, 1993, 1997, 1998a).

In the advanced screening stage of the 2000/01 season, highly significant differences were obtained among the genotypes in the pre-spray aphid count (seven weeks after germination). Mean number of aphids per 130cm^2 was low on varieties Chalew and R-186, and higher on DZ-Local and ACC-207307 (Table 4). The varietal difference disappeared 11 weeks after germination. In the second year, the aphid population peaked nine weeks after germination. At this stage, mean number of aphid was low on Chalew, FLIP-87-75L, and R-186 (Table 5). Like in the first year, the varietal difference disappeared in the subsequent growth stages (DZARC, 1993, 1998a, b, 1999, 2000, 2001).

The estimated yield loss due to pea aphid on lentil is depicted in Fig. 2. Despite the lower incidence of the pest on Chalew and R-186 considerable amount of yield loss was recorded. On the contrary, the yield loss on accessions FLIP-86-17L and LL-57 was low in spite of the highest aphid incidence (Table 4). This might suggest that FLIP-86-17L and LL-57 are tolerant to pea aphid, which require confirmation. The two released varieties, namely, Chalew and R-186 are late-maturing ones, thus the yield loss might be partly attributed to the inability of the weak (weakened by aphids) plants to resist the terminal moisture stress (DZARC, 2002, 2003).

Table 3. Net benefit (Birr/ha) due to insecticide spraying against *A. pisum* on lentil at Akaki.

Aphid population level	Crop season						
(No./10x13cm^2)	1992/93	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00
<25	3300.5(3)	4055.94(2)	26.5(2)	1103.9(2)	226.83(2)	250.85(2)	625.29(2)
26-50	3171(2)	3224.55(2)	4.4(2)	373.4(2)	negative return/loss	159.19(1)	525.87(2)
51-75	2191(1)	1603.21(2)	1346.4(2)	459.7(1)	798.34(1)	-	943.68(1)
76-100	2271(1)	937.58(1)	633.7(1)	-	1319.17(1)	-	411.78
101-150	2170(1)	2044.81(1)	580.6(1)	-	-	-	1261.8
151-200	2142(1)	360.01(1)	663.8(1)	-	-	-	584.37
201-250	-	129.5(1)	194.0(1)	-	-	-	-
>251	-	72.52(1)	188.9(1)	-	-	-	-
Weekly Spray	3514(7)	3301.76(5)	530.5(3)	221.5(4)	1210.8(3)	Negative return/loss	544.77(4)

Note: Figures in parenthesis indicate frequency of spray. Source: Summarized from the respective crop season annual reports of DZARC.

Table 4. *A. pisum* incidence and grain yield of some lentil genotypes.

Accession	Mean number of aphids per 10X13 cm² white board		Grain yield, kg/ha (mean)	
	Pre-spray** (2000/01 season)	Post-spray * (2001/02 season)	2000/01** season	2001/02** season
87s-93014	5.92abc	3.395abc	1284.71c	1295.032a
87s-93056	6.42abc	2.708abc	1763.92ab	1317.293a
ACC-207307	8.78a	3.042abc	1595.40bc	1315.249a
ACC-215707	6.21abc	4.167a	1466.26bc	1348.329a
Chalew	1.75c	1.653c	2037.69a	1100.458ab
DZ-local	8.75a	3.153abc	1324.11c	1169.819a
EL-142	7.67abc	3.677ab	1670.67abc	1341.02a
FLIP-86-17L	4.21abc	3.098abc	1522.17bc	1407.292a
FLIP-86-83L	3.42bc	2.110bc	1515.21bc	760.499b
FLIP-87-75L	2.71bc	1.557c	1401.21bc	759.988b
LL-57	2.88bc	3.735ab	1597.07bc	1235.248a
R-186	1.79bc	1.667c	1832.75ab	1328.601a
CV(%)	31.8	15.9	15.3	19.1

**Means followed by the same letter within a column are not statistically different at P<0.01, Means followed by the same letter within a column are not statistically different at P<0.05.

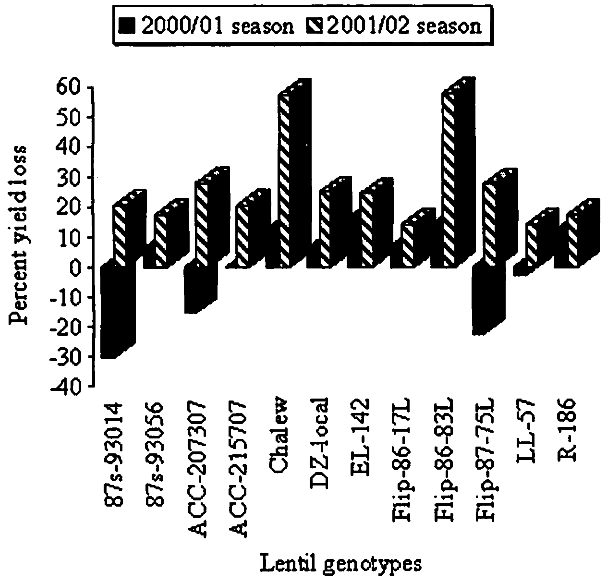


Fig. 2. Yield loss due to pea aphid on different genotypes of lentil at Akaki. Source: Summarized from the respective annual reports of DZARC.

Cultural Control

***Effect of plant density on the incidence of pea aphid*:** This experiment was conducted with the objective of determining a seed rate, which compensates the loss due to pea aphid or minimizes pea aphid incidence. Four elite lentil varieties, viz., EL-142, Ada (FLIP-84-78L), Gudo (FLIP-86-41L) and Chekol (NEL-2704) were sown at Debre Zeit and Akaki using five seed rates of 40, 70, 100, 130, and 160 kg/ha. At Debre Zeit, the initial incidence of aphid on the crop was unaffected by seed rates used (Fig. 3a). However, at the flowering stage marginally significant difference among seed rates was obtained in three consecutive crop seasons except in 1999/2000 cropping season (Fig. 3b). In all the years, aphid population tended to increase as the seed rate increased. The tendency of aphid population increment with seed rate might be attributed to the availability of more food or to the creation of micro-environment suitable to aphids when the seed rate was high. This, however, did not influence the seed yield. Besides, locations did not have any effect except that the aphid pressure at Debre Zeit was higher than at Akaki. This pattern was similar over years. With respect to varieties, as opposed to the small-seeded varieties El-142 and Chekol, the large-seeded variety Gudo and the medium-seeded variety Ada gave better yields at the highest seed rate (Tebkew and Mekasha, 2001).

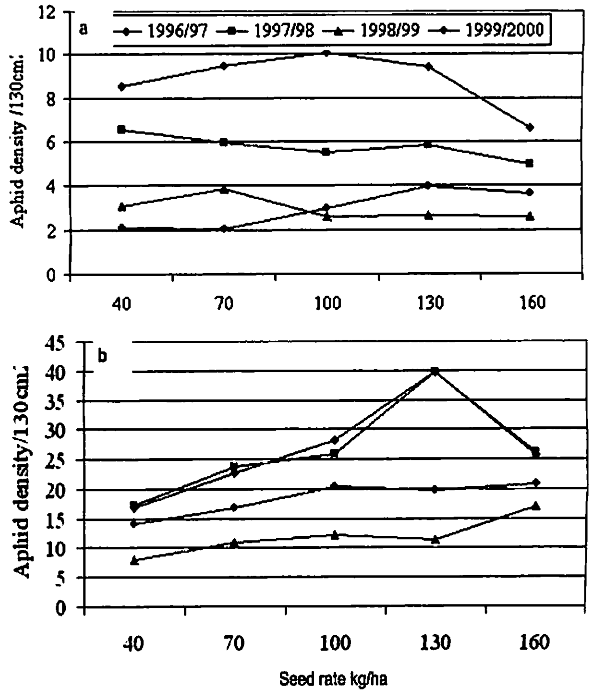


Fig 3. The impact of seed rate on *A. pisum* population at pre-bloom(a) and full flowering(b) stage of lentil at Debre Zeit.

***Effect of sowing date*:** The effect of sowing date on the incidence of pea aphid in lentil was investigated for four seasons (1992/93 to 1995/96) at Debre Zeit and three seasons (1993/94 to1995/96) at Akaki. At Debre Zeit, except in pre-spray count of aphid in 1994/95 season, aphid population showed a continual decline both in pre- and post-spray period as the sowing date was delayed (Table 5). In 1994/95 season, however, aphid count after each spray revealed that infestation was higher on lentils sown on the third (July 20) and fourth (July 30, 1994) dates (DZARC, 1993, 1996, 1997, 1998a, b). High aphid incidence on earlier-planted materials was favored by relatively high relative humidity and warm temperature of late-September to mid-October. During this period, earlier planted lentils were at the stages of flowering to pod setting, which are most susceptible stages to aphid attack (DZARC 1993). Generally, yield was higher when planting was made mid- to late-July. In 1995/96 crop season, there was an unusual outbreak of pea aphid at and around Debre Zeit. As a consequence, insecticide-untreated materials were equally attacked regardless of the difference in the date of planting. This is an instance that shows the difficulty of ascertaining cultural control practices and the need to complement with insecticides (DZARC, 1998a, b). At Akaki, the incidence of aphid was different from the incidence at Debre Zeit. Early- or late-planted materials had relatively lower aphid infestation than those sown at the middle of the season. Thus, lentils sown in July reached flowering to podding stage in late-September to end-October. During this period, the aphid infestation attained its peak. On the other hand, planting in late-June and late-August resulted in lower infestation (Table 6) (DZARC, 1996, 1997).

Despite the higher aphid infestation in lentils sown in mid- to late-July and early-August better seed and biomass yields were obtained from them than early- or late-planted ones (DZARC, 1997, 1998). The low yield of early-sown lentil at both locations is partly attributed to the confounded effect of water-logging, which is a common problem on most Vertisols of Ethiopia (DZARC, 1998a, b). Insecticide application significantly reduced the aphid population. Depending on the degree of incidence and severity of damage caused by the aphid in a given year, the reduction in aphid population due to insecticide application may or may not be related to increased grain and biomass yield of insecticide treated lentils (DZARC, 1996, 1998a, b).

***Evaluation of Botanicals*:** Several botanicals were evaluated against pea aphid in 2001/02 and 2002/03 cropping seasons at Debre Zeit. In the first season, it was not possible to separate the effect of botanicals from mortality of aphids caused by unidentified entomopathogenic fungi. This mortality factor caused drastic reduction in aphid number. Also in the subsequent season there was incidence of this pathogen during dumpy weeks of September on boarder rows in certain parts of the experimental field. In the pre-spray count as high as 25 pea aphids per 130cm^2 and other insects like thrips, cowpea aphid (*A. craccivora*), coccinelidae beetles (predator), African bollworm (*H. armigera*) and a few unidentified insects were recorded. In the post-spray period there was no significant difference among the tested plant species in reducing aphid number, although aphid population showed continuous decrease on plots treated with Alashume (dried), Amfar, *Argemon mexicana* seed (mature seed) and *Argemon mexicana* leaf and stem (fresh) extract. On plots treated with sisal and Endahola relative reduction in aphid number was observed five days after spraying. There were marginally significant differences ($p<0.1$) in seed yield among the various treatments. Thus, plots treated with extract of Alashume, Argemon seed, Flea, Oleander, Tagetus and Yeferenji zigita gave better yield than the others (DZARC, 2004).

Table 5. Aphid density, seed and biomass yield of lentil as affected by different sowing dates, Debre Zeit.

Sowing date	Aphid density per 130cm² **		Biomass (kg per 3, 4-m rows)*	Grain yield (kg/ha)			
	Pre- spray*	Post- spray*		Insecticide-treated	Untreated	Mean*	Loss (%)
July 19, 1995	2.3a	2.2a	0.5a	817.1	225.5	521.3a	72
August 2, 1995	2.3a	2.3a	0.5a	818.4	193.0	506.7a	76
August 11, 1995	1.8b	1.6b	0.3b	767.3	238.7	503.1a	69
August 22, 1995	1.5b	1.6b	0.2b	384.4	95.9	240.2b	75
Sep. 3, 1995	0.4c	0.2c	0.2b	173.9	226.0	200.b	0
CV(%)	14.3	16.8	38.4	-	-	42	-

* Means followed by the same letter within a column are not statistically different at P<0.05, ** Transformed to log x value. Source: DZARC, 1998a, b.

Table 6. Aphid density, grain and biomass yield of lentil as affected by different sowing dates at Akaki.

Sowing date	Aphid density per 130cm²		Biomass (kg per 3, 4-m rows of 4m length)	Grain yield (kg/ha)
	Pre- spray*	Post- spray*		
June 30, 1994	1.71	1.73	0.93	1174.78
July 8, 1994	1.73	1.74	0.88	986.31
July 20, 1994	1.83	1.75	0.98	1134.33
July 30, 1994	1.73	1.84	0.81	1024.70
August 13, 1994	1.6	1.44	0.71	762.11
LSD (5%)	0.08	0.08	0.147	228.4
Cv(%)	5.78	10.56	20.7	19.19

* Transformed to Log x value. Source: DZARC, 1997.

CHICKPEA

Population Dynamics of Pod-borer

The population dynamics of pod-borer was studied for three years (1987/88, 1988/89 and 1991/92) at DZARC. In all the monitoring periods, there was a continuous flight of the moths throughout the year. However, two distinct peaks, one after the main rain season - *meher* peak, and the other after the small rainy season - the *belg* peak was obtained. Moreover, the fluctuation of pod-borer was characterized more by temporal shift in peak incidence (Tebkew and Mekasha, unpublished; Seid and Tebkew, 2002). After interrupting the monitoring activity for some time, the activity was resumed at Debre Zeit and Akaki between 1998/99-2000/01 and 1998/99-1999/00 crop seasons, respectively. Similar to the earlier findings, there were continuous flights of moths throughout the year. Thus, in 1998/99 season at Akaki, flight activity of moths activity was high only during the last week of December - up to 184 moths per trap per day. At Debre Zeit the population-build up and flight activity was similar to that of Akaki. Moreover, at both locations there was temporal shift in peak incidence from one season to the other. The only difference between the two locations, however, was that more number of moths was caught at Akaki than Debre Zeit. This might be associated with chickpea maturity, i.e., it stays greener for longer time in Akaki than in Debre Zeit area (DZARC, 2000, 2001, 2002).

Insect-pest Surveys

Insect-pest surveys were conducted in the major chickpea growing regions of the country for several years to determine the type of insect-pests that attack chickpea, and to assess the perception of farmers. It was found that the most prevalent insect-pest on chickpea was pod- borer *(H. armigera).* The pest was recorded in all the surveyed localities except some parts of northern Shoa (Sendafa, Aleltu and Sheno) (DZARC, 1994, 1996, 1997). However, results of a recent survey revealed that the pest caused some damage in these localities (DZARC, 2004). Further surveys showed that the pest caused more damage in central Ethiopia, i.e., western and eastern Shoa than in any other part of the country (Table 7). In northern Shoa the pest did cause very low damage, however, exceptionally in Inewari and Jihur areas in 2001/02 season, and in Woyera Amba area the pest caused 11.9 and 15.0% pod damage, respectively, in 2002/03 season. In northwestern Ethiopia, i.e., eastern and western Gojam pod-borer caused relatively low damage (DZARC 2000, 2001, 2002, 2003). Nonetheless, other workers reported in this region particularly in some localities of Yilmana Densa and Mota areas of Gojam a pod-borer damage as high as 99%, and a complete pod damage at Achefer (AdARC, 2002a). Similarly, Mekasha and Geletu (1999) reported that 39.7%, 22.0%, 13.2% and 10.9% of the interviewed farmers believed that this pest caused very severe (76-100%), severe (51-75%), substantial (25-50%) and very little (<25%) damage, respectively. Moreover, in all the surveyed regions farmers identified insect-pests particularly pod-borer (52.2%) and cutworm, *Agrotis spp.* (24.7%) as economically important pests of chickpea. These authors also indicated that the majority of the farmers did not use any control measures for these pests. However, very few farmers practiced insecticide spraying and some used some traditional means to control pod-borer (Mekasha and Geletu., 1999).

Another pest of minor importance recorded in the field was cutworm (*Agrotis* sp). Percentage of seedlings severed by this worm varied between 4.5% at Shenkora and 8.25 % at Tefki. Generally, cutworm was more prevalent in plain areas that could retain moisture for longer duration (DZARC, 1993). Similarly, this worm caused substantial damage to chickpea in Mertole Mariam and Ginde Woin areas of northwestern Ethiopia (AdARC, 2002a).

Natural Enemy Surveys and Alternate Hosts

Different chickpea fields were visited around Debre Zeit, Dukem, Akaki, Inewari, and Bichena areas. The activity was carried out for three successive cropping seasons (1999/00-2001/02) to collect larvae infected or killed by enthomopathogens. However, infected or killed *H. armigera* larvae in chickpea fields were not encountered. This is partly attributed to the poor efficiency of the methodology followed and time of survey, and partly to the nature of entomopathogens, which remain dormant in the larvae in the field (DZARC, 2003). A single parasitoid species, i.e., Ichneumon wasps, however, was recorded in Wollo area, and it caused 5-10% mortality on this pest in chickpea (Mulugeta Negere, personal communication; Seid and Tebkew, 2002). In Akaki area pod borer was found infesting snail medics *(Medicago scutelata)* (unpublished data).

Table 7. Pod damage (%) due to *Helicoverpa armigera* in different zones of Ethiopia.

	Zone					
Crop Season	East Shoa (mean ± SE)	West Shoa (mean ± SE)	North Shoa (mean ± SE)	East Gojam (mean ± SE)	West Gojam (mean ± SE)	South Gondar (mean ± SE)
1991/92	32.30±8.82	48.26 ±5.09	-	-	-	-
1992/93	25.60 ±9.51	23.63± 6.43	-	-	-	-
1993/94	14.80± 6.52	31.17±4.53	-	-	-	-
1994/95	-	21.57 ± 10.48	7.16 ±6.73	-	-	-
1999/00	4.29 ±3.63	8.34± 4.18	1.58 ±1.03	1.92± 0.55	-	-
2000/01	9.13± 4.33	9.06± 2.65	3.38	4.73 ±1.97	-	9.16± 3.1
2001/02	9.01± 2.31	12.41 ±5.42	9.23± 4.34	7.34±4.59	4.09 ±1.71	7.35± 0.77
2002/03	11.24± 4.01	18.37 ±9.17	5.21± 6.04	4.704±2.3	5.63 ±2.26	4.88± 0.30

Source: Summarized from the respective season annul report of DZARC.

Host Plant Resistance

A total of 78 chickpea genotypes were tested for their resistance to pod-borer at Woreta in 1994/95 cropping season. Although most of the tested entries showed less than 6% pod damage, the improved variety Marye and genotypes ICCL-981/83-DZ/2-1, ICCL-7958/83-DZ/1-1, ICC-7881/82-DZ/4, and ICC-84204 suffered less (1% pod damage). On the other hand, 22.02% pod damage was recorded on ILC-2876 (AdARC, 2002a). Similar work was carried out at Debre Zeit Center under open field conditions using 10 genotypes known to have some level of resistance to pod-borer. These materials were obtained from ICIPE/ICRISAT. Four released chickpea varieties were also included, and the experiment was carried out under insecticide-protected (Endosulfan at the rate of 475 ai/ha) and unprotected conditions.

In the first season, there were no statistically significant differences among accessions/varieties in larval density and seed yield but there were significant differences in percent pod-damage. However, based on yield loss assessment ICCV-7, ICCX-730020-11-2-1HB, ICCV-95992 and ICC-4935-2793 were less affected by pod-borer. Similarly, in the second season evaluation there were no significant differences among accessions/varieties in all parameters. Although non-significant, the highest number of larvae per plant was recorded on unprotected plots of ICCV-7, ICC-1381 and variety Akaki. Nonetheless, the relative ranking of genotypes based on larval density was highly variable between sampling dates. This might be partly attributed to the sampling method (direct observation) followed to estimate larval population and partly to the movement of the pest from plant to plant. When percentage pod damage was considered, the maximum damage was obtained on released varieties, viz., Worku, Mariye and Dubie in decreasing order. This was followed by accessions ICCV-93122, ICC-1381, and ICCX-730041-8-1B-BP. On the contrary, the minimum damage was recorded on accession ICCV-7 despite the highest number of larvae it supported at the vegetative stage, and this was coupled with the lowest yield loss (unpublished data).

Application of insecticide did significantly affect larval population at the third spraying date. And this in turn significantly affected the percent pod damage. However, the reduction in larval populations and pod damage was not reflected on the seed yield, i.e., there was no variation between insecticide-treated and -untreated chickpea in seed yield. There was no interaction effect between insecticide and genotypes. The overall analysis of percent pod damage over four years revealed that accession ICCV-7 suffered consistently less damage than the other genotypes tested (unpublished data).

Economic Threshold Level

To determine the larval population level that causes economical yield loss different larval densities, i.e., 0, 1, 1.5, 2.0, and 2.5 larvae per plant were evaluated at Debre Zeit for four years. In all the years, non-significant differences among the different larval densities were recorded. Although statistically non-significant, the highest and the lowest pod damages were recorded at a density of 2.5 and 0 larvae per plant, respectively (Fig. 4). The damage on the larvae-free plot was due to other moth species. The lack of difference in seed yield reduction due to the different larval population might be attributed to the luxuriant and succulent growth of chickpea under caged condition. Under such conditions larvae fed mostly on the young shoots and leaves. Moreover, caged plants remained greener for longer time than un-caged chickpeas sown at the same time. This might enable them to compensate the lost parts. Nonetheless, this study indicates that as larval density increases the damage due to *H. armigera* also increases (DZARC, 2001, 2002, 2003, 2004).

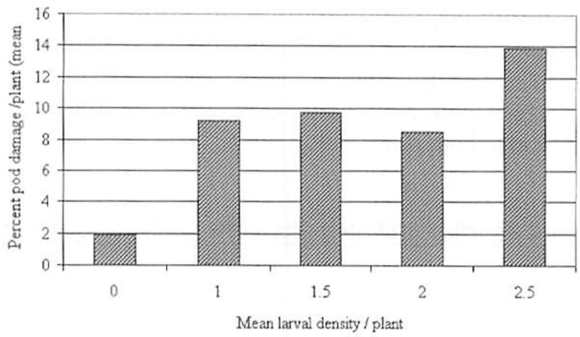


Fig. 4. The effect of different larval density of *H. armigera* on the extent of pod damage in chickpea. Source: DZRC (2004).

Sowing Date and Insecticide Application

The combined effect of sowing date and insecticide application on pod damage due to pod-borer was investigated at Woreta in 1992 and 1993. The results indicated that sowing date had no impact in reducing pod damage, whereas insecticide application significantly reduced damaged pods. Thus, only 1.7% and 9.1% pod damage was recorded on treated and untreated plots, respectively. However, there was no variation among insecticide-treated and -untreated plots in seed yield. The tested insecticides, namely, endosulfan and cypermethrin were effective in reducing damage due to pod-borer (AdARC, 2002a).

Similarly at Akaki, a sowing date experiment was conducted to determine optimum sowing time at which pod-borer caused minimal losses in chickpea. Variety Mariye was planted at the recommended seed rate under insecticide (cypermethrin)-treated and -untreated conditions. The result was similar to the effect of sowing date in Woreta area, i.e., by and large planting dates did not affect the number of larvae per plant. However, early-planted materials had relatively greater number of larvae per plant than those materials sown late in the season. The pattern was similar for damaged pods (Table 8). Although there were yield increases in all sowing dates resulting from insecticide application, late-planted chickpea showed significantly higher pod damage. This suggests the possibility of reducing damage by pod-borer by planting earlier in the season (DZARC, 1994, 1997, 1998a). Similarly, the impact of seed dressing, insecticide baiting with wheat bran or spraying of heptachlor directly onto the soil at the time of planting on incidence of cutworm (*Agrotis sp.*) and yield of chickpea was investigated under on-farm condition in Bichena and Mertole-Mariam areas using improved variety (Mariye) and the local check. It was found that although the incidence of the pest was variable between years, spraying heptachlor at the time of planting reduced damage due to cutworm. However, baiting with wheat bran gave better yield than the other application methods (AdARC, 2002a).

Plant Density

The influence of different plant densities (600, 200,120 and 86 plants per 4.5m^2) on the incidence of pod-borer was studied in Debre Work area. As indicated in Table 9 the incidence of pod- borer increased with increase in plant density, whereas cutworm incidence was more prevalent at low plant density (AdARC, 2002b). There was no significant difference between Worku and the local check in their reaction to both insect-pests.

Evaluation of Botanicals and Animal Waste

The effect of different botanicals, animal waste, insecticide (endosulfan) and their combination on pod damage due to *H. armigera* and yield of chickpea is indicated in Table 10. Compared to *neem* oil and endosulfan *neem*-seed-powder (NSP) from Melka Werer alone or in combination with other botanicals or animal wastes highly reduced pod damage due to *H. armigera*. Although the performance of endod-seed-powder (ESP), cow dung (CD), cow urine (CU) alone and their pair combination did not reduce pod damage, their combination with NSP or half dose of endosulfan (1/2ES) was effective. The overall effect of *neem* oil, NSP, CD, neem oil +CD, NSP+CD, ESP or CU with 1/2ES on yield was much better than both the full rate of endosulfan and the untreated check. However, their influence on yield was comparable with *neem* oil. On the other hand, the effect of the other treatments was even worse than the untreated check. The combined analysis over years revealed significant variation between years in all parameters, which might explain the influence of a particular season on the incidence of the pest and the subsequent damage it causes (DZARC, 1999, 2001, 2002).

Table 8. The effect of planting date on the incidence of pod-borer and grain yield of chickpea at Akaki.

Planting	Larval count*			Percent pod damage**			Grain yield, kg/ha		
date	Treated	Untreated	Mean	Treated	Untreated	Mean	Treated	Untreated	Mean
20 Aug. 1992	0.68	1.06	0.87	18.66	8.98	13.82	1917.94	1776.64	1847.29
30 Aug. 1992	0.64	1.15	0.90	12.18	11.63	11.63	1463.10	1322.30	1392.70
10 Sep. 1992	0.49	0.94	0.72	9.69	12.30	10.99	1213.16	966.95	1090.05
20 Sep. 1992	0.49	0.68	0.59	16.10	20.21	18.16	569.18	183.63	376.41
Mean	0.58	0.96	-	14.2	13.14	-	1290.84	1062.38	-
LSD(5%)		NS			NS			NS	
CV(%)		25.3			47.8			40.8	

* Values transformed to log (x+1), ** Values transformed to arcsine. Source: DZARC (1994).

Table 9. Effect different plant densities on the incidence of pod-borer and cutworm in chickpea at Debre Work

	Percent pod damage due to pod- borer (mean of 5 plants)		Percent seedling damage due to cutworm	
Plant density per 4.5m^2	Worku	Local check	Worku	Local check
86	1.19	1.42	9.87	8.47
120	1.27	1.16	5.36	9.31
200	3.00	1.84	5.05	6.02
600	3.30	1.69	2.47	3.54

Source: AdARC (2002b).

Table 10. The effect of botanicals and animal waste alone or in combination with insecticide on pod damage and seed yield of chickpea.

	Percent pod damage per plant			Grain yield, kg/ha		
Treatment	1998/99	1999/00	2000/01	1998/99	1999/00	2000/01
Neem-seed-powder (NSP)	2.7	2.16	1.29	4022.21	7895.00	5021.56
Cow dung (CD)	5.23	7.01	3.12	3884.92	8190.83	5753.83
Cow urine (CU)	5.99	7.18	4.49	3268.33	4352.50	4958.22
Endod-seed-powder (ESP)	5.29	5.42	3.51	2934.79	7919.17	6224.06
NSP+CD	4.15	3.94	1.85	4141.33	8166.67	5980.56
NSP+CU	4.29	3.46	3.29	3525.58	7145.00	4604.33
NSP +ESP	4.48	2.18	2.76	3012.92	6877.50	4757.83
CD +CU	5.89	7.47	5.58	3203.17	8400.83	4392.22
CD+ ESP	4.90	7.82	4.63	3073.54	7434.17	3937.72
CU +ESP	4.61	6.07	4.38	4163.67	7200.83	5111.22
NSP +1/2 Endosulfan (ES)	5.44	3.31	1.00	2967.83	6449.17	5085.17
CD +1/2ES	3.37	2.48	1.19	3504.67	6915.00	5491.06
CU + 1/2ES	5.90	4.57	0.84	4630.38	7996.67	5763.50
ESP+1/2ES	4.88	2.16	1.72	4236.50	7622.50	5240.74
ES FULL	4.80	5.83	1.22	3004.58	6865.00	5608.61
Neem oil	4.85	4.01	3.22	4116.08	7417.50	5471.72
Untreated	9.03	6.34	3.88	3223.50	7116.67	5186.83

Identification of Vectors of Chickpea Stunt Virus

To identify the vector of chickpea stunt caused by beet western yellows virus (BWYV), two species of aphid: pea aphid (*A. pisum*) and cowpea aphid (*A. craccivora)* were reared on lentil and cowpea, respectively. Their progenies were divided into two sets and were allowed to feed on chickpea plants with typical stunt symptoms. The first set consisted of aphids that were allowed 24 hr acquisition feeding and 48 hr inoculation feeding, and the second set consisted of aphids, which were allowed 15 min acquisition feeding and 24 hr inoculation feeding. Chickpea plants infested with aphids, which were allowed to feed on diseased chickpea plants, did not show stunt symptom (DZARC, 2000).

Evaluation of Food Lures

Honey, molasses, orange squash, *teji* and *tela* were evaluated at Debre Zeit for their attractive- ness for *Helicoverpa* moths. The effectiveness of the tested food lures varied from one season to the other. In 2001/02 cropping season, for instance, none of the tested food lures attracted *H. armigera* moths. In the preceding season, however, all of them attracted *H. armigera* moths though there was no statistically significant difference among the food lures (DZARC 2004). The average catch per trap per day was generally lower than one moth for all treatments. On the contrary as high as seven male moths per trap per day were trapped using old frozen septa during the same period. Unlike the synthetic septa, which attract only males, these food lures attract both male and female *Helicoverpa* moths. Surveying of chickpea fields in major chickpea growing regions revealed that the incidence of the pest and the damage it caused was unusually higher than the previous season. This might suggest that these food lures can help in dictating *Helicoverpa* moths when the population is high. Besides *Helicoverpa* moths many other moths and few butterfly species were attracted by different lures (DZARC, 2004).

GRASS PEA

Survey

Survey of grass pea fields revealed that grass pea suffered from pea aphid attacks particularly in northwestern parts of the country. Around Wond Ata area in 1998/99 crop season for instance about 600-800 aphids were counted per 10 sweeps (AdARC, 2002b). Similarly, a preliminary monitoring during off-season periods showed that other than pea aphid irrigated grass pea in Debre Zeit area was attacked by blue butterfly, *Lampides boetucus* (unpublished data). It was reported in early 1980s as an insect-pest of lupin, *Lupinus albus* (Tsedeke et al., 1982) though in Ethiopia this butterfly species was recorded as a new pest of grass pea.

Management Practice of Pea aphid

Botanicals: Detergent (Ommo powder) at the rate of 0.12g/ plot (4m^2), crude extracts of *neem*-seed-powder, garlic juice, and chilies juice each at the rate of 25ml/plot and kerosene at the rate of 0.4ml/plot were evaluated at Wond Ata between 1999/00 and 2001/2002 seasons. These treatments were applied at different spraying times, i.e., at seedling, pre-flowering, flowering, and pod-setting stages. Primicarb (insecticide) and untreated check were included for comparison (AdARC, 2002b; Melaku Wale, unpublished data). The effects of these treatments on pea aphid on grass pea and its natural enemies are presented in Table 11 and 12. Primicarb gave consistently good control of aphid during the whole study period. Among the tested botanicals, chilly juice relatively reduced the aphid population than *neem* seed and garlic extracts. On the contrary, soap alone was not efficacious in affecting aphid population. Application of kerosene caused burning of grass pea plants. Nonetheless, in all cases aphid population showed sudden increase in number towards podding and/or maturity stage of the crop. At this stage, more than 700 aphids/10 plants were recorded. As a consequence, untreated plots showed an average of 87% plant damage, while primicarb-treated plots exhibited no damage (AdARC, 2002b; Melaku Wale, unpublished data). Moreover, percent parasitism of aphids was significantly higher on insecticide (primicarb)-treated plots than the others. However, the rest of the treatments resulted in comparable levels of parasitism with the untreated check. Nonetheless, in terms of predator, the least number of predators was recorded on insecticide-treated plots. Based on grain yield, primicarb and chilly-treated grass pea gave better yield than the other treatments (Melaku Wale, unpublished data).

Insecticides:

The effect of time of insecticide application on pea aphid on grass pea was also investigated between 1996/97 and 1999/00 seasons. Two insecticides, namely, primicarb and dimethoate and the aforementioned application times and their combinations were included (AdARC, 2002b; Melaku Wale, unpublished data). In 1996/97 and 1997/98 seasons, there was no variation among different time of application of insecticides in reducing aphid population. However, in the subsequent two years clean check, i.e., four times application (at seedling, pre-flowering, early-flowering, and pod-setting stages) generally reduced aphid population, and this was followed by spraying at early-flowering, and one spray at any other growth stage. This was coupled with relatively higher seed yield (Melaku Wale, unpublished data) (Table 13). Nonetheless, it is necessary to undertake cost-benefit analysis to determine the most economical treatment. Since the tested insecticides were equally effective in affecting pea aphid populations, they can be alternatively used in grass pea production.

Host Plant Resistance

Several grass pea genotypes were screened at Wond Ata to select resistant or tolerant genotypes to pea aphid. Accessions 46034, 46047, 46048, 46095, 201556, 214802, 46075/1/Ad87, 46072/11Ad87, 46076/1/Ad87, 46075, 201545, 226007, 46098, and NC8a-84 showed less than 10 aphids per five plants during three different sampling periods. On the contrary, as high as 107 aphids per five plants were recorded on accession PGRC/E 46064 (AdARC, 2002a). Moreover, at Debre Zeit in the 2002 off-season attempt was made to visually scale pod damage caused by blue butterfly *(Lampides boeticus)* on grass pea sown in breeding plots. It was found that there was considerable variation among different genotypes in the amount of pod damage incurred on them. For instance, late-type accessions like 190-1, 387-5, B-104-2, and F1-ILAT-LSK-289X ILAT-LSK299 and ILAT-LSK-33 X ILAT-LSK104 and mutant lines IVAT-15-290-40KR were free from infestation. On the contrary, accessions 390-1, B-103-1, B-103-2, and several others had high percentage of damaged pods (unpublished data).

POST-HARVEST INSECT-PESTS

Post-harvest Loss Assessment

Teshome et al. (1998) reviewed all available information on post-harvest losses in Ethiopia. According to them, the reports on post-harvest losses lack clarity i.e. it is not clear whether the figures refer to the amount of damage, the total amount of grain lost or reduction in grain quality or the cause of the damage. However, they mentioned that, although negligible, all legumes with the exception of vetch (*Vicia sativa*) showed sign of infestation at the time of harvest. Moreover, under farmers' storage system for chickpea 8.2% in eastern Shoa zone of Oromiya in 1990 and 3.7% in 1996 in southern Gondar zone of Amhara Regions were recorded.

To determine the amount of losses caused by Adzuki bean beetle (*C. chinensis*) in stored chickpea variety Mariye and DZ-10-11 were tested under insecticide (Actellic 2% dust)-treated and -untreated conditions. Although the loss generally ranged from 6.7-24% on insecticide- treated and 18.3-52.6% on insecticide-untreated chickpeas within six months, there was difference between years in the magnitude of loss incurred on each variety by this storage pest. Thus in 1994/95 season, highest number of eggs and emergence holes per seed were recorded on variety Mariye both under insecticide-treated and -untreated conditions (Table 14). As a consequence, weight loss due to this storage pest on this variety was greater than the loss caused on DZ-10-11. This is attributed to the smooth seed testa and large seed size of Mariye (DZARC, 1997). In the preceding year, however, the loss on both varieties was nearly equal both under protected and unprotected conditions (DZARC, 1998).

Table 11. Effect of time of insecticide application against pea aphid on grass pea.

	Aphid density per 10 plants at its peak			Grain yield, kg/ha		
Time of application	1997/98	1998/99	1999/00	1997/98	1998/99	1999/00[ab]
Seedling stage (SS) only	23.65	722ab	119.3de	2113.30	107.8f	2029.45c
Pre-flowering stage (PF) only	41.30	670ab	216.8ab	2158.30	272.3df	1241.67c
Early-flowering stage (EF) only	25.30	631ab	228.0a	2271.65	845.2b	1696.1a-c
Pod-setting stage (PS) only	38.95	729ab	189.5a-d	2178.35	214.8ef	2185.0a
SS+PF	32.95	863a	135.5c-e	2235.00	331.7c-f	1167.22c
SS+EF	14.65	654ab	186.2a-c	2466.65	813.1bc	1468.33bc
PF+EF	18.6	532ab	155.3a-e	2276.7	726.5b-d	1304.43c
EF+PS	15.95	495ab	140.8b-e	2101.7	672.1bc	1749.45a-c
PF+PS	54.95	821ab	213.5a-c	2166.7	606.3b-e	1604.97a-c
Clean check (sprayed at all stages)	22.30	352b	141.2b-e	2225.0	1354.0a	1634.45a-c
Untreated check	44.95	670ab	106.5e	2025.00	187.2ef	1623.33a-c

Source: Melaku Wale (unpublished data).

Table 12. Pea aphid population/10 grass pea plants sprayed with different botanicals, soap, kerosene and insecticide at Wond Ata (1999 to 2002).

		Treatments						
Year	Crop growth stage	Soap	Neem	Garlic	Chilies	Kerosene	Primicarb	Untreated check
1999/2000	Seedling stage	7	34	22	32.0	16	14	15
	Pre-flowering stage	16	117	51	38.0	38	33	55
	Flowering stage	16	110	41	47.0	24	1	74
	Pod-setting stage	116	124	128	147.0	103	172	98
	Maturity	754	625	617	485.0	351	237	532
2000/2001	Pre-flowering stage	62.7	59.7	68.3	67.0	43.3	4.3	69
	Flowering stage	128.0	98.0	143.7	5.7	133.7	12.3	119.3
	Pod-setting stage	391.0	376.0	396.3	191.0	442.0	58.0	444.7
2001/2002	Seedling stage	1.3	8.3	0.7	2.3	2.0	4.7	2.7
	Flowering stage	93.7	55.0	62.3	29.7	37.3	24.7	61.3
	Pod-setting stage	384.7	549.7	620.3	418.0	256.0	204.3	617.3
	Maturity	699.0	747.7	741.0	533.0	514.0	18.3	755.7

Source: Melaku Wale (unpublished data).

Table 13. Aphid parasitism by parasitoids (%) and damaged grass pea plants (%) due to pea aphid at Wond Ata (2000 to 2002).

		Treatments						
Year	Description	Soap	Neem	Garlic	Chilies	Kerosene	Primicarb	Untreated check
2000/01	% plant damage	86.7	83.3	83.7	60.0	78.3	2.0	86.7
	% parasitism	11.3	22.3	13.6	16.5	8.6	42.0	13.4
2001/2002	% parasitism at podding stage	5.2	8.5	7.4	6.1	4.6	44.2	6.3
	% parasitism at maturity stage	10.1	6.0	9.2	8.3	9.1	5.2	14.2
	No. of ladybird beetles per plot	6.7	9.3	14.3	13.0	12.7	2.3	7.7

Source: Melaku Wale (unpublished data).

Table 14. The effect of variety and insecticide application on loss caused by Adzuki bean beetle in stored chickpea.

Duration of		Eggs/seed (mean)		Emergence hole/seed (mean)			Percent weight loss		
storage	Variety	Treated	Untreated	Treated	Untreated	Mean	Treated	Untreated	Mean
4 months	Marye	2.17	2.67	2.08	2.36	2.22	6.7	24.4	15.55
	DZ-10-11	1.95	2.49	1.98	2.24	2.11	6.8	18.3	12.55
	Mean	2.06	2.58	2.03	2.30	-	6.75	21.35	-
6 months	Marye	2.36	2.76	2.20	2.53	2.37	24.1	52.6	38.35
	DZ-10-11	2.24	2.64	2.00	2.30	2.15	19.0	20.2	19.60
	Mean	2.3	2.70	2.10	2.4	-	21.6	36.4	-

Source: DZARC (1997).

Botanical Screening

Several botanicals were evaluated for their efficacy in controlling Adzuki bean beetle (*C. chinensis)* in stored chickpea, using the improved variety Mariye (DZARC, 2003). The desired plant part was dried, ground using mortar and pestle, and mixed with the grain at 5% W/W. Only two plant species, namely, "Birbira" (*Mellettia ferruginea)* and fermented tobacco gave complete protection for six months, although 33% of the seeds treated with fermented tobacco contained eggs of the beetle. *M. ferruginea* deterred egg laying, whereas fermented tobacco killed the larvae either before or shortly after they bored the seed coat. Both had no negative effect on germination of chickpea. The 10 species used by farmers in place of pesticides were not effective in controlling this pest (Tebkew and Mekasha, 2002).

DISCUSSION AND CONCLUSIONS

Compared to the 1980s research work that focused mainly on chemical control of insect-pests on lentil and chickpea (Kemal and Tibebu, 1994), the current research efforts were geared towards finding alternatives to pesticides and towards generating baseline information on biology and seasonal abundance of key pests. Although these attempts incorporate variety of strategies, continuity and standardized evaluation methodologies are lacking. For instance, the biology of pea aphid was studied under laboratory conditions (Melaku et al., 2000; Tebkew et al., 2002). Thus, the generated information would have been used as background information to study its biology under field conditions. Similarly, in investigating the seasonal abundance of this aphid and *H. armigera* it was found that these insect-pests exist throughout the year (DZARC, 1996, 1997, 1998, 2000, 2001). However, further attempts were not made to detect if there was or not local migration of these pests from one region to the other or if these insects from other host crops such as field pea, faba bean or other hosts migrated and infested lentil, chickpea and grass pea sown late in the season. Moreover, several lentil, grass pea and chickpea genotypes were screened for their resistance or tolerance to their respective major insect-pests (DZARC, 1993, 1997, 1998, 2000; AdARC, 2002a). But the work was either carried out for one season or emphasized on obtaining immune or only genotypes with high yield potential. This method definitely eliminated several useful materials like those genotypes that have low pest density but poor yield. Besides, detection of mechanism of resistance is totally unexplored. The difficulty of ascertaining cultural practices in pest management has also been mentioned (DZARC, 1998). Nonetheless, attempts were not made to courage selective application of insecticides within cultural practices in an integrated manner.

In determining the economic threshold for spraying against pea aphid on lentil, plots that have higher infestation level than the untreated check plots were deliberately assigned to higher aphid density treatments. This difficulty of randomization and ensuring uniform infestation certainly yields biased result.

Different levels of pod damage within similar area or different sampling methods were used to sample single pest specie on the same crop. This might be attributed to the lack of standardized sampling method that fitted the existing farming system.

Similarly, efforts were made to evaluate botanicals/plant derivative insecticides for their efficacy in controlling storage or field pests (Tebkew and Mekasha, 2002; Melaku Wale, unpublished data; DZARC, 19999, 2001, 2002, 2004). However, further attempts were not made to formulate the extracts into most effective formulation or to identify the active ingredient involved in the insecticidal activity.

In the past, grass pea was considered to be a healthy crop. The healthy nature of this crop is not ascribable to its immunity to insect-pests but partly to the lack of research attempts on insect- pests of grass pea and partly to the limited area it occupies. Recently, however, its production is expanding at a fast rate. As its area coverage increases, and the production of some crops like field pea and lentil decreases, grass pea could become a suitable host for some insect- pests.

FUTURE RESEARCH DIRECTIONS

Based on the gaps indicated above the future research should be geared towards:

1. The development of standardized screening methods and evaluation criteria for selection of resistant or tolerant host plants.
2. Obtaining and evaluating more germplasm for resistance or tolerance to economically important insect-pests.
3. The development/selection of simpler and more accurate sampling methods and monitoring devices.
4. Finding a better way of using existing botanicals and further research for new botanicals.
5. Survey, collection and evaluation of natural enemies of key pests.
6. Study of pest biology under field conditions (dispersal and over-seasoning).
7. Integrating the available management options.
8. Yield loss assessment due to insect-pests under Ethiopian conditions
9. Even though most farmers do not use insecticides, the insecticides currently in use were recommended some 20 years ago. Hence, re-evaluation or screening new insecticides is required

Acknowledgement

The authors acknowledge Ato Melaku Wale of the Adet Agricultural Research Center for providing his unpublished data.

REFERENCES

AdARC. 2002a. Summary of research achievements (1987-2001). Adet Agricultural Research Center (AdARC), Bahir Dar, Ethiopia.

AdARC. 2002b. Progress report for the period 2000/01, Adet Agricultural Research Center, Bahir Dar, Ethiopia.

Abraham Taddese, and Adane Kasa. 1998. Some arthropod pests of agricultural importance in Western Ethiopia. A Handbook. Institute of Agricultural Research, Addis Ababa.

Adane Abraham, and Alemu Lencho. 2000. Grass pea severe stunt virus disease in Ethiopia. *Pest Mgt. J.* Eth. 4: 85-88.

Adane Abraham, and Habtu Assefa. 2000. Virus and virus like disease of plants in Ethiopia. *Pest Mgt. J.* Eth. 4: 1-10.

CSA. 2002. Report on the preliminary result of area, production and yield of temporary crops. Part I. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

DZARC. 1993. Annual report for the period 1991/92. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 1994. Annual research report for the period 1992/93. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 1996. Annual research report for the period 1993/94. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 1997. Annual research report for the period 1994/95. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 1998a. Annual research report for the period 1995/96. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 1998b. Annual research report for the period 1996/97. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 1999. Annual research report for the period 1997/98. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 2000. Annual research report for the period 1998/99. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 2001. Annual research report for the period 1999/2000. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 2002. Annual research report for the period 2000/01. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 2003. Annual research report for the period 2001/02. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

DZARC. 2004. Annual research report for the period 2002/03. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

Geletu Bejiga, Million Eshete, and Yadeta Anbesa. 1996a. Improved cultivars and production
technology of chickpea in Ethiopia. Research Bulletin No. 2. DZARC, AUA, Debre Zeit, Ethiopia.

Geletu Bejiga, Million Eshete, and Yadeta Anbesa. 1996b. Improved cultivars and production technology of lentil in Ethiopia. Research Bulletin No. 3. DZARC, AUA, Debre Zeit, Ethiopia.

Kemal Ali, and Tibebu H/Wold. 1994. Research on insect pests of cool-season food legumes. p. 367-396. *In* Asfaw et al. (Eds.) *Cool Season Food Legumes of Ethiopia*. Proc. First National Food Legumes Review Conference, 16-20 December 1993. Addis Ababa, Ethiopia.

Mekasha Chichaybelu, and Geletu Bejiga. 1999. Farmers' perception of the importance and management of chickpea insect pests in Ethiopia. *NVRSRP Newsletter* No. 2: 35-37.

Melaku Wale. The effect of some botanicals, detergent and kerosene on pea aphid (*Acyrthosiphon pisum*, (Homoptera: Aphididae) on grass pea *(Lathyrus sativus)*. (Unpublished).

Melaku Wale, Bekele Jembere, and Emiru Seyoum. 2000. Biology of the pea aphid, *Acyrthosiphon pisum* (Homoptera: Aphididae) on cool season food legumes. *Insect Science and Its Application* 20: 171-180.

Melaku Wale, Bekele Jembere, and Emiru Seyoum. 2003. Effect of density on reproduction and survival of pea aphid on cool season food legumes. Pest Mgt. J. Eth. 7: 63-69.

Seid Ahmed, and Tebkew Damte. 2002. African boll worm *(Helicoverpa armigera (Hubner)):* A key pest affecting pulses production in Ethiopia. Paper presented at Joint Workshop (EARO/ICIPE) on African Bollworm Management, Research Status, Needs and Opportunities in Ethiopia, 17-18 April, Ambo, Ethiopia

Taddese, N., K. Ali, D. Gorfu, A. Yusuf, A. Abraham, M. Ayalew, A. Lencho, K.M. Makouk, and S.G. Kumari. 1999. Survey for chickpea and lentil virus diseases *in* Ethiopia. *Phytopath. Medit.* 38: 149-158.

Tebkew Damte, and Mekasha Chichaybelu. 2001. Pea aphid (Acyrthosiphon pisum, Homoptera: Aphididae) management in lentil (*Lens culinaris*). Paper presented at the Nile Valley and Red Sea Regional Program Regional Coordination Meeting. Food Legume Research Program, 23-27 September, Cairo, Egypt. .

Tebkew Damte, and Mekasha Chichaybelu. 2002. The efficacy of some botanicals in controlling Adzuki bean beetle (*Callosobruchus chinensis)* in stored chickpea. *Tropical Sciences* 42: 92-195.

Tebkew Damte, B. Ulber, and S. Vidal .2002. Biology and biotypes of two strains of pea aphid, *Acyrthosiphon pisum* on lentil. *Pest Mgt. J.* Eth. 6: 13-21.

Teshome Lemma, Emana Getu, and R. A. Boxall. 1998. A review of published and unpublished information on post-harvest losses in Ethiopia. p. 27-36. *In Grain Post Harvest Loss Assessment in Ethiopia.* Report No. 2377.

Tsedeke Abate, Tadesse Gebremedihin, and Kemal Ali. 1982. Arthropod pests of grain legumes in Ethiopia: Their importance and distribution. Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia. 56 pp.

Review of Lowland Pulses Insect-Pest Research in Ethiopia

Emana Getu[1], Ahemd Ibrahim[2] and Firdisa Iticha[2]

[1]Ethiopian Agricultural Research Organization,Melkassa Agricultural Research Center (EARO), Melkassa, Ethiopia
[2]Bako Research Center, P.O. Box 3, Bako, Ethiopia

ABSTRACT

Several insect-pests attack bean plants during the various stages of development and cause damage by defoliation, tunneling of stems and pods, as well as removal of plant sap, flowers, and floral parts. This may result in poor plant growth, losses in the quality and quantity of pods and seeds, and in severe cases results in plant mortality. In storage, beans are also attacked by several species of insects, which in some cases may result in complete crop loss. Over 60 insect species have been recorded on different species of lowland pulses. However, only bean stem maggot (*Ophiomyia* spp.) and African bollworm (*Helicoverpa armigera*) in the field, and bruchids (*Acanthoscelides obtectus, Zabrotes subfasciatus* and *Callosobruchus maculatus*) in store are the major pests. For the control of these major pests, attempts were made to develop integrated pest management, which gave due attention to varietal resistance, biological control, botanical control, and chemical control. Research on lowland pulses entomology started in 1972 and has been coordinated from the Nazareth Agricultural Research Center. In this article, detailed entomological research activities of the lowland pulses undertaken in Ethiopia since the establishment of the discipline are presented. Moreover, future research directions are outlined.

INTRODUCTION

About 13 species of lowland pulses are grown in Ethiopia. However, the most commonly grown across the country are haricot bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), soybean (*Glycine max*), mungbean (*Vigna radiata*) and pigeonpea (*Cajanus cajan*) (Ferede, 1994; Abate, 1990a,b; Imru, 1980; Kyamanywa & Ampofo, 1988). These lowland pulses are grown for food, market and soil conservation. The national yield average for most of the lowland pulses is below 1 t/ha (Abate et al., 1985a,b). Several factors contribute to low yield among which entomological problems are the most visible ones (Imru, 1980). Entomological research on lowland pulses in Ethiopia started in the early 1970s with the main focus on pest surveys, documentation, and establishing the economic importance during the initial phase, and devising appropriate management measures for major pests on major lowland pulses once the pests have been identified (Abate, 1990b, 1995; IAR 1889. This article highlights the research progress on pests of lowland pulses over the last 30 years. Suggestions are also made for future research directions.

BASIC STUDIES

Surveys and Identification

Although a large number of arthropod pests have been recorded on major lowland pulse crops, only a few of them are of economic importance. The bean stem-maggot (*Ophiomyia* spp.) and bean bruchids (*Acanthoscelids obtectus, Zabrotes subfasciatus, Callosobruchus* spp.) are the most important pests of haricot bean in the field and in storage, respectively (Ferede and Abate, 1986). The African bollworm (*Helicoverpa armigera*) is also an important pest of haricot bean in the Rift Valley and other drier parts of Ethiopia (Abate and Adhanom, 1981; Abate et al., 1985a). Important arthropod pests and total number of pest species recorded on selected lowland pulses in Ethiopia are summarized in Table 1.

Table 1. Important arthropod pests and total number of pest species recorded on selected lowland pulses in Ethiopia.

Crop	Important pest(s)	Number of pests recorded
Cowpea	Aphids	35
	Bruchids	
	Cotton leaf worm	
	Flower thrips	
	Pod bugs	
	Pod-borer	
Haricot bean	Bruchids	36
	African bollworm	
	Red spider mite	
	Pod bug	
	Aphids	
Soybean	Green stink bug	54
	Banded stink bug	
	Pod bug	
	Bruchids	
	Aphids	
Mungbean	Black pod-weevil	13
	Green stink bug	
	Pod bug	
	Bruchids	
Pigeonpea	Pigeon pea pod-borer	16
	African bollworm	
	Pod bug	
	Cottony cushion scale	

Source: Abate (1995).

Bean stem maggot (BSM) (*Ophiomyia spp.*)

Population dynamics studies: This study was conducted at Awassa and Areka between 1991 and 1993. The results obtained indicated that *O. phaseoli* was the dominant species in bean plots sown between early-May and mid-June. In contrast, *O. spencerella* constituted 60 to 100% in plots sown during the cooler and wetter months of July and August. At Areka, *O. spencerella* ranged between 73% and 100% in 1992 and between 57 and 100% in 1993. Here, *O. phaseoli* was found in appreciable numbers only in plots sown during the warmer and relatively drier months of February to May (Abate, 1995).

Host-range studies: Studies conducted so far indicated that BSM are restricted to the plant family Leguminosae. These include, in descending order, haricot bean, cowpea, the wild host (*Crotalaria laburnifolia*), and soybean (*Glycine max*) (Abate 1990a).

Ecological studies: Ecological studies carried out so far show that three species of BSM occur in Ethiopia. These are: *Ophiomyia Phaseoli* (Tryon), *O. spencerella* (Greathead) and *O. centrosematis* de Meijere on haricot bean. Of these, *O. phaseoli* and *O. spencerella* are the most widely distributed and abundant. *O. centrosematis* occurs rarely and represents less than 2% of the total BSM population in most instances. It has been recorded from Jimma, Arsi-Negele, Awassa and Melkassa, and occurs in appreciable numbers at Melkassa only in beans sown after September. The incidence of BSM species is influenced by one or a combination of environmental factors and cultural practices, including altitude, sowing date, and growth stage and type of the host plant. *O. phaseoli* and *O. centrosematis* are more prevalent at altitudes below 1800 m asl and warmer climatic conditions, whereas *O. spencerella* is dominant at higher altitudes and cooler and wetter environments. *O. phaseoli* is more abundant in early-sown bean whereas *O. spencerella* becomes more common later in the season. *O. phaseoli* is more frequent on thin-stemmed, narrow-leaf, small-seeded, pea bean types, whereas *O. spencerella* and *O. centrosematis* show preference for more succulent, broad-leaf, large-seeded, navy bean types. BSM intensity (as measured by BSM per 10 plants) and species composition vary with location and sampling date (or sowing date). Samples of bean plants collected at Welenchiti, Bulbula, Ambo (Shoa); Hirna, Chelenko, Kobo, Kunie, Kulubi (Hararghe); and Abelti and Seka (Kaffa) did not yield BSM although they showed characteristic symptoms (stunting, yellowing and dying) of damage caused by this insect. BSM intensity at some localities, such as Kersa, Wakmolie, Yabete Anbessa (Hararghe); Melkassa, Shashemene (Shoa); Metu (Ilubabor); and Bonga, and Jimma (Kaffa) is relatively low, suggesting that these insects may not be a limiting factor in haricot bean production in these areas (Abate, 1995).

Bruchids

Bruchids of economic importance in Ethiopia include, the bean bruchid (*Acanthoscelides obtectus*), the Mexican bean weevil or spotted bean weevil (*Zabrotes subfasciatus*), and the cowpea bruchids (*Callosobruchus maculates*). *Acanthoscelides* and *Zabrotes* are important on haricot bean (and may occur together), whereas *C. maculatus* is the major pest of cowpea. *C. chinensis* is important on both crops (bean and cowpea). In general, beans and cowpea are preferred grains. One or more of these insects in storage also attacks a wide range of pulses including pigeonpea, soybean, mungbean, chickpea and faba bean. Maize is also reported to be an alternative host but bruchids are not important on this crop. The Mexican bean weevil is of recent introduction to Ethiopia. It had not been recorded in Ethiopia until Ferede (1994) reported it as being the major pest in stored beans in the Rift Valley areas. According to studies in Latin America, the prevalence of the two species of bruchids is influenced by the ambient temperature regimes in that *A. obtectus* prefers cooler climates at higher altitudes where it is the dominant species, whereas *Z. subfasciatus* prefers warmer climates in the lower altitudes and, therefore, is more important in the tropical and subtropical regions (van Rheenen et al., 1983 as cited in Ferede, 1994). Recent studies in southern Africa (Giga and Chinwada, 1993) and in Ethiopia (Ferede, 1994) showed that this is not always the case possibly due to: (i) the African strain of *Z. subfasciatus* may be different from that in Latin America, and (ii) there may be factors other than altitude and hence temperature differences alone (such as time of year) that influence abundance of the two species.

Loss Assessment Studies

Data on losses due to major insect-pests on the two major lowland pulse crops are shown in Table 2. In general, losses in the two pulse crops ranged from 9 to 100%. However, BSM caused the maximum yield loss that ranged from 11-100% followed by African bollworm (12-16%). In cowpea, cotton leaf worm caused the maximum damage (range of 27-39%) (Abate, 1995).

Table 2. Pre-harvest yield loss estimates due to insect-pests in haricot bean and cowpea in Ethiopia.

Crop	Pest	Loss (%)
Haricot bean	Bean stem maggots	11-100
	African bollworm	12-16
Cowpea	Cotton leaf worm	27-39
	General	9-12

Source: Abate (1995).

MANAGEMENT OPTIONS

Cultural Control Methods

Bean Stem Maggot: Cultural control studies on management of BSM consisted of determining the effects of sowing date and plant density, and of habitat management on BSM numbers. Studies conducted by Abate (1990a) revealed that both seeding date and plant density had significant effects on BSM intensity, crop damage and yield. Abate observed that the effects of sowing date were location specific, and in general, at both the locations, Awassa and Melkassa, seedling mortality and the resulting yields did not follow any specific trend among sowing dates. However, the effects of plant density on seedling mortality and grain yield were more apparent at both the locations; with both increasing with increase in plant density.

African Bollworm: In general, work on the African bollworm (ABW), Helicoverpa armigera, focused on trap-cropping, strip-cropping and habitat management. It has been shown that pod damage by

ABW was lowest and seed yield was the highest in haricot bean strip-cropped with maize (Abate, 1988). In another experiment, where the effects of strip-cropping beans with maize under weedy and weed-free conditions were tested, natural enemy (including the tachinids, Voria ruralis, V. capensis, and Periscepsia carbonaria; and the wasp Tiphia sjostedii) numbers were significantly greater in the diverse weedy and inter-cropped plots than in bean monoculture (Abate, 1995).

Bruchids: Currently available cultural control measures for bruchids control under smallholder conditions depend on storage conditions. Stores must be free from bruchids and only adequately dried, clean seeds should be stored. The crop should be grown away from the store to discourage field infestation. All unwanted seeds within and around the store must be collected and destroyed. Well-ventilated, cool storage conditions discourage pest establishment (Ferede, 1994).

Host Plant Resistance

Bean Stem Maggot: Several genotypes with resistance to BSM and high grain yields have been identified from studies conducted between 1986 and 1988 (Abate, 1990a). Examples of these are shown in Table 3. Crosses of some of these materials have been made with commercial varieties in the bean improvement program and their progenies are evaluated for BSM and disease resistance, grain yield, and food and cooking quality, which resulted in the release of two varieties, Melka and Bashbash.

Table 3. Mortality, dry grain yield and yield loss due to *Ophiomyia phaseoli* in selected haricot bean genotypes at Awassa, 1988.

Genotype	Mortality (%)	Yield (kg/ha)	Loss (%)
G 5773	12.9	3891	6.6
G 5253	7.6	3419	7.6
G 2005	12.4	3955	12.8
G 2472	17.2	3910	16.1
EMP 81	24.1	3007	16.7
Mexican 142	63.4	757	71.3

Source: Abate (1985b).

Bruchids: Research on host plant resistance of bruchids has identified promising cultivars against Zabrotes. Out of 100 CIAT accessions tested in the laboratory, the genotypes 'RAZ 1', 'RAZ 7', 'RAZ 8', 'RAZ 11' have shown high levels of resistance to this insect (Abate et al., 1985b). No sources of resistance have been found so far against the other bruchids.

Several accessions of cowpea were also tested for resistance to Callsobruchus maculates. The IITA accessions 'IT-81D-985' showed high levels of resistance to the bruchids; in comparison with the recommended variety 'White Wonder Trailing', which was highly susceptible (Table 4).

Table 4. Reaction of haricot bean accessions to the Mexican bean weevil (*Z. subfasciatus*).

Genotype	Eggs/10 grain	Adult emergence (%)	Damaged grain (%)
RAZ 1	299	0.0	0.0
RAZ 7	91	0.0	0.0
RAZ 8	4	0.0	0.0
RAZ 11	78	0.0	0.0
Diacol Calima	155	91.0	80.0
Awash 1	191	84.3	92.0

Source: Firdessa (unpublished).

Botanical Control

Bruchids: Research with botanicals (plant products) has yielded promising results. For example, preparations of *neem* (Azadirachata indica), pepper tree (Schinus molle), Persian lilac (Melia azadirach) (pounded and admixed with bean seed at the rate of 10 kg per kg) gave effective control of bruchids for up to 90 days (Ferede, 1994). Experiments by Lemma (1993) showed that vegetable oils could also give effective control of bruchids in stored beans.

Biological Control

Studies on the biological control of BSM were directed at delineating natural enemies that occur in Ethiopia. Seventeen species of parasitoids have been identified from surveys carried out so far (Abate, 1990a, 1995). Of these, the Braconid *Opius phaseoli* is the major parasitoid on *Ophiomyia phaseoli* in haricot bean. Average parasitism at Awassa is roughly 78%, and at Melkassa it is about 38% (Abate, 1990a). Seeding rate did not influence *Opius* numbers, whereas sowing date had significant effects (parasitoid numbers increased with the increase in BSM numbers).

The pteromalids, *Sphegigaster stepicola* and *S. brunneicornis*, were also common but they accounted for about 5% of total parasitism in haricot bean. In contrast, they were the major parasitoids of BSM on the wild host *Crotalaria laburnifolia* where the average parasitism reached about 26%. As is the case in other parts of eastern Africa, it is possible that the same parasitoids attack *O. spencerella* (Grteathead, 1969 as cited by Ferede, 1969).

Studies on Insecticidal Control

Bean Stem Maggot: Insecticidal control studies have been conducted at Kobo, Mekele, Melkassa, and Awassa primarily to replace aldrin (Ferede and Abate, 1986; Abate, 1990a). Although seed dressing with carbofuran (35% liquid formulation) significantly reduced BSM infestation at Kobo and Mekele it had phytotoxic effects, especially where there was a shortage of rainfall (Abate et al., 1985a, b). Experiments at Melkassa and Awassa demonstrated that an effective control of BSM could be obtained with endosulfan seed dressing at the rate of 5 g a.i./kg of seed (Abate, 1990a).

Bruchids: Several tests have been carried out using insecticides against bruchids on beans. Pirimiphos-methyl at the rate of 4-5 ppm a.i. provided effective control of bruchids (Abate et al., 1985a, b), and is widely used at present, at least in commercial stores.

FUTURE RESEARCH DIRECTIONS

Due attention should be given to non-chemical methods of control. Likewise, the following areas of research need high priority:

1. Periodic survey for major pests and their natural enemies and mapping of their distribution.
2. Further screening of germplasm against major lowland pulses pests such as BSM, bruchids, ABW and others.
3. Ecological studies on major lowland pulses insect-pests such as habitat management and others.
4. Intensive studies to develop sound IPM for major pests.

REFERENCES

Abate, T. 1988. Experiments with trap crops against African bollworm, *Heliothis amerigera*, in Ethiopia. *Entomol. Experi. et Applic.* 48: 135-140.

Abate, T. 1990a. Studies on genetics, cultural and insecticidal control against the bean fly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae), in Ethiopia. Ph. D. Thesis. Simon Fraser University, Burraby, BC, Canada. 177 pp.

Abate, T. 1990b. Bean entomology. p. 54-57. *In* Proc. of Research on Haricot Bean in Ethiopia, 1-3 October 1990, Institute of Agricultural Research, Addis Ababa, Ethiopia.

Abate, T. 1995. Pest management in lowland pulses: Progress and prospects. p. 181-194. *In* Proc. 25th Anniversary of Nazareth Research Center, 22-23 September 1995, Melkassa, Ethiopia.

Abate T., and N. Adhanom. 1981. Chemical control of African bollworm (*Helicoverpa armigera*) (Hubner) with ultra-low-volume sprays. *Ethiopian J. Agric. Sci.* 3: 49-55.

Abate, T, N. Ferede, and A. Kemali, A. 1985a. A review of grain legume pest management research in Ethiopia. p. 327-344. *In* T. Abate (Ed.) *A Review of Crop Protection Research in Ethiopia.* Institute of Agricultural Research, Addis Ababa, Ethiopia

Abate, T., A. Gashawbeza, and G. Amannual. 1985b. Ecology of bean stem-maggots in Ethiopia. Paper presented at the 2nd International Crop Science Conference, eastern and southern Africa, Malawi, 19-24 February 1995.

Ferede, N. 1994. Studies on the economic importance of and control of bean bruchids in haricot bean. M. Sc. Thesis. Alemaya University of Agriculture, Alemaya, Ethiopia. 103 pp.

Ferede, N., and T. Abate. 1986. Studies on the control of bean fly, *Ophiomyia phaseoli* (Tryon) (Diptera: Agromyzidae). *Ethiopian J. Agric. Sc.* 8: 47-59.

Giga D., and P. Chinwada. 1993. Progress in bean bruchids research in SADC. *In* Proc. Second PAN-African Working Group on Bean Entomology, Harare, Zimbabwe, 19-22 September 1993. CIAT African Workshop Series, No. 25.

IAR. 1985. Department of Crop Protection progress report for the period 1983/84. Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia.

IAR. 1989. Research Program Directory, 1989. IAR, Addis Ababa, Ethiopia.

Imru, A. 1980. "Lowland pulses"- an introduction. *Ethiopian Grain Review* 6: 16-22.

Kyamanywa, S., and J.K.O. Ampofo. 1988. Effect of cowpea/maize mixed cropping on the incident light at the cowpea canopy and flower thrips, *Megalurothrips Sjostedri* (Trybornn) (Thripidae). *Insect Sci. Applic.* 9: 255-259.

Lemma, T. 1993. Evaluation of neem (*Azadirachta indica*) and vegetable oils against the adzuki bean beetle (*Callosobruchus chinensis*) (Abstract). p. 31. In Proc. Joint EPC//CEE Conference. Crop Protection Society of Ethiopia, Addis Ababa, Ethiopia.

Weed Research in Highland Food Legumes of Ethiopia

Rezene Fessehaie[1] and Gerba Leta[2]

[1]Holetta Agricultural Research Center, PO Box 2003, Addis Ababa, Ethiopia, [2]Debre Zeit Agricultural Research Center, PO Box 32, Debre Zeit, Ethiopia

ABSTRACT

Weed growth, population density and distributions in highland food legumes (faba bean, field pea, lentil and chickpea) of Ethiopia vary from place to place depending upon soil and climatic factors, and farmers' management practices. Recent survey records indicated that these crops, faba bean in particular, are vulnerable to damage by the parasitic weed species *Orobanche crenata* L. in some areas of northern Ethiopia. Additional survey information on other non-parasitic weed species for the highlands of Shoa and Bale are also provided by Holetta and Sinana Agricultural Research Centers. Studies on improved weed management in these crops in the past decade stressed practices that benefit small-scale farmers. These were done by improving weed control techniques to match other agricultural operations that are practiced by farmers. Efforts towards introducing chemical weed control were not successful due to lack of inexpensive and effective broad-spectrum herbicides for controlling annual grassy and broadleaf weed species. With this background, this article reviews the available recent information in weed research in highland food legumes that has been accumulated since the last decade.

INTRODUCTION

Highland food legumes (HFL) are usually plagued by a wide variety of early- and late- emerging weeds including annual grass weeds such as *Avena fatua, Snowdenia polystachya, Bromus pectinatus, Phalaris paradoxa, Setaria pumila,* and several annual broadleaf weed species particularly, *Bidens* species (collectively known as *'meskel'* flowers); *Guizotia scabra, Rumex* spp., *Galinsoga parviflora, Galium spurium, Polygonum nepalense, Commelina benghalensis, Flaveria trinervia, Launea cornuta, Medicago polymorpha* (Rezene, 1986, 1994; Kedir et al., 1999). With this diversity of weed species there is seldom an effective method available that will control all weeds in HFL.

Faba bean and lentil are very sensitive to weed competition from seedling establishment to early-flowering stages. Field pea is not as sensitive to early weed competition as other legumes. However, yield reduction can occur if there is no attention to weed control. Chickpea is sensitive to early weed competition and is less competitive than lentils. However, because it is sown late in the season and grown on residual moisture, it seldom encounters much weed competition.

Hand-weeding is the major weed control method used in HFL production and is labor intensive and slow compared to other manual weeding operations and is usually delayed until the weeds are tall enough to be firmly held in the hand. Thus, these crops suffer from the adverse effects of early weed interference because of delayed weeding (Rezene, 1986, 1994). Generally, herbicides are not recommended for subsistence agriculture at this time unless grown for large-scale commercial production.

Past weed research activities in HFL have been reviewed by Rezene (1986, 1994). The aim of this article is to give a broad view of recent information in weed research in HFL that has been accumulated in Ethiopia during the last decade.

WEED SURVEYS

Major surveys carried out during this period under report include:

1. Occurrence of broomrapes *(Orobanche spp.)* and dodder (*Cuscuta spp.)* in HFL.
2. Distribution and economic importance of *Orobanche* spp. in northern and northwestern Ethiopia.
3. Qualitative and quantitative determination of faba bean weeds in western and northwestern Shoa.
4. Weed survey in major field pea and faba bean growing areas of Bale highlands.

Occurrence of Broomrapes (*Orobanche* spp.) and Dodder (*Cuscuta* spp.)

The survey methodology applied under this report allowed rapid data collection on the occurrence of the target parasites and was found to be useful as indicative tool for future work (HARC, 2001). A survey was conducted to identify *Orobanche* and *Cuscuta* species attacking HFL and their associated hosts and to determine the geographical distribution and hot spot areas. Questionnaires were sent to cooperators at various research centers, Regional bureaus of agriculture, agricultural colleges and plant health clinics to supply specific information on the distribution, host range and economic importance of *Cuscuta* and *Orobanche* species in cultivated lands of their respective areas.

The survey covered all HFL growing areas of Ethiopia with the exception of Benshangul Gumuz Region. *Orobanche* species reported and their distribution and main hosts are presented in Table 1 and 2. Results indicated that of the three species reported, *Orobanche crenata* was found to be an actual and potential threat to HFL production particularly with more pronounced effect in faba bean fields in Kedijo and Haroye-Flagober.

There are already pocket areas in Dara and Tach Gayint in southern Gonder and Alamata in southern Tigrai where severe infestation of this species has been recorded. Thus, there could also be a real danger for the cool season food legume production areas of northern and northwestern Ethiopia to be invaded by *O. crenata* (Rezene, 1998).

All cooperators did not indicate the incidence of *Cuscuta* spp. But, this by no means could be considered to reflect the real situation as all HFL were reported among the host range checklist of this parasite.

Table 1. Records of species composition, distribution and host range of *Orobanche* species in HFL surveyed areas.

Species	Host crops reported	Distribution	Hot spot areas
Orobanche minor	Extremely wide ranges of hosts: Faba bean, clovers, including non-crop hosts in Compositae, Solanaceae and Umbeliferae and wild Trifolium	Widely spread throughout the high-land pulses growing areas under report	None
Orobanche ramosa	Faba bean, chickpea, lentil, field pea, clovers including long list of wild hosts in Chenopodiaceae, Amaranthaceae, Rubiaceae, Oxalidiaceae, Lineaceae, Polygoniaceae, Labiatae and Plantiginaceae	Some localized situation of highland pulses growing areas of Arsi, western Shoa in Chelia *woreda* (neighboring localities of Guder).	None
Orobanche crenata	Chickpea, faba bean, lentil, and field pea. The crop most affected was reported to be faba bean. Non-crop hosts reported were members of Leguminosae, Umbeliferae, and Compositae	Northern Wello, southern Gonder, and southern Tigrai	Kedijo, Geter(Gerado) SE of Dessie; Kutaber north of Dessie; Dara and Tatch Gayint (southern Gonder) and Korem area (southern Tigrai)

Source: HARC (2001).

Table 2. Results of questionnaire survey on the occurrence of *Orobanche* and *Cuscuta spp.* in HFL surveyed areas of Ethiopia.

			Status of *Orobanche* spp		
District/*woreda*	Zone[1]	Crop(s) reported	*Species* reported	Importance[a]	Spread[b]
Dita darmallo	N. Omo	Fb	*Orobanche* sp.	X	L
Kobo	N. Wello	Fb, Cp	*O. minor*	Xx	M
All districts	Sidama	Fb	*O. minor*	X	M
Habru	N. Wello	Fb, Cp, Ln,	*O. minor*	X	M
Tehule Dere	S. Wello	Fb, Cp, Ln,	*Orobanche* sp.	X	M
Ambassel	S. Wello	Fb, Cp, Ln,	*Orobanche* sp.	Xx	M
Dessie Zuria	S. Wello	Fb	*O. crenata*	Xxx	W
Woldeya	S. Wello	Fb	*Orobanche* sp.	X	L
Babile	E.Harerge	Fb	*Orobanche* sp.	Xx	L
Chilga	N. Gonder	Fb, Cp, Ln	*Orobanche* sp.	Xx	M
Gonder Zuria	N. Gonder	Fb, Cp, Ln	*Orobanche* sp.	Xx	M
Belessa	N. Gonder	Fb, Cp, Ln	*O. minor*	X	M
Dara	S. Gonder	Fb, Cp, Ln	*O. crenata*	Xxx	W
Tatch Gayint	S. Gonder	Fb, Fp	O. crenata	Xxx	W
Meseia	W. Hararge	Fb	Orobanche *sp.*	X	L
Darolabu	W. Hararge	Fb	*Orobanche* sp.	X	L
Boke Habro	W. Hararge	Fb	*Orobanche* sp.	X	L
Quni	W. Hararge	Fb	*Orobanche* sp.	.x	L
Guba Koricha	W. Hararge	Fb	*Orobanche* sp.	X	L
Alamata	S. Tigrai	Fb	*O. crenata*	Xxx	W
Korem	S. Tigrai	Fb	*O. crenata*	Xxx	W
Raya Azebo	S. Tigrai	Fb	Orobanche *sp.*	X	L
Adwa Zuria	S. Tigrai	Fb	*Orobanche* sp.	X	L
Tahtay Keraro	Tigrai	Fb	*Orobanche* sp.	X	L
Wekero	Tigrai	Fb, Cp, Ln	*O. minor*	X	L
Afla	Tigrai	Fb	Orobanche *sp.*	X	M
Inda Mehoni	S. Tigrai	Fb	*Orobanche* sp.	X	M
Indetrta	C. Tigrai	Fb	*Orobanche* sp.	X	M
Mekele	C. Tigrai	Fb	*O. minor, O. ramosa*	Xx	M
Wajrat	Tigrai	Fb	Orobanche *sp.*	X	M
All districts	E Welga	Fb	*O. minor*	Xxx	W
All districts	W. Welga	Fb	*O. minor*	Xxx	W
All districts	Arsi and Bale	Fb, Fp, Cp	*O. minor, O. ramosa*	Xx	M
All Districts	E. Gojam	Fb, Cp, Ln	*O. minor*	Xx	L
All Districts	W. Gojam	Fb, Cp, Ln	*O. minor*	Xx	M
All Districts	Bahr Dar Zuria	Fb, Cp, Ln	*O. minor*	Xx	M
All Districts	W. Shoa	Fb, Cp, Ln	*O. minor, O. ramosa*	Xx	M
All Districts	E. Shoa	Fb, Cp, Ln	*O. minor, O. ramosa*	Xx	M
All Districts	N. Shoa	Fb,Fp	*O. minor*	X	L

[1]N.= Northern; S.= Southern; E. Eastern; W.= Western; C.-Central, aImportance, bSpread: L = Localized; M = Moderately spread; W = Widely spread, xxx = Very serious (heavy yield loss); xx = Serious (moderate yield loss); x = Not serious (present but no effect on crop), Fb = Faba bean, Fp = Field pea, Cp = Chickpea, Ln = Lentil. Source: HARC (2001).

Distribution and Importance of *Orobanche* in Faba bean Production Areas of Northern and Northwest Ethiopia

The discovery of crop damaging species of *Orobanche* in cool season food legumes in Ethiopia indicated the hazard of the spread of this parasite and the necessity for precautions against its spread. In earlier reports (Rezene, 1986, 1994), *Orobanche* was not often considered a problem for subsistence farming systems of high land food legumes production areas. Asefa and Endale (1994) reported that *O. crenata* was observed as a new invader in faba bean fields at two localities in south Wello: Kedijo Geter (Gerado), and Kutaber. At that time even though the introduction of this species was questionable, no follow up has been made to confirm the existence of the parasite in these localities. Later, specific follow up surveys were conducted at two locations in *Orobanche*-infested areas of selected districts of Gojam, Gonder and Wello during 1998-2001 (Besufikad et al., 1999; AdARC, 2002).

Orobanche survey results in Gojam and Gondar are summarized in Table 3. Results indicated that the average prevalence (percentage of crop fields infested) by the parasite across all surveyed districts was higher in field pea than faba bean. However, the highest infestation level of *Orobanche* species was recorded for faba bean at Tatch Gayint followed by field pea in the same district. These data confirmed the earlier report by Adugna et al., (1998) where a crop-damaging species of *Orobanche* was observed in faba bean fields of Dara and Tatch Gayint of southern Gonder.

In southern Wello, the prevalence and distribution of the parasite is extremely high at Kedijo than Haroye-Flagober (Table 4 and 5). Owing to this problem, large faba bean farms have already been replaced by wheat and oil crops. The undulating topography of the area (3-5% slope) along with dispersal agents of wind and flood, contribute to the spread and possible contamination of grazing areas by the parasitic weed. At both locations, the practice of harvesting green pods is becoming customary so as to prevent further yield loss by the weed. According to farmers, crop loss could reach as high as 75 - 100% (Besufikad et al., 1999). Farmers in Kedijo area indicated that the weed appeared for the first time in 1983 in Dehit area (Goshi-locality). But they were not familiar with the weed and could not realize the potential threat at that time. This area seems to have been the source of infestation for all other areas in Kedijo. How the weed was introduced into the country at large is still unknown. There was an erroneous speculation that the species occurring in the area was *O. crenata* brought in with imported crop seeds (Asefa and Endale, 1994). Farmers continually uproot the weed, 4-5 times, with a local implement called *Ankase* (an implement with sharp pointed end) and mattock. The removal of the weed by hand pulling is laborious as new flushes of the weed appear every 2-3 days after weeding. In the effort to prevent the weed by hand pulling, much labor is wasted which otherwise could be used for other farm activities. There are conflicting ideas among farmers concerning the impact of soil fertility on the weed. Some farmers suggested that the application of manure reduces the damage and hence helps the crop to resist the attack. Others suggested that cattle manure aggravates the infestation as it can contain weed seeds.

Table 3. Prevalence (percent of infested crop fields) and infestation levels of *Orobanche* on faba bean and field pea in Gojam and Gonder.

	Faba bean		Field pea	
Location	Prevalence	Intensity level[a]	Prevalence	Intensity level[a]
Mecha	-	-	-	-
Yilmana Densa	0	0	-	-
Bahir D. Zuria	66.7	1	-	-
Machakel	0	0	-	-
Gozamin	25	1	0	0
Baso-Liben	0	0	33	2
Bibugne	0	0	0	0
Awabel	0	0	25	1
Goncha-Siso	14.3	1	100	2
Debark	0	0	-	-
Dabat	0	0	-	-
Estie	0	0	-	-
Tatch-Gayint	68.2	5	53.8	3
Lay-Gaint	30.8	2	30	2
Simada	63.6	1	23.5	1
Farta	27.3	1	16.7	1
Ebenat	-	-	-	-
Prevalence by crop	19.7	-	31.3	

[a]Intensity of infestation in faba bean fields were estimated using the following scale: Level 0 = no *Orobanche*; Level 1 = *Orobanche* sporadically present; Level 2 = *Orobanche* present in the entire field; Level 3 = Majority of the host plant with up to two *Orobanche* shoots; Level 4 = All host plant with more than two *Orobanche* shoots (the field retains the character of faba bean field); Level 5 = Faba beans are barely visible (the field resembles an *Orobanche* field); Level 6= Field completely destroyed by *Orobanche* (no yield expected). Source: AdARC (2002).

Table 4. *Orobanche* shoot count and infestation level at Kedijo peasant association, southern Wello.

Surveyed plot No.	Area (ha)	Weed prevalence score (0-6 scale)	Live* faba bean shoots/m²	Dead** faba bean shoots/m²	Weed count/m²	*Orobanche* shoots/plant (mean)
1	0.03	6	0	67	248	14
2	0.06	4	30	6	69	6
3	0.06	4	17	33	115	5
4	0.05	4	17	51	108	7
5	0.02	4	8	28	55	4
6	0.09	5	9	59	149	6
7	013	6	0	18	127	9
8	0.50	4	14	24	150	14
9	0.50	3	16	15	41	2
10	0.13	4	4	34	164	6
Total		3-6	115	335	1226	2-14
Mean		4	11.5	33.5	122.6	7

*Infested faba bean shoots with harvestable green pods, **Dead faba bean shoots (no harvestable product). Source: Besufikad et al. (1999).

Table 5. Orobanche shoot count and infestation level at Haroye-Flagober peasant association, southern Wello.

Surveyed plot no.	Assessed farm size (ha)	Weed prevalence level (0-6 scale)	Live* faba bean (shoots/m²)	Dead** faba bean (shoots/m²)	*Orobanche* species (count/m²)	Shoots/faba bean plant (mean)
1	0.13	5	8	46	119	6
2	0.02	4	21	0	109	6
3	0.03	5	10	27	301	8
4	0.25	5	9	25	108	8
5	0.13	5	0	58	148	11
6	0.20	5	7	33	154	5
7	0.13	4	28	49	57	5
8	0.25	3	26	39	88	4
9	0.25	4	30	19	43	4
10	0.25	1	8	26	120	5
Total		1-5	147	322	1247	4-11
Mean		4	14.7	32.2	124.7	6

*Infested faba bean shoots with harvestable green pods, **Dead faba bean shoots (no harvestable product). Source: Besufikad et al. (1999).

In Haroye, *Orobanche* existed among shrubs and bushes since 1980. Farmers of both high and low elevations were using the weed to treat wounds and sores. Farmers pointed out that the primary sources of infestation were neighboring lowland areas, from where farmers have brought the weed to their area as a medicinal plant. Furthermore, the weed was thought to have been introduced from Kedijo area by means of farm tools and planting materials (seeds) (Besufikad et al., 1999).

During the assessment, it was noticed that the weed was as tall as, and sometimes even taller and more vigorous, than the faba bean crop. Frequent hand weeding (on average five times) is the usual practice that creates shortage of labor for the other farm activities. At Haroye-Flagober, one can observe severe infestation of Orobanche from flowering up to the harvesting period of faba bean. Seeds of the weed that shatter become the source of infestation for subsequent seasons. All surveyed faba bean fields (size range of 0.02-0.25 ha) were infested. The average prevalence level was four with more than two shoots per faba bean plant. On a 1m x 1m area, 43-301 Orobanche shoots were counted. From the same sample area an average number of 125 Orobanche shoots and 15 live but parasitized faba bean plants were recorded. The average of Orobanche shoots on a single faba bean plant was six.

Qualitative and Quantitative Determinations of Weeds

Qualitative and quantitative determinations of weeds in faba bean fields were conducted in nine and five *weredas* of western and northwestern Shoa zones, respectively, during the period of 2000-2001. The frequency, abundance, dominance and species composition of weeds occurring in faba bean fields were determined (HARC, 2002).

In western Shoa zone, the frequency and dominance level of individual weed species ranged from 0.48 % to 60.09 % and 0.01% to 8.36 %, respectively. Similarly, the respective order of frequency and dominance level of individual weed species for northern Shoa zone of Oromia Region were 12.03% to 86.57 % and 0.49 % to 15.43 % (HARC, 2002). Only weed species which had frequency and infestation levels greater than 25% and 2.5%, respectively, were considered as major weeds because they constituted more than 30% of the total weeds infesting faba bean fields. In this regard, the most frequent, abundant and dominant weed species for both zones were: *Guizotia scabra, Cerastrium octandrum, Plantago lanceolata, Phalaris paradoxa, Polygonum nepalense, Medicago polymorpha,* and *Spergula arvensis*. Similarly, major weeds for western Shoa Zone were *Corrigiola capensis, Avena fatua, Setaria pumila and Snowdenia polystachya*. For northern Shoa, *Galium spurium, Alchimela sp., Bromus pectinatus, Juncus bufonius, Galinsoga* *parviflora, Commelina benghalensis, Athraxon quantinanus* were determined as major weed species. Forty weed species were identified which belong to 18 plant families. Overall, Poaceae and Asteraceae contributed nine and six species, respectively. Most of weed species important to faba bean belong to these families although there are other families with a single species that cannot be ignored. All faba bean fields were severely plagued by *meskel* flowers (*Bidens pachyloma, B. peristenaria* and *Guizotia scabra*) (HARC, 2002).

The similarity index (SI) matrix of weed species found in faba bean growing areas of the surveyed locations is shown in Table 6. If the index of similarity is below the threshold value 60%, it is said that the two locations have different weed communities. This helps to use the same kind of management for the areas having similar weed communities (SI >60%) and different weed management systems for areas having different weed communities (SI < 60%).

Weed Survey in Bale Highlands

A survey was conducted in field pea production areas of Sinana, Gasera and Agarfa districts during the belg season only. During the *meher* season, both field pea and faba bean fields were surveyed at Agarfa, Gasera and Dinsho, and field pea only at Sinana. A total of 43 weed species were identified. The most important weed species in both crops were: Guizotia scabra, Galinsoga praviflora, Bromus pectinatus, Galium spurium and Amaranthus hybridus. During belg season, the frequency and dominance of individual weed species ranged from 3.7 to 87% and 0.06 to 13.9%, respectively, in field pea fields. However, in the bona (meher) season, the frequency of individual weed species ranged from 5.6 to 75% and 11.1 to 88.9% for field pea and faba bean, respectively. The dominance level was 0.4 to 16.2, and 0.5 to 20.5, for field pea and faba bean, respectively. Weed species having frequency and dominance levels below 5.0 and 0.4%, respectively, were excluded because they occurred rarely and at low densities. The similarity index across locations, between the two crops and seasons were less than 60% (Tables 7), indicating the variation of weed species composition across locations, between seasons and crops. Taye and Yohannes (1999) indicated that if the similarity index among locations or between seasons is less than 60%, the weed composition of locations or seasons should be considered as different. Although the same major weed species were found in faba bean and field pea fields, the infestation level of a specific weed species in one crop was different from the other. For instance, *Galinsoga parviflora* infested faba bean fields up to 21%, but it represented only 6% of the weeds in field pea. Because farmers plowed their fields more frequently for faba bean than for field pea, the grass weed infestation was prevalent in field pea fields. On the contrary, higher broadleaf weed infestation was observed in faba bean than in field pea fields (Kedir et al., 1999). *Galinsoga parviflora, Amaranthus hybridus* and *Chenopodium* spp. were major weed species in faba bean, but they were not as common in field pea fields. However, *Digitaria scalarum* and *Commelina benghalensis* were the major weeds observed in field pea (Kedir et al., 1999).

WEED CONTROL

Cultural

Field trials were conducted at Akaki to study the effects of seeding rates and weed management practices on grain yield of lentil and their efficacy in controlling major weed species. The major weed flora recorded within the experimental plots were: *Scorpiurus muricatus, Phalaris paradoxa, Launea cornuta* and *Plantago lanceolata* (DZARC, 1996, 1997). Seeding rates did not show significant differences in grain yield and density of weed species except that of *Launea cornuta* where lower rates (60 and 70 kg/ha) resulted in lower count. Unlike seeding rates, weed management practices showed significant differences in grain yield, total weed biomass, and density of *Scorpiurus muricatus, Phalaris paradoxa* and *Launea cornuta*. Hand-weeding twice and Topogard (2.0 l/ha) gave higher yields, lower weed biomass and individual weed counts, which indicated better efficacy in controlling weeds (DZARC, 1996, 1997). The interaction effects of seeding rates and weed management practices revealed that, at all the seeding rates that used Topogard (2.0 l/ha) and hand-weeding twice, were better in increasing the grain yield of lentil and reducing populations of *Scorpiurus muricatus*. However, there was no significant interaction effect between the two factors in reducing total weed biomass and population of other weed species (Table 8).

A three-year study was initiated in 1998 to evaluate the influence of hand-hoeing and hand-weeding timings on faba bean production at Holetta and Denbi. Treatments were factorially arranged to establish interaction of initiation timings of hand-hoeing and hand- weeding on faba bean yield response. When averaged over timings of initiation of hand- hoeing, the supplementary hand-weeding treatments carried out during 5, 6, or 7 weeks after crop emergence (WAE) reduced dry matter weight of weeds significantly when compared to the zero supplementary hand-weeding. However, differences for weed dry matter between the three supplementary hand-weeding timings were not significant. As a whole, reduced weed dry matter weight associated with higher grain yield was obtained from hand-hoeing at 2 WAE supplemented by hand-weeding at 5-7 WAE (HARC, 1999, 2000 and 2001).

Field experiments were carried out for three years at Holetta (1998-2000) and for two years at Denbi (1999-2000) to study the effect of time of single hand-weeding on weed control in mixed cropping of faba bean and field pea. Weed control treatments tested were six single hand-weeding timings during 2, 3, 4, 5, and 6 WAE. Farmers' weed control practice (no weeding) was also included for comparison. Results of these experiments indicated that weed infestation levels were highly significant to reduce the combined grain yields of the companion crops (faba bean + field pea) in the untreated weedy check (the treatment which represented the local weeding practice by majority farmers in the testing locations). In contrast, weed density in all single hand-weeded plots between 2-6 WAE was low to influence the combined grain yield of the test crops and density of late-emerging weeds was significantly low in treatment weeded between 4 –6 WAE (HARC, 1999, 2000 and 2001).

Table 6. **Indices of weed communities in faba bean fields at different locations in western and northern Shoa Zones.**

Location	WE	DE	EJ	AM	CH	WO	JE	IL	AG	SU	YD	KU	WU	DE
Welmera (WE)	100													
Dendi (DE)	29.4	100												
Ejerie (EJ)	68.6	32.1	100											
Ambo (AM)	42.2	28.6	54.5	100										
Chelia (CH)	50.0	25.0	60.9	70.6	100									
Wonchi (WO)	39.4	44.4	38.5	42.1	42.9	100								
Jeldu (JE)	24.2	37.5	26.9	35.3	38.9	42.9	100							
Illu (IL)	9.1	6.7	14.3	6.3	11.1	7.1	9.1	100						
Alemgena (AG)	30.3	27.8	36.0	50.0	28.6	53.3	21.4	7.7	100					
Sululta (SU)	60.5	45.8	57.1	50.0	55.0	66.0	42.9	8.7	40.0	100				
Y.G.&D.L (YD)	60.0	48.1	58.7	48.0	46.2	60.0	33.3	10.5	45.0	81.5	100			
Kuyu (KU)	52.6	45.5	52.0	52.4	45.8	50.0	40.9	10.0	33.3	31.5	70.4	100		
Wuchale (WU)	60.0	50.0	58.6	50.0	54.2	60.0	40.9	11.1	41.7	88.9	92.6	70.4	100	
Degem (DE)	58.8	37.5	62.9	61.9	52.0	60.6	38.1	17.4	42.9	65.5	76.0	86.4	80.8	100

Source: HARC (2002).

Table 7. Similarity index (%) of weed communities in field pea and faba bean fields at different locations in Bale highlands in *meher* and *belg* seasons.

A. Fieldpea in Bale highlands, *meher* season 1997

Location	Sinana	Agarfa	Dinsho
Sinana	100		
Agarfa	45.8	100	
Dinsho	56	54.16	100

B. Faba bean in Bale highlands, *meher* season 1997

Location	Gasera	Agarfa	Dinsho
Gasera	100		
Agarfa	38.8	100	
Dinsho	40.00	29.40	100

C. Fieldpea in Bale highlands, *belg* season 997

Location	Sinana	Agarfa	Gasera
Sinana	100		
Agarfa	47.05	100	
Gasera	60.97	58.8	100

Source: Kedir et al. (1999).

Table 8. Effect of seeding rates (SR) and weed management (WM) practices on weed biomass and grain yield of lentil at Akaki, 1994-1996.

	Weed dry wt.			
	g/m²	kg/m²	Grain yield (kg/ha)	
Treatment	1995	1996	1995	1996
Hand-weeding x 1 30 DAE*	38.0	1853	1145	1533
Hand-weeding x 2 30+60 DAE	13.3	906	1334	1533
Topogard	2.0	2069	1461	1494
Weedy check	19.3	2984	848	1267
LSD (0.05)	14.8	777.5	168	200
Seed rate				
60 kg/ha	25.1	195.)	1101	1467
70 kg/ha	15.0	1866	1307	1267
80 kg/ha	16.0	2016	1220	1353
90 kg/ha	16.3	1978	1160	1353
LSD (0.05)	NS	NS	NS	NS
WM x SR	NS	NS	**	NS

*DAE = Days after crop emergence. Source: DZARC (1996, 1997).

Chemical

Very little work was done on herbicides in the past decade. Prior to 1993, seven herbicides, of which six were pre-emergence and one was post-emergence, were recommended for HFL weed control. But, currently only one of these herbicides is officially registered (Rezene, 1994).

Experiments were conducted at Debre Zeit (black soil) during 1994-96 crop seasons to evaluate terbutryn + terbutylazyn, and linuron ± hand-weeding in lentil (DZARC, 1996 and 1997). The major weed flora recorded within the experimental plots was: *Commelina benghalensis, Plantago lanceolata, Scorpiurus muricatus, Amaranthus* spp. and *Cichorium intybus*. According to the results obtained, there was no statistical difference between the two herbicides in all the parameters considered (Table 9). The three rates of the herbicides, however, showed significant difference ($P \leq 0.05$) among themselves in reducing the dry matter accumulation of total weeds and population of most weed species, the highest rate being the best in reducing the dry matter. All the treatments, including the interaction effect did not show any significant effect on the population of *Scorpiurus muricatus* and *Amaranthus* spp. However, hand-weeding once proved better for control of all other weeds tested than the unweeded check. The supplementary effect of hand-weeding is clearly observed in the interaction effect between herbicides and hand-weeding treatments. Better yield of lentil and lower weed biomass were obtained from plots where herbicides were coupled with hand-weeding, indicating better control of the weeds.

Table 9. Effect of weed control practices on grain yield, dry weight accumulation of weeds in lentil at Debre Zeit, 1994-1996.

Treatment	Weed dry wt.(g/m²)		Seed yield (kg/ha)	
	1995	1996	1995	1996
Topogard	323.8	126.8	471.7	976.7
Linuron	331.7	164.5	531.3	1062.2
LSD(0.05)	NS	NS	NS	NS
Weedy check (W0)	451.5	200.7	276.6	886.7
Hand-weeding x 1 (W1)	204.0	90.6	726.4	1152.2
LSD(0.05)	**	**	**	**
Topogard+W0	432.5	165.5	296.2	929.4
Topogard+W1	215.1	88.2	647.2	1023.9
Linuron+WO	470.6	235.8	256.9	843.9
Linuron+W1	192.9	93.1	805.7	1280.0
LSD (0.05)	NS	**	**	**

Source: DZARC (1996, 1997).

Pre- and post-emergence herbicides in faba bean were evaluated at Holetta Nitosols during 1993-94 crop seasons. The treatments comprised one pre-emergence herbicide terbutryn + metolachlor, and four grass killer post-emergence herbicides (fluazifop-buthyl, diclofopmethyl, propaquizafop, and fenoxaprop-p-ethyl) and one broadleaf killer herbicide (Bentazone) (HARC, 1994, 1995). Management of broadleaf weeds with herbicide treatments was much more variable than it was in grasses. Broadleaf and grass weeds were managed more effectively with pre-emergence herbicides than with the sequential application of Bentazone with grass killer herbicides. The efficacy of Bentazone against broadleaf weeds was reduced when applied sequentially with grass-killer herbicides. However, when the antagonistic effects occur, faba bean grain yields do not appear to be affected by reduced broadleaf control.

On-farm Verification

A participatory on-farm trial was conducted at Wolmera and Chelia *woredas* to verify the effectiveness of single hand-weeding timings coupled with the recommended mixed-cropping pattern of faba bean and field pea. Total grain yield of the companion crops (faba bean and field pea) differed significantly at Wolmera and the highest yield was obtained from the single hand-weeded treatment at 6 WAE with an yield increase of 57.4 % over the check yield of 1113 kg/ha. The treatment weeded during the 4th WAE also significantly outyielded the check treatment resulting in a yield increase of 49.9% (Table 10). At Chelia, hand-weeding at 6 WAE resulted in numerically higher yield for both crops than the check treatment but differences were not significant (P = 0.05) (Table 11). Initiation of hand-weeding timings at 4 and 6 WAE resulted in significantly reduced total weed biomass weight relative to the check treatment at both sites, and the respective total weed biomass reduction was found to be 42.4% and 49.7% for Wolmera and 8.0% and 27.7% for Chelia, respectively (Table 12 and 13) (HARC, 2003; Rezene and Getachew, 2003). Comparing the recommended hand-weeding treatment with their traditional practice (no weeding), host farmers in both locations said that a single hand-weeding at 6 WAE was more preferable for mixed crop of faba bean and field pea in terms of its effectiveness in controlling late-emerging weed species and reducing weed interference during early crop growth stage and time of harvesting. The same farmers also suggested that using weed control recommendation coupled with crop rotation were useful to increase crop yield and control late-emerging weeds.

Table 10. Effect of hand-weeding treatments on faba bean and field pea grain yield and its components, Wolmera, 2002.

Treatment[a]	Plant height (cm)		1000-seed weight (g)		Crop biomass (kg/ha)	Grain yield (kg/ha)		
	FB	FP	FB	FP	FB+FP	FB	FP	FB+FP
HW x 1 (4WAE)	102.1	120.8	506.4	231.5	3586.5	599.0	941.5	1669.0 a[b]
HW x 1 (6WAE)	102.9	116.7	509.2	229.2	4593.5	712.5	969.0	1751.5 a
Farmers practice	106.6	120.4	509.2	236.0	3786.0	434.0	695.5	1113.0 b
CV%	5.47	2.60	4.82	3.18	20.63	28.53	23.38	14.67

[a] HW = Hand weeding; WAE = Weeks after crop emergence. [b] Means followed by the same letter within a column do not differ significantly according to LSD test (P = 0.05). Source: HARC (2003); Rezene and Getachew (2003).

Table 11. Effect of hand-weeding treatments on faba bean and field pea grain yield and its components, Chelia, 2002.

Treatment[a]	Plant height (cm)		Crop biomass weight (kg/ha)	Grain yield (kg/ha)
	FB	FP	FB+FP	FB+FP
HW x 1 (4WAE)	109.9	152.0	2758.3	1902.9
HW x 1 (6WAE)	108.3	156.7	3425.0	2701.2
Farmers practice	113.8	156.0	3372.4	2532.2
CV%	12.01	6.49	23.61	18.67

[a] HW = Hand-weeding; WAE = Weeks after crop emergence. Source: HARC (2003); Rezene and Getachew (2003).

Table 12. Effect of hand-weeding treatments on weed control, Wolmera, 2002.

Treatment[a]	*General weed control score[d]*		Individual weed control score[d]		Weed biomass weight / (kg/ha)
	69 DAE[c]	113 DAE	*Guizotia scabra*	*Spergula arvensis*	
HW x 1 (4WAE)	2.7 ab[b]	2.7 b	1.3 b	2.0 b	850.0 b
HW x 1 (6WAE)	2.0 b	2.0 b	1.0 b	1.7 b	741.5 b
Farmers practice	3.7 a	4.7 a	4.0 a	3.7 a	1475.0a
CV%	18.97	16.94	24.97	13.64	12.38

[a] HW = Hand-weeding; WAE = Weeks after crop emergence, [b] Means followed by the same letter within a column do not differ significantly according to LSD test (P = 0.05), [c] DAE = Days after crop emergence, [d] Weed control score (scale 1 - 5 where: 1 = weeds effectively controlled and 5 = no effect on weed control. Source: HARC (2003); Rezene and Getachew (2003).

Table 13. Effect of hand-weeding treatments on weed control, Chelia, 2002.

Treatment[a]	Weed density /(plants m-2)		Individual weed control scorec		Weed biomass weight (kg/ha)
	Guizotia scabra	Snowdenia polystachya	Guizotia scabra	Snowdenia polystachya	
HW x 1 (4WAE)	96e	52e	2e	3e	1891.7 abb
HW x 1 (6WAE)	48	36	2	2	1500.0 b
Farmers practice	88	52	5	5	2075.0 a
CV%	--	--	--	--	42.03

[a] HW = Hand-weeding; WAE = Weeks after crop emergence, [b] Means followed by the same letter within a column do not differ significantly according to LSD test (P = 0.05), [c] DAE = Days after crop emergence, [d] Weed control score (scale 1- 5, where 1 = weeds effectively controlled and 5 = no effect on weed control, [e] Means are values of one location only, Source: HARC (2003); Rezene and Getachew (2003).

Two hand-weeding timings applied during 5 and 7 WAE after hand-hoeing at 2 WAE were compared for maximum yield benefit in faba bean associated with effective control of early- and late-emerging weed species under on-farm participatory verification trials at Wolmera and Chelia (HARC, 2003; Rezene and Getachew, 2003). At Wolmera, biomass and grain yield of faba bean were significantly affected by weed control treatments. The treatments with supplementary hand-weeding during 5 or 7 WAE yielded 44.5% or 28.7% more than the check yield (farmers' practice receiving no weed control) (Table 14). The corresponding efficacy (i.e. % weed biomass reduction) for the 5 or 7 WAE supplementary hand-weeded treatments after the recommended hand-hoeing (2 WAE) was 63.4% and 72.3% compared to the check treatment in that order (Table 15). At Chelia, biomass and grain yield of the crop were not influenced by the weed control treatments. However, even though not at significant level the highest yield for this location was obtained from the sequential application of hand-hoeing and hand-weeding treatment applied during 2 and 7 WAE, respectively (Table 16 and 17). Farmers in both locations believed that supplementary hand-weeding during 7 WAE after the recommended hand-hoeing at 2 WAE effectively controlled most late-emerging weed species and improved crop performance. With regard to future use of the recommended weeding practices 27% of 41 farmers in Chelia showed their interest to use hand-hoeing with supplementary hand-weeding if the hoeing implement was available to them. But, farmers at Wolmera suggested comparison of one early season hand-weeding during 5 WAE without hand-hoeing as alternative practice.

CONCLUSIONS AND FUTURE DIRECTIONS

Hand-weeding has remained the most widely used method of weed control in HFL in Ethiopia and has seen little modifications over the years. Work on HFL at agricultural research centers has emphasized the need for determinimg the crop growth period when weeds are most injurious and when they are relatively harmless. In this regard, the efficacy of mixed cropping in reducing weed control requirements, weed surveys, interaction effects of cultural practices with weed control methods, studies on economic importance of specific weed and the efficacy of chemical control have all been attempted.

In order to augment the adoption of high yielding crop varieties and fertilizer use there is a need to stress on the development of a weed management program that makes cultural weed control more efficient to complement the inputs like improved varieties and fertilizers. The major weed management research needs and priorities are suggested as follows:

Parasitic Weeds (*Orobanche* spp.)

It is now recognized that *Orobanche* is likely to constitute a problem in the northern HFL production areas of the country (Gonder, Gojam, Welo, Tigray and neighboring localities of northern and western Shoa). The present awareness of the problem should lead to the formulation of a national and regional programs designed to exploit the genetic possibilities of the host plants and also to improve the understanding of the evolution of the parasite in the environment of the host. The following areas of research, awareness creation and collaboration activities are suggested:

The research areas: The following areas are suggested:

1. The geographical distribution of *Orobanche*
2. An inventory of host plants (wild as well as cultivated)
3. Precise data on yield loss
4. Tolerance level of local varieties
5. Host-parasite interaction
6. The influence of rotation, nitrogen fertilizers, farmyard manure, tillage inter-cropping, date and density of sowing the crop and weeding of *Orobanche* plants.
7. The influence of other weeds and rainfall
8. The influence of soil physical and chemical characters

Awareness creation and collaborative actions: There is a need to create awareness of the *Orobanche* problem in HFL among farmers, researchers, extension personnel and policy makers through information campaigns and pre-extension work on the risks of re-infestation and on the methods and systems by which *Orobanche* infestations, and the losses due to the parasite, may be reduced. Since *Orobanche* is a serious problem in North Africa and some localities in the Nile Valley Region, it would be desirable to work out joint research projects at a regional level. This would enable the member countries to make maximum use of both material and scientific resources, which in the case of small-scale program for each individual country would be difficult to achieve. Such a joint project would enable these countries to define and evolve a strategy for *Orobanche* control in HFL, and the outcome would be to enhance regional cooperation through the dissemination of information and transfer of techniques to farmers and technicians, and training of extension workers.

Table 14. Effect of hand-hoeing and -weeding treatments on faba bean grain yield and its components, Wolmera, 2002.

Treatment[a]	Crop stand (/m²)	No. of pods/ plant	No. seeds/ pod	Plant height (cm)	1000- seed wt. (g)	Crop biomass (kg/ha)	Grain yield (kg/ha)
HH+HW (2+5WAE)	105.3	7.8	2.0	99.2	473.9	3231.7 a[b]	1362.3 a
HH+HW (2+7WAE)	114.6	5.3	2.5	90.0	478.5	2948.1 a	1213.5 a
Farmers practice	102.7	5.6	2.5	99.6	473.6	2278.3 b	942.7 b
CV%	7.99	31.32	11.35	5.57	2.98	13.89	18.03

[a] HH= Hand-hoeing; HW = Hand-weeding; WAE = Weeds after crop emergence, [b] Means followed by the same letter within a column do not differ significantly according to LSD test, (P = 0.05). Source: HARC (2003); Rezene and Agajie (2003).

Table 15. Effect of hand-hoeing and -weeding treatments on weed control, Wolmera, 2002.

	General weed control score[d]		Individual weed control score[d]				Weed biomass weight
Treatment[a]	69 DAE[c]	113 DAE	PN[e]	SP	PP	GS	(kg/ha)
HH+HW (2+5WAE)	2.3 b[b]	2.0 b	4.0	4.0	3.0	1.0 b	1617 b
HH+HW (2+7WAE)	1.3 b	1.3 b	3.7	3.3	3.0	1.3 b	1183 b
Farmers practice	4.3 a	4.7 a	3.7	3.3	3.0	4.0 a	4417 a
CV%	21.65	15.31	8.83	18.15	19.25	15.97	31.14

[a] HH= Hand-hoeing; HW = Hand-weeding; WAE = Weeds after crop emergence, [b] Means followed by the same letter within a column do not differ significantly according to LSD test (P = 0.05), [c] DAE = Days after crop emergence, [d] Weed control score (scale 1- 5, where 1 = weeds effectively controlled and 5 = no effect on weed control, [e] PN = *Polygonum nepalense*, SP = *Snowdenia polystachya*, PP = *Phalaris paradoxa*, GS=*Guizotia scabra*, Source: HARC (2003); Rezene and Agajie (2003).

Table 16. Effect of hand-hoeing and -weeding treatments on faba bean yield and yield components, Chelia 2002.

Treatment[a]	No. of pods/ plant	No. of seeds/ pod	Plant height (cm)	Crop biomass (kg/ ha)	Seed yield/(kg/ ha)
HH+HW (2+5WAE)	12.2	2.5	119.5 bb	4666.7	1964.7
HH+HW (2+7WAE)	16.1	2.8	132.0 b	6041.7	2337.5
Farmers practice	13.9	2.8	139.8 a	5541.7	2012.2
CV%	13.6	6.48	3.64	26.36	41.46

[a] HH= Hand Hoeing; HW = Hand Weeding; WAE = Weeds after crop emergence, [b] Means followed by the same letter within a column do not differ significantly according to LSD test (P = 0.05), Source: HARC (2003); Rezene and Agajie (2003).

Table 17. Effect of hand-hoeing and -weeding treatments on weed control, Chelia, 2002.

	General weed control score[c]		Individual weed control score[c]			
Treatment[a]	102 DAE[b]	119 DAE	PN[e]	SP	PP	GS
HH+HW (2+5WAE)	2.5	3.0	4.0	3.5	1.0	2.0
HH+HW (2+7WAE)	2.0	1.5	4.0	4.5	2.0	1.0
Farmers practice	4.0	4.5	5.0	4.5	4.0	4.0
CV%	d	--	--	--	--	--

[a] HH= Hand -hoeing; HW = Hand-weeding; WAE = Weeds after crop emergence, [b] DAE = Days after crop emergence, [c] Weed control score (scale 1 - 5, where 1 = weeds effectively controlled and 5 = no effect on weed control, [d] -- = Values are means of two trial sites and were not subjected to statistical analysis. [e] PN = *Polygonum nepalense*, SP = *Snowdenia polystachya*, PP = *Phalaris paradoxa*, GS= *Guizotia scabra*. Source: HARC (2003); Rezene and Agajie (2003).

Non-parasitic Weed Species:

The following areas will need attention and strengthening:

1. Identification and characterization of the weed flora associated with HFL need to be strengthened. Determination of quantitative and qualitative losses caused by weed species also need to be extended for areas and crops not previously covered.
2. The thresholds are the basis for the concept of flexible weed control. Accordingly, weed control measures need to be determined based on knowledge of actual or potential weed densities and their economic thresholds, rather than executed on a routine or fixed basis.
3. Considering the increasing weed status and potential risks of *Parthenium hysterophorus* to HFL production, there is a need to develop prevention and control measures through which an integrated management of this invasive weed can be formulated.
4. There is a need to improve the traditional weeding practices by exploring the feasibility of row-seeding of HFL using animal-drawn seeders in conjunction with a push-type or animal-drawn inter-row weeders.
5. It appears that the country still have large cheap labor pool that can effectively be used for weeding. Thus, research into chemical weed control need to be emphasized for large-scale mechanized situations only.
6. Efforts should be strengthened towards integrated weed management approach that combines cultural, mechanical, biological and chemical measures. This approach is especially important for the control of prolific annual weeds that are generally inadequately controlled by any of the methods solely.

REFERENCES

AdARC. 2002. Progress report for the period of 2001/2002. Adet Agricultural Research Center (AdARI), Adet.

Adugna Wakijira., Amare Gizaw, Kemal Ali, Chilot Yirga, and Berhanu Bekele. 1998. Crop loss assessment of 1997 in Gojam and Gonder, Amhara Regional State. A Survey Report. Holetta Agricultural Research Center (HARC), IAR, Addis Ababa.

Asefa Admasu, and Endale Berhe. 1994. *Orobnache crenata*: A potential threat to food legumes in Ethiopia. *EWSS Newsletter* 2: 1-2.

Besufikad Tadesse, Legesse Admasu, and Rezene Fessehaie. 1999. *Orobanche* problem in South Welo. *Arem* 5: 1-10.

HARC. 1994. Progress report for the period of 1993/1994. Holetta Agricultural Research Center (HARC), Holetta.

HARC. 1995. Progress report for the period of 1994/1995. Holetta Agricultural Research Center (HARC), Holetta.

DZARC . 1996. Annual research report for the period 1995/96. Debre Zeit Agricultural Research Center (DZARC), AUA.

DZARC. 1997. Annual research report - 1996/97. Debre Zeit Agricultural Research Center (DZARC), AUA.

DZARC . 1999. Annual research report for the period 1997/98. Debre Zeit Agricultural Research Center (DZARC), AUA.

DZARC. 2000. Annual research report - 1998/99. Debre Zeit Agricultural Research Center (DZARC), AUA.HARC. 1999. Progress report for the period of 1998/1999. Holetta Agricultural Research Center (HARC), Holetta.

HARC. 2001. Progress report for the period of 2000/2001. Holetta Agricultural Research Center (HARC), Holetta.

HARC. 2002. Progress report for the period of 2001/2002. Holetta Agricultural Research Center (HARC), Holetta.

HARC. 2003. Progress report for the period of 2002/2003. Holetta Agricultural Research Center (HARC), Holetta.

Kedir Nefo, Feyissa Tadesse, and Tilahun Geletu. 1999. Results of a weed survey in the major field pea and faba bean growing areas of the Bale highlands. *Arem* 5: 109-121.

Rezene Fessehaie. 1994. Weed research in cool season food legumes. p. 252-275. *In* Asfaw et al. (Ed.) *Cool Season Food Legumes of Ethiopia.* Proc. First National Cool-season Food Legumes Review Conference 17-20 December 1993. Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA: Aleppo, Syria.

Rezene Fessehaie. 1986. Review of weed science research activities in pulses in Ethiopia. p. 403-426. *In* Tsedeke Abate (Ed.) *A Review of Crop Protection Research in Ethiopia.* Proc. First Ethiopian Crop Protection Symposium. 4-7 February, 1985. Addis Ababa, Ethiopia. IAR, Addis Ababa.

Rezene Fessehaie. 1998. Review of broomrapes (Orobanche spp.) in Ethiopia. *NVRSRP Newsletter* 1: 20-22.

Rezene Fessehaie, and Agajie Tesfaye. 2003. On-farm verification of hand weeding timings after the recommended hand hoeing in faba bean. Progress Report of Client Oriented Research for the period of 2003. Holetta Agricultural Research Center, Holetta.

Rezene Fessehaie, and Getachew Agegnehu. 2003. On-farm verification of weed control methods in mixed cropping of faba bean and field pea. Progress Report of Client Oriented Research for the period of 2003. Holetta Agricultural Research Center, Holetta.

Taye Tessema, and Yohannes Lema. 1999. Qualitative and quantitative determination of weeds in tef in West Shewa zone. *Arem* 4: 46-60.

Review of Weed Management Research in Lowland Pulses

Fasil Reda

Melkassa Agricultural Research Center
P.O. Box 436, Nazareth, Ethiopia

ABSTRACT

Weeds are major constraints in pulses production in Ethiopia, particularly in the lowlands, where competition between crops and weeds is exacerbated due to the prevalent problem of moisture stress. Loss assessment trials showed that weeds could cause over 30% yield reduction in important lowland pulse crops such as haricot bean and cowpea. However, the damaging effect of weeds is not fully appreciated and many crops are left un-weeded or weeded very late in the season to no avail. Nevertheless, manual weeding is the control option open to all the subsistence farming community. Studies showed that proper timing was critical for the method to be effective. The results across different crops, years and locations invariably showed that pulse crops were specially sensitive to weed competition in the first four weeks after sowing. One timely, early-weeding at 25 days after emergence resulted in 70% yield increase of haricot bean, and up to 300% increase in cowpea compared to the un-weeded control. Similar results were obtained in soybean. Mid- to late-season weeding, regardless of the number of operations, failed to adequately control weeds and improve yield performance of crops. Among a range of herbicides, Igran Combi, Alachlor and Dual suppressed weeds effectively and subsequently improved yield of haricot bean by three-fold. Although pulses are main food crops, source of protein and income, very little research work has been done on these important crops in terms of alleviating damaging effects of weeds. A concerted effort is required to strengthen weed management research in lowland pulses in the future. New and effective methods need to be developed for future weed problems which are certain to arise with further changes in agricultural practices, land and water management. The weed flora will be in continuous change due to increased fertilizer, herbicide usage, and changes in cropping patterns, which would favor some weeds at the expense of others.

INTRODUCTION

Pulses are major food crops in Ethiopia and occupy 12.7% of the cultivated land, and account for 11% of total crop production (CSA, 2000). Pulses are the main source of protein and income for the farming community and thus are widely cultivated, but their national yield average is very low (<1 t/ha). The crops are grown under low input conditions. In the year 2000, fertilizers and pesticides were applied on less than 4% and 2% of the cultivated land, respectively (CSA, 2000). Furthermore, the crops are adversely affected by a range of biological constraints of which weeds are one of the most important yield limiting factors. This is especially true in the lowlands where the damaging effect of weeds is exacerbated by the aberrant weather conditions prevalent in these areas. When moisture stress occurs, plant species, which are efficient in water use, have competitive advantage. Evidences suggest that weeds are more resilient and more capable of exploiting such environments to the disadvantage of pulse crops, which are known to be very poor competitors. Results of yield loss assessment trials showed that uncontrolled weed growth could result in over 36% yield loss in haricot bean and more than 50% in soybean. The weed species responsible for yield reduction in pulse crops are many and varied and include annual and perennial grasses and broadleaved weeds, and invasive weed species (Table 1). The weeds vary in relative importance and composition depending on the type of agro-ecological conditions.

Proper weed control is crucial to ensure optimum crop performance but in pulses either the operation is not done at all or employed too late to provide any benefit to the crop. Labor is in short supply during the peak crop season in the months of July and August. As a result, some important crops such as haricot bean are often left un-weeded. Efforts have been made to identify and characterize the major weed species, assess crop losses due to weeds and identify effective control/management methods to reduce the impact of weeds. However, the effort was largely limited to manual and chemical control aspects because of shortages of trained manpower. This article reviews the advances made in lowland pulses weed management research over the past 10 years.

Table 1. Major weed species in lowland pulse crops.

Grass weeds
Digitaria scalarum, Digitaria velutina, Eleusine africana, Eleusine indica, Rottboellia cochinchinensis, Setaria verticillata, and Sorghum arundinaceum,
Broadleaved weeds
Ageratum conzoides, Amaranthus spp, Argemone mexicana, Bidens pilosa, Celosia argentia, Commelina spp., Convolvulus arvensis, Datura stramonium, Flaveria trinervia, Galinsoga parviflora, Guizotia scabra, and Tagetes minuta
Sedges
Cyperus rotundus, Cyperus esculentus
Invasive species
Parthenium hystrophorus, Prosopis juliflora

Source: Nazareth Agricultural Research Center Herbarium.

WEED CONTROL STUDIES-HANDWEEDING

A hand-weeding trial was conducted on two cowpea varieties with different growth habits at three sites in the central Rift Valley area, namely Black eye bean (erect type) and White Wonder Trailing (semi-erect type) (Giref and Etagegnehu, 1999). Although these varieties were morphologically different they had similar response to the timing of weeding operation. At Melkassa, one early-weeding was sufficient to increase yield by three-fold compared to the un-weeded control.

Cowpea showed similar response to early-weeding at Wolenchiti and Zeway. Their findings demonstrated that one timely early-weeding could be sufficient for optimum performance of cowpea in dryland environments. Late-weeding, regardless of the number of operations, did not improve crop yield.

In a separate experiment, hand-weeding significantly affected weed infestation intensity and crop yield parameters of haricot bean at Awassa (Tenaw et al., 1997). The study revealed that preventing early competition of weeds through one manual weeding was sufficient for optimum yield of haricot bean under Awassa conditions. One early-weeding at 25 days after emergence reduced weed infestation from 35% to 50%, and subsequently increased grain yield by 55% to 70%. The results further showed that genotype by weeding interaction was significant for grain yield. Mexican 142 required two weedings to produce significantly higher yields than the un-weeded control, whereas, one early-weeding was sufficient for optimum yield performance of the other two, apparently more competitive varieties, Ex-Rico and Red Wolaita. At Jimma, two haricot bean varieties, Roba-1 (improved) and Jimma Local, required at least two early-weedings (15 and 30 days after emergence) for efficient weed control, which led to significantly higher crop yields (Tilahun, 1998). One time-weeding later in the season (45 days after crop emergence) led to significantly reduced yields due to the extended exposure of the crop to weed competition. It was shown that if not weeded early, Roba-1 and Jima Local could lose up to 66% and 90% of their yield potential, respectively, depending on the season. It was confirmed that soybean was a weak competitor with weeds compared to other pulse crops. At Awassa, exposure of the crop to prolonged weed competition resulted in up to 98% loss in grain yield (Beyenesh, 1989). Twice hand-weeding at 25 and 55 days after sowing was the optimum practice to enhance crop performance. Weeding during the indicated times resulted in the highest grain yield of 1320 kg/ha and net economic return of 305 Ethiopian Birr/ha. Late-weeding led to yield reduction and consequently negative net economic returns.

Chemical Weed Control

A range of herbicides was tried for weed control in lowland pulses. Although, the chemicals were effective in suppressing weeds, this was not often reflected in terms of enhanced yield performance of the crops. In fact, some of the crops were highly sensitive to the herbicides and, as a result, sustained unacceptable level of damage. Pre-emergence application of Igran Combi, Dual, and Alachlor suppressed weeds effectively leading to significantly improved grain yield of haricot bean (Tenaw and Mathias, 1998). Igran Combi spray resulted in up to 4-fold increase in grain yield and 70% reduction in weed infestation. Improved crop performance due to herbicides was accounted for by improvement in yield attributes, particularly pods per plant and seeds per pod. The post-emergence herbicide, Agil was neither effective on weeds nor safe to the crop.

Working on a different set of herbicides, Beyenesh and Gemeda (1988) found encouraging prospects for chemical weed control in haricot bean. All herbicides tested showed superior performance against the major weeds. However, some of the herbicides have also caused unacceptable level of damage on the crop. Especially notable in this regard were the highest rates of Cyanazine and Topogard. Alachlor at 1.9 and 2.4 kg a.i./ha, Prometryne and Pendimethaline at 1.5 kg a.i./ha registered the highest rating, in terms of weed control, and substantially improved grain yield (over 1600 kg/ha). The herbicides offered fair to good control of *Nicandra physalodes*, *Tagetes minuta*, *Amaranthus hybridus*, *Cyperus* sp., *Conyza bonariensis* and *Galinsoga parviflora* but failed to adequately suppress *Commelina benghalensis*.

FUTURE PROSPECTS

Efforts have to be made to boost the productivity of lowland pulse crops. One way of achieving this is through effective management of weeds, which are among the major production constraints. The weed problem in the country is worsening due to the alarming spread of aggressive exotic weed species such as *Parthenium hysterophorus* and *Prosopis juliflora*. The occurrence of the dreaded parasitic weed species *Orobanche crenata* in north Wello could pose a serious potential threat to pulse production. A concerted effort is therefore needed to build the research capacity required to control and manage weeds effectively. It is imperative to adopt a strategy, which integrates the training, research and development endeavors for a holistic approach to the problem of weeds. Future work in this regard should therefore emphasize:

1. Identification and characterization of most problematic weeds in pulses.
2. Studying the biology and ecology of major weed species.
3. Developing integrated management approaches including tillage, cropping systems, and mechanical, biological and manual control.
4. Strengthen internal and external quarantine to prevent further entry and build up of problematic weed species. Special emphasis and vigilance to protect areas not yet infested by invasive and parasitic weeds.
5. Involving the farming community in weed management activities through campaigns for the eradication of invasive alien species.
6. Develop a better understanding of the weed problem in the country through training and sensitization activities for different stakeholders of the lowland pulses.

7. Ensure that weed science discipline is adequately represented in the university curricula around the country so that young people can take up and build a career in this important area to strengthen national capacity.

REFERENCES

Beyenesh Zemichael. 1989. Estimated yield loss and relative profitability of different time of weedings in soybean and haricot bean. p. 47-51. *In* Rezene Fessehaie (Ed.) Proc. 7th Annual Conference of the Ethiopian Weed Science Committee. Addis Ababa, Ethiopia.

Beyenesh Zemichael, and Gemeda Eme. 1988. Chemical weed control in haricot bean. p. 135-140. *In* C. Parker and Rezene Fessehaie (Eds.) Proc. 6th Annual Conference of the Ethiopian Weed Science Committee. Addis Ababa, Ethiopia.

CSA, 2000. Agricultural sample survey 1999/2000. Vol. 1. Area and production for major crops. Statistical Bulletin No. 227. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Giref Sahle, and Etagegnehu Gebremariam. 1999. Assessment of cowpea yield loss due to weeds in the Central Rift Valley of Ethiopia. *Arem* 5: 138-145.

Tenaw Workayehu, and Mathias Mekuria. 1998. Evaluation of pre- and post-emergence herbicides for weed control in haricot bean. *Arem* 4: 126-133.

Tenaw Workayehu, Beyenesh Zemichael, and Waga Mazengia. 1997. Effect of variety, seed rate, and weeding frequency on weed infestation and grain yield of haricot bean. *Arem* 2 & 3: 61-69.

Tilahun Tadious. 1998. Weed competition study on haricot bean in the sub-humid zone of Jima. *Arem* 4: 61-68.

Section V. Forage Legumes and Food Science

Major Herbaceous Forage Legumes: Some Achievements in Species and Varietal Evaluation in Ethiopia

Getnet Assefa[1], Tekleyohanes Berhanu[2], Lemma Gizachew[3], Mesfin Dejenie[4] and Driba Geleti[3]

[1]*Ethiopian Agricultural Research Organization, Holetta Research Centre, P.O. Box, 2003, Addis Ababa,*[2]*Southern Agricultural Research Institute, Awassa Agricultural Research Center, P.O. Box 6, Awassa,* [3]*Oromia Agricultural Research Institute, Bako Agricultural Research Center, P.O. Box 74, Bako,* [4]*Amhara Regional Agricultural Research Institute, Sirinka Agricultural Research Center,P.O. Box 74, Woldia, Ethiopia*

ABSTRACT

The article summaries some of the results of species and varietal evaluation of major herbaceous forage legumes tested in various agro-ecologies of Ethiopia. Unlike food legumes for which the primary objective is grain production, the aim of forage and pasture legume collection, introduction and evaluation is to recommend superior species or varieties for large-scale production and utilization as pasture, hay or silage in a particular farming system. Little emphasis has been given in the past for forage seed research and development. Ethiopia is the center of diversity for some herbaceous legumes in the genus *Trifolium, Vigna, Lablab, and Neonotonia.* Among the native herbaceous forage legumes, a total of 158 species (1151 accessions) in the moist and sub-moist, 151 (886) in humid and sub-humid, and 24 (59) in arid and semi-arid agro-ecologies were collected and conserved by the International Livestock Research Institute (ILRI). About 119 species of herbaceous forage legumes were tested in Ethiopia at about 40 testing sites, which represent different agro-ecological zones. Of these species, about 82% were either exotic or commercial species introduced from various parts of the world, which indicates that low emphasis has given for the native species. No forage legume has officially been released in the country for not following standard procedures for evaluation and lack of rules and criteria for releasing varieties and species for forage crops. Also, the evaluation has been limited at the species level for forage yield without any systematic breeding approach. Generally, the performance of herbaceous legumes in the highlands is low compared to the mid-altitude areas. Nevertheless, about 11 species of which six are clovers for the highlands and 13 species for mid-altitude areas are recommended for different agro-ecological zones of Ethiopia. Similarly, only five species are well-adapted to the lowlands. Among the recommended herbaceous legumes, detailed information is given on *Trifolium* and *Vicia* species for the highlands; and *Lablab, Stylo, Desmodium, Medicago* and *Macroptilium* species for the mid- and low-altitude areas. For successful species and varietal development of herbaceous forage legumes there is a need for well-designed procedures and methodologies of species and varietal evaluation with more emphasis on a few high potential indigenous species.

INTRODUCTION

The main objective of cultivation of forage legumes is to produce vegetative material (forage) for use as livestock feed and to some extent for improvement of soil fertility. But seeds are produced to a limited extent and usually produced as a by-product. The aim of forage and pasture legume collection, introduction and evaluation is to ultimately release the superior cultivars or species for large-scale production and use them as pasture, hay or silage in a particular farming system.

Since the early 1950s when agricultural research began in Ethiopia, a number of institutions of teaching and development have conducted research on native and exotic forage and pasture species and informally collected native forage and pasture germplasm (Solomon, 1989). Over the past 15-20 years, the International Livestock Research Institute (ILRI) has been involved in the evaluation of native Ethiopian forage legume germplasm as part of the normal procedures of the ILRI genetic resource section. Research has also been conducted by various institutions in the country including: Alemaya University, Agricultural Colleges in the country (Ambo, Jimma, and Debre Zeit), Ethiopian Agricultural Research Organization (EARO, formerly IAR), Arsi Rural Development Unit (ARDU), Addis Ababa University, Ministry of Agriculture (MOA), and recently established regional research centers and other non-government organizations (Alemayehu, 1997). A large numbers of forage and pasture species have been evaluated on multiple locations by the Forage Network in Ethiopia (FNE) in a range of environments.

Review of the research status on forage and pasture crops showed that emphasis has been given to the exotic and commercial species. Preliminary screening and adaptation trials were done for a wide range of native, commercial and exotic species. However, except for few commercial lines and *Trifolium* species there have not been any advanced agronomic and animal evaluation studies for native species. This is reflected in the recommended forage and pasture crops by the various researchers for different agro-ecologies and farming systems where the majorities are commercial lines of exotic origin.

The greatest constraint on animal performance in Ethiopia and elsewhere in the seasonally dry tropics is the low nutritional value of most animal feeds. Effects of legumes in the diet on animal production have been studied, and almost all showed significant increases in animal production through feeding legumes. Crop residues and pasture grasses are mostly fibrous and poor in feed quality. They are generally low in digestability, protein and non-protein nitrogen, and variably deficent in a number of minerals. Low quality feeds can be improved by supplementation to correct deficiencies and achieve efficient microbial growth in the rumen, resulting in better feed utilization. Thus for small holder, low cost feed supplements from legumes may be attractive. As legumes can also serve a vital function in soil nutrient managment, integrating them in the production systems is of high significance to the long-term land use. More research and extension efforts are needed to bring about integrated land managment systems, for example, involving forage legumes as companion crops with food crops for the overall benefit of farmers, and environment.

To achieve this objective, proper selection, evaluation and assessment of the specific features of herbaceous legumes, such as species diversities, varietal differences, growth habits, forage productivity, nutritional quality, disease and pest resistance and other factors should be investigated for forage legumes adopted and available in the different agro-ecologies. This article summarizes the general status of forage legume biodiversity, evaluation systems, species and varieties tested and recommended for the various agro-ecologies, and the performance of recommended species targeted for the various production systems under the Ethiopian farming system conditions.

SPECIES DIVERSITY OF HERBACEOUS FORAGE LEGUMES IN ETHIOPIA

The species and varieties of forage legumes are many in number and adapted to wide environmental conditions compared to food legumes. They have also different characteristics in terms of growth habit, persistence and adaptation to the various environmental conditions. They can broadly be grouped by their life cycle as annuals and perennials; by growth habit as erect, creeping and climbing; by climatic as tropical and temperate; and other minor classifications. These characteristics of legumes determine the utilization, production and the various management practices.

Ethiopia is known to be a center of origin and diversity to a number of domesticated crops, and also as the center of diversity for herbaceous legumes such as *Trifolium, Vigna, Lablab,* and *Neonotonia.* Among the native herbaceous forage legumes, a total of 186 herbaceous forage legume species from 43 genera are documented (Getahun et al., 2003). However, the threat of genetic erosion of herbaceous legumes is serious due to the fact that they are palatable and easily affected by over grazing.

Since 1982, ILRI has initiated systematic exploration and conservation by actively collecting forage germplasm from different ecological regions of the country and by acquiring the world's collections of the more promising material. ILRI is maintaining this germplasm collection in collaboration with the Institute of Biodiversity Conservation and Research (IBCR), ex-PGRC/E (Ethiopian Plant Genetic Resources Center of Ethiopia).

The current ILRI herbaceous legumes germplasm collection contains 1990 accessions consisting of 103 identified species (Getahun et al., 2003). Over three fourths of the accessions were collected from the Ethiopian highlands and about two third belong to the genus *Trifolium*, showing the predominance of clovers in the Ethiopian highlands. On the contrary, only few species and accessions are collected and conserved inform and in the arid and semi-arid agro-ecological zones. Despite that, this area is largest where large population of pastoralists and huge livestock population exist. Drought and population pressure are important factors contributing to disappearance of important forages and encroachment of undesirable species, which have low feeding value. This calls special attention to exploration, collection and conservation of the forage legume biodiversity in semi-arid regions.

A number of forage germplasm, which are mostly of exotic origin, are also conserved and utilized by national institutes involved in research. At EARO in Holetta, a total of about 2000 exotic and native accessions belonging to forage legumes, grasses and browses are conserved and maintained in a natural cold room. EARO provides germplasm in small quantities to different organizations for research and development purposes.

SPECIES AND VARIETIES EVALUATION SYSTEMS

Breeding of forage legumes has received little attention in Ethiopia, where the selection is usually made at species level. Only few species, accessions and varieties are evaluated by mass selection. Advanced forms of breeding such as pure line selection and crossing are virtually not practiced. In the national agricultural research system, evaluation of forage legumes is generally done at the preliminary stage. Some advanced practice of variety and species selections for a limited number of species is done by ILRI.

The main objective of species or varietal selection of forage legumes is to produce high amount of biomass yield with good nutritional quality, especially in terms of crude protein content and high animal intake. To achieve this objective, two major directions of varietal development are presently followed in Ethiopia. The first evaluation system is in pure stands with recommended agronomic practices, harvesting, conservation methods and feeding systems. The second direction of selection is non-conventional such as integration with other food and industrial crops for production of feed and other benefits. Such a system is highly important and appropriate in areas where land shortage is a problem and the agricultural production system is subsistence.

So far, 119 species of herbaceous forage legumes have been tested in Ethiopia at about 40 sites, representing different agro-ecologies (Getahun et al., 2003). Of these, 98 species were either exotic or commercial species introduced from various parts of the world. This indicates the very low emphasis given to the native species. Most evaluations did not follow standard procedures like those of food legumes. ILRI has developed an evaluation manual for forage crops (Tarawali et al., 1995) but it is not comprehensive enough for the national system to release forage species and varieties.

Species and Variety Release

There is a national variety release committee for food and industrial crops in Ethiopia. For a long time efforts have been made to officially release forage crops. Experiences and problems in releasing forage crops in Ethiopia and elsewhere have been discussed by Zinash et al. (1996). The major limitation for variety development and release was lack of standard procedures in the evaluation process. As forage crops are intermediate products, their evaluation requires intensive procedures through laboratories and animals, which are very expensive and not adequately available in the country. In spite of this, several forage legume species were recommended for different agro-ecologies of the country (Table 1). Herbaceous legumes such as vetch, alfalfa, Lablab, Desmodium, Stylo and Siratro are widely utilized by farmers. Recently, the national variety release committee has initiated the development of standards for officially releasing forage crops.

Table 1. Recommended forage legumes species which are used at different altitudes in Ethiopia.

High-altitudes
Vicia spp.(Vetch)
Trifolium quartinianum (Clover)
Trifolium rueppellianum (Clover)
Trifolium tembense (Clover)
Trifolium decorum
Melilotus altisimus
Lotus corniculatus (Birdsfoot trefoil)
Trifolium repens (White clover)
Trifolium pratense (Red clover)
Medicago sativa (Lucerne, Alfalfa)
Medium-altitudes
Lablab purpureus (Lablab)
Desmodium unicinatum (Silver leaf Desmodium)
Desmodium intortum (Green leaf Desmodium)
Stylosanthes spp (Stylo)
Macroptilium atropurpureum
Medicago spp. (Medics)
Arachis pintoi
Lotononis bainesii (Lotononis)
Centrosema pubescens
Pueraria phaseoloides (Tropical kudzu)
Neonotonia wightii
Clitoria ternatea
Medicago sativa (Lucerne, Alfalfa)
Low-altitudes
Lablab purpureus (Lablab)
Neonotonia wightii
Stylosanthes spp (Stylo)
Clitoria ternatea
Medicago sativa (Lucerne, Alfalfa)

Source: EARO (2001).

PERFORMANCE OF THE MAJOR HERBACEOUS FORAGE LEGUME SPECIES

Clover (*Trifolium* spp.)

There are 240-300 clover species of the genus *Trifolium* distributed around the world, and clovers are ubiquitous in natural grasslands in cooler climate (Allen and Allen, 1981). Forty *Trifolium* species are found in Sub-Saharan Africa of which about 25% are endemic in Ethiopia (Gillet, 1952; Thulin, 1982). About two thirds of the clover species in Ethiopia are annuals and one third are perennials; biennials are not found in Ethiopia. Though Ethiopia has important *Trifolium* species, there have been few studies to evaluate their varietal differences. Some germplasm collections and preliminary screening were done by ILRI but most germplasm was evaluated at species level. In addition, the Ethiopian Agricultural Research Organization (EARO) and some other organizations conducted experiments in various agro-ecologies on evaluation and selection of clovers.

Annual clovers: Most of the annual clovers were tested at different research centers in the highlands including Holetta, Sheno, Adet, Sinana, Sirinka, Ginchi, Debrezeit, and Kulumsa. Annual clovers showed variability in terms of their adaptation to different agro-ecologies in the highlands, soil type and fertility status, days to maturity and forage yield (Table 2). Among the tested clovers, *T. quartininanum, T. decorum and T. ruppellianum* generally performed well across locations (Table 3 and 4). Despite the fact that there are excellent forage producers in few locations in the highlands like Sinana, general performance of clovers doesn't encourage cultivation of clovers in pure stands as a conventional pasture. Their performance in most natural pastures is better than when they are cultivated. Most species of *Trifolium* have their own niche when they grow naturally. *T. tembense* usually grows very well on waterlogged areas, while *T. ruepellianum* and *T. quartininaum* dominate drained pasture and arable land borders. Clovers are often major weeds in fields of cereals and other food crops. In most highland areas, farmers weed their crops and use them as a major source of feed for livestock during the wet season when feed is scarce.

Perennial clovers. There has been only a little research undertaken on perennial clovers. However, *T. africanum, T. burchellianum, T. cryptopodium, T. semipilosum, T. repens and T. pratense* were tested at different locations in the highlands. The overall performance in terms of biomass yield of these perennial clovers is very poor. However, *T. cryptopodium* at Shola, and *Trifolium pratense* at Sinana, (Bale) performed well (Kahurananga, 1988; SnARC, 1988-2000).

Table 2. The most important native annual *Trifolium* species recommended for the highlands of Ethiopia.

No.	Species (common name)	No of accessions available	Average days to forage harvesting	Maturity
1	Trifolium quartinianum *(Quartin clover)*	40	124	Late
2	*Trifolium steudneri*	83	122	Late
3	*Trifolium decorum*	73	115	Intermediate
4	Trifolium rueppellianum *(Rueppell clover)*	103	111	Intermediate
5	*Trifolium tembense* (Temben's clover)	182	105	Early
6	*Trifolium schimperi*	28	112	Intermediate

Table 3. Average dry matter forage yield (t/ha) of major annual *Trifolium* species tested at different sites in the Ethiopian highlands.

		Testing site					
No.	Species (Common name)	Holetta Red soil	Holetta Black soil	Mehal Meda	Inewari	Areka	Debre Zeit
1	Trifolium quartinianum	1.62	2.12	1.39	2.15	11.4	-
2	*Trifolium rueppellianum*	5.24	-	2.80	1.57	7.6	7.32
3	*Trifolium decorum*	4.54	3.23	1.68	1.28	4.9	4.19
4	*Trifolium steudenari*	1.71	1.47	-	1.73	-	6.53
5	*Trifolium tembense*	-	2.49	1.92	-	2.5	2.17

Source: HARC (1995); SnARC (2003); AwARC (1999) and DZARC (1995).

Table 4. Average dry matter yields (t/ha) of annual *Trifolium* species tested at Sinana in the *belg* (March to July) and *meher* (August to December) seasons.

		Average forage yield, DM (t/ha)		
No.	Species (common name)	*Belg*	*Meher*	Mean
1	Trifolium rueppellianum *(Rueppell clover)*	10.00	2.10	6.1
2	Trifolium quartinianum *(quartin clover)*	8.90	0.80	4.8
3	*Trifolium steudneri*	1.11	1.65	1.38
4	*Trifolium resupinatum*	7.02	1.77	4.40
5	*Trifolium tembense* (Temben's clover)	3.89	1.67	2.78
6	*Trifolium schimperi*	2.31	1.77	2.04
7	*Trifolium subteranium*	5.10	0.96	3.03
8	*Trifolium alexandrium*	1.22	-	1.22

Source: SnARC, 1988-2000.

Berseem clover: Most of the clovers are well-adapted in the cooler highlands. However, berseem or Egyptian clover (*Trifolium alexandrinum*) is well-adapted in the lowland areas in the tropics under irrigation. It was tested in many highland areas under rainfed conditions but its performance was very poor. Preliminary results at Melka Werer under irrigation in the mid-Awash Valley performed very well. Carmel mulicut, Genest and Westland were the best among the tested varieties and gave DM forage yields of 28.6, 23.4 and 23.2 t/ha in six harvests, respectively (MWARC, 2003). They were harvested almost at a monthly-interval under irrigation. As berseem is not perennial, the yield at the first harvest was about 40% of the total of six harvests and it declined continuously thereafter. Berseem clover has also been tested in many highland areas of the country under rain-fed conditions, but its performance has been poor. Despite the large number of annual and perennial species of clovers available in the country, their utilization as cultivated forage crop is very minimal. Diseases and pests are no serious problems for clovers. Their low forage productivity, however, especially on marginal soil fertility conditions is the major constraint besides their annual nature, which increases the cost of production in terms of land preparation, labor and other inputs. They have a potential to be cultivated in integration with small cereals like barley and wheat. Most clover varieties are early in relation to small cereals, which commonly limit compatibility especially in growth. Thus, their potential as cultivated forage crop is very limited. In contrast, for most of the natural pastures from high-mid altitude areas, clovers make a very good mix with native grasses. Renovating and managing the natural pasture with better grazing management and resting practices could improve the potential of utilization of clovers as livestock feed. Areas such as Bale (Sinana and Gasera) are an exception where annual clovers have shown excellent performance. Thus, their cultivation and utilization under this condition and similar agro-ecologies are still promising.

Vetch (*Vicia* spp.)

Vetch species are the most important and widely utilized annual forage legumes in the highland farming systems throughout different production strategies in Ethiopia. Until recently, about six vetch species have been widely evaluated and utilized, which show some features of these species (varieties) and their performance at different testing sites (Tables 5-8). In most tested areas, there hasn't been any significant disease and pest incidence on the vetches except for the narbon vetch.

Hairy and wooly-pod vetches are recommended for various locations in the highlands and are widely utilized by farmers. The two mostly utilized hairy vetch varieties are 'Lana' and 'Namoi'. These two varieties and purple vetch have similar growth habit (creeping), days to maturity, and forage yield. Hairy vetch is usually well-adapted to higher altitudes and cooler areas, and is comparatively late-maturing and resistant to frost, while woolly-pod vetch is suitable for intermediate-altitude areas within the highlands. Purple vetch is better for warmer, high rainfall areas. These species are suitable for cultivation in pure stands conventionally for forage, and could serve as a break crop on fallow lands, or used for green manuring. For forage, they are also recommended for cultivation in mixture with oats.

Common vetch is early-maturing and its biomass productivity is lower than the other vetch species. It is not much popular as compared to the other late-maturing vetch species. An old variety of common vetch, which was utilized for many years, was very low in forage yield and hence it was not popularized in the farming system like hairy and woolly-pod vetches. However, in 1998, about 255 accessions of common vetch were introduced from ICARDA. The accessions were screened for higher forage yield, desired morphological features such as growth habit, and disease resistance at Holetta, Ginchi and Debre Zeit (HARC, 2002). Generally, very promising varieties have been advanced for forage production in pure stands and in integration with small cereals in the highlands. The new common vetch varieties also have great potential for integration with other small cereals and food legumes, especially in relay, sequential cropping (using residual moisture or short rains) and intercropping.

Narbon vetch has been very recently introduced in the country. About 81 accessions were introduced and tested at Holetta and Ginchi. Unlike other vetch species, narbon vetch is susceptible to diseases and insects. It is morphologically similar to faba bean, and also attacked by chocolate spot around Holetta. At Holetta, it was also highly attacked by beetles usually towards the end of the rainy season and at flowering stage. However, a few varieties were identified for further evaluation in integration with small cereals like barley and wheat.

In addition, there are also other vetch species, which have been tested at Holetta including *Vicia ervilia* (bitter vetch) and *Vicia benghalensis*. However, their performance under Holetta condition was not encouraging for further evaluation.

Alfalfa or Lucerne (*Medicago sativa* L.)

Alfalfa is a perennial legume, which is best adapted to warm and wet climate and non-acid soils. In Ethiopia, alfalfa can be grown in many places both under irrigation and rain-fed conditions. Many experiments conducted in Ethiopia are with two commercial varieties, Hunter River and Hairy Peruvian. However, more than hundred accessions were tested at Holetta, Debre Zeit, and Melka Werer under rain-fed, and Sinana under irrigation and rain-fed conditions. The herbage yield performances of some of the varieties tested are shown in Tables 9 and 10. In addition, the varieties are tested in the highlands, mid-altitude areas, and lowlands. In the highlands such as Holetta, Sinana, Kulumsa and Sheno, there is a severe seedling die-back particularly on acid soils, and at a later stage survived plants suffered from leaf diseases, which were more serious during the wet season. Besides, control of wild animals that graze, especially during the dry season, is very difficult in the highlands, and thus the overall average forage yield is very low compared to warmer areas.

In the mid-altitude and lowland areas such as Melka Werer and Adamitulu, alfalfa is doing excellent under irrigation. At Melka Werer, alfalfa matured for harvesting within 35-45 days, and is usually disease-free and very productive.

Lablab (Lablab purpureus, synonym Dolichos lablab L.)

Lablab is a vigorous annual or short-lived perennial legume adapted to a wide environmental range, from low-altitude up to 2500 m asl, and suited to a range of soils. It is drought-resistant, and produces good yield even in 400 mm rainfall. Lablab performed well at Amaro, Kocher, Sirinka, Melka Werer, Bako and Chefa. However, in the high-altitude areas such as Ginchi and Holetta, its performance was poor as it was highly susceptible to cool temperature and frost which makes growth very stunted. It is highly infested and attacked by insect-pests. Herbage yield performances of some of the varieties are shown in Tables 11-12.

Table 5. The major vetch species recommended and utilized in the highlands of Ethiopia.

No.	Common name	Latin name	No. of accessions tested	Growth habit	1000-seed weight (g)	Days to forage harvesting	Maturity
1	Hairy vetch	*Vicia villosa*	15	Creeping	32.3	142	Late
2	Wooly pod vetch	V .villosa subsp. dasycarpa	2	Creeping	42.5	126	Intermediate
3	Purple vetch	*V. atropurpurea*	1	Creeping	44.8	132	Intermediate
4	Common vetch	*V. sativa*	255	Erect*	53.5	109	Early
5	Narbon vetch	*V. narbonensis*	81	Erect	157.1	109	Early
6	Bitter vetch	*V. ervilia*	19	Erect	-	-	Early

* Lodges on fertile soils and has a tendency of creeping.

Table 6. Average dry matter (DM) forage yield, height at harvest, days to forage harvesting of vetches and their growth habit tested at Holetta, 2000- 2002.

Common name	Latin name	Height at harvest* (cm)	Average forage yield, DM (t/ha)	Grain yield (t/ha)
Hairy vetch	*Vicia villosa*	145.8[a]	4.80[bc]	8.76
Wooly-pod vetch	*V. villosa subsp. Dasycarpa Lana*	156.5[a]	7.07[a]	11.08
Wooly-pod vetch	*V. villosa subsp. Dasycarpa namoi*	148.2[a]	6.97[a]	11.96
Purple vetch	*V. atropurpurea*	151.9[a]	5.78[ab]	10.96
Common vetch	*V. sativa*	70.8[b]	3.95[cd]	11.16
Narbon vetch	*V. narbonensis*	69.6[b]	2.75[d]	9.48

* Stretched heights for creeping species. Source: HARC (2000-2002).

Table 7. Average proportion of botanical fractions in different vetch species at Holetta.

Common name	Latin name	Dry matter proportions (%)			
		Stem	Leaf	Green pod	Flower
Hairy vetch	*Vicia villosa*	60.07[a]	31.26[b]	5.49[cd]	3.18[ab]
Woolypod vetch	*Vicia villosa subsp. Dasycarpa lana*	56.53[a]	29.80[b]	11.87[bc]	1.80[cb]
Hairy vetch	*Vicia villosa subsp. Dasycarpa namoi*	56.27[a]	37.44[ab]	1.22[d]	5.07[a]
Purple vetch	*Vicia atropurpurea*	58.46[a]	36.55[ab]	2.63[d]	2.95[ab]
Common vetch	*Vicia sativa*	41.63[b]	42.42[a]	15.99[b]	0.56[c]
Narbon vetch	*Vicia narbonensis*	24.74[c]	18.21[c]	57.05[b]	0.00[c]

Source: HARC (2000-2002).

Table 8. Average dry matter yield (t/ha) of vetch species at the different highland areas, 1988-2002.

No.	Common name	Latin name	Holetta	Inewari	Sinana *Belg*	Sinana *meher*	Adet*	Areka	Delanta	Mean
1	Hairy vetch	*Vicia villosa*	4.80	4.82	12.8	4.4	10.74	9.00	4.55	7.76
2	Woolypod vetch	V. villosa subsp. *Dasycarpa Lana*	7.07	3.82	8.3	3.6	7.04	7.3	3.98	6.19
3	Hairy vetch	V. villosa subsp. *Dasycarpa namoi*	6.97	-	8.7	5.6	-	-	-	
4	Purple vetch	*V. atropurpurea*	5.78	-	6.6	2.3	6.53	6.9	3.59	5.62
5	Common vetch	*V. sativa*	3.95	2.08	7.7	2.7	1.55	5.3	1.29	3.88
6	Narbon vetch	*V. narbonensis*	2.75	-	-	-	-	1.0	-	2.75

Source: Adopted from Holetta, Sheno, Sinana, Sirinka and Awassa Research Centers Progress Report (1988-2002); *Tessema (1998).

Table 9. Average annual dry matter forage yield (t/ha) of alfalfa varieties tested at different highland areas under rain-fed condition.

Variety	Adet	Debre Zeit	Holetta	Sinana	
				Belg (3 cut)	*Meher* (1 cut)
Cody	6.9	5.5	-	-	-
CUF 101	11.4	-	-	6.6	2.0
Deputies	10.5	9.7	-	7.9	1.7
Gilba	10.3	5.6	2.7	7.0	1.3
Hairy Peruvian	9.1	6.2	3.1	7.5	1.6
Hunter River	7.6	4.8	2.6	7.6	1.6
Sonora	-	6.6	2.6	-	-
Terre Verde	-	7.8	2.6	-	-
Unico	12.2	5.3	-	6.2	2.0
UC-76c	10.9	6.9	-	6.5	2.0
Vernal	9.0	6.8	0.8	-	-
WL-514	11.3	-	-	7.2	2.3

Table 10. Average annual dry matter forage yield (t/ha) of alfalfa varieties tested at Melkawerer (a lowland site) with irrigation.

Variety	DM (t/ha)	Variety	DM (t/ha)
Arkonsaw	2.21	Moapa	2.87
AS 13	2.93	Pioneer 571	1.85
Calinet	3.33	Ramagnola	2.30
EL Unico	2.60	Sonora	2.99
Hunter River	2.03	Simson & White law	3.35
Hairy Peruvian	3.09	Terre Verda	2.45
Unico	2.70	Titan	2.01
Anchor	2.04	Cody	1.98

Table 11. Dry matter (DM) yield, height (Ht) at harvest and days taken to harvesting of tested lablab accessions at Sirinka and Chefa, 2001.

	Sirinka			Chefa		
Accession	DM yield/ (t/ha)	Plant height (cm)	Days to harvesting	DM yield/ (t/ha)	Plant height (cm)	Days to harvesting
147	5.1	87.8	89	7.25	188	88.3
6529	15.6	104.7	105	9.28	152	100.3
6536	20	106.2	105	9.49	147.6	102.7
6920	10.9	105.9	99.7	7.84	159.3	94.3
6930	12.3	89.6	99.7	7.44	144.1	94.3
7072	19.3	107.9	106	6.23	144.1	103.3
7278	18.5	107.7	106	8.15	129.5	105.7
7319	11.5	96.2	94.3	7.35	143.4	88.3
7379	5.9	75.7	94.3	8.42	150.3	82.3
7519	10.8	113	108	3.87	159.9	106.3
10954	15.8	95.8	99.7	8.51	152.2	100.3
11615	7.3	82.5	94.3	9.92	143.7	96.7
11617	12	118	100.7	5.68	135.4	91.3
11620	10.9	105	99.7	7.42	154.8	82.3
Mean	12.6	99.7	100.1	7.63	146.7	95.5
LSD	NS	NS	NS	NS	NS	0.05

Source: SnARC (2001).

Table 12. Dry matter yield (t/ha) of *Lablab purpureus* at six different districts of Southern Region during 2000-2003.

	District	2000	2001	2002	Mean
1	Shebedino	4.41	4.76	4.20	4.46
2	Awassa Zuria	*4.10*	7.7		5.90
3	Kocher		2.31	10.56	7.59
4	Amaro		11.91	28.33	20.12
5	Derashe	9.59		3.14	6.37
6	Kembata A & T	6.43	2.70		4.57

Source: AwARC (2002).

Desmodium

Desmodium is a perennial forage legume well-adapted to wide range of soil types in warmer areas throughout the tropics. There are some 350 species of Desmodium in the tropics. The most widespread and cultivated species are *D. uncinatum* (silver leaf) and *D. intortum* (green leaf). *D. uncinatum* is indigenous to northern Argentina, Brazil and Venezuela, while *D. intortum* is common in northern parts of South America, on the eastern slopes of the Andes, and in a restricted area of Brazil. It is now widespread in pastures and nursery plots throughout the tropical and subtropical world (ILRI-FAO, CD). Herbage yield performances of the varieties tested at different testing sites of the country are shown in Tables 13-14.

Stylo (*Stylosanthes* spp.)

Stylosanthes is an important forage legume that has been widely used for livestock feed. The genus contains about 30 species, but most research programs have concentrated on a fairly narrow range of species. Most species are native to South and Central America, including the Caribbean, except for *S. fruticosa* and *S. erecta*, which have their center of origin in Africa. Interest in Stylosanthes, which began about 70 years ago, was stimulated by the species *S. humilis* and *S. guianensis* due to their adaptability to drought and low fertility acid soils and their persistence in pastures (Hanson and Heering, 1994). The use of Stylosanthes as a forage legume in Africa increased in the 1960s when several new improved cultivars, developed in Australia, were introduced into West Africa. Among other introduced species and varieties, S. *guianensis* cvs. Cook and Schofield, and *S. hamata* cv. Verano have remained the most widely used germplasm in the region. However, these early cultivars proved susceptible to anthracnose. Recently, *S. guianensis* CIAT 184 (=ILRI 164) was developed by CIAT and stands out for its anthracnose resistance. The herbage and seed yield performances of some Stylosanthes varieties tested in the country are shown in Tables 15-16.

Table 13. Average dry matter forage yield (t/ha) of *Desmodium* species tested at different testing sites (in the high-, mid- and lowland areas), 1998-2002.

	Desmodium species	
Testing sites	Green leaf	Silver leaf
Bako	*4.61*	5.47
Melka Werer	*11.80*	-
Melkasa	8.02	7.14
Areka	4.40	2.90
Sinana	1.70	2.00
Holetta	4.35	2.05

Table 14. Dry matter forage yield (t ha-1) of green leaf Desmodium (Desmodium intortum) at six different sites of southern region during 2000-2002.

	Site	2000	2001	2002	Mean
1	Shebedino	1.32	6.87	3.38	3.86
2	Awassa Zuria	*2.8*	7.50	-	5.15
3	Kocher	*2.25*	-	4.42	3.34
4	Amaro	-	4.46	7.57	6.02
5	Derashe	-	4.46	5.34	4.90
6	Kembata A & T	1.32	2.68	-	2.00

Source: AwARC (2002).

Table 15. Range of adaptation to rainfall, altitude and soil pH of the collections of major Stylosanthes species in the ILCA and CIAT Gene Banks.

Species	Rainfall (mm)	Altitude (m asl)	Soil pH
S. capitata	190–2150	50–1220	4.3–6.2
S. fruticosa	382–1580	10–2080	4.5–8.0
*S. guianensis**	635–9050	5–2000	4.5–5.8
S. hamata	310–2500	2–1600	5.4–8.5
S. humilis	410–4030	10–1000	5.1–5.3
S. scabra	400–2890	5–1660	4.0–5.8
S. viscose	230–3200	5–1200	4.0–6.5

* Includes *S. gracilis*.

Table 16. Two years average dry matter forage (t/ha) and seed (kg/ha) yield of Stylosanthes species and varieties tested at Bako.

Species	ILRI Accession No.	DM (t/ha)	Seed (kg/ha)
S. hamata	*75*	4.16	439
	167	3.68	461
	14212	3.95	457
	14218	3.36	249
	14237	9.82	240
S. guianensis	*04*	6.76	295
	73	9.70	157
	163	4.18	108
	164	9.34	97
	11737	9.57	90
S. scabra	140	5.70	413
	441	8.00	512
	6854	12.31	724
	9262	4.17	629
	11525	9.60	195

Other Important Herbaceous Forage Legumes

Cowpea (Vigna unguiculata): Cowpea is a dual-purpose annual legume crop which is mainly productive in the lowland parts of the country. Its grain is used for human consumption while the forage part for animal feed. Therefore, varietal evaluation and selection of this legume could be either for grain, for fodder or dual purpose depending on the objective for selection.

Lotus: The two introduced species tested at different highland areas are *L. corniculatus* and *L. pendiculatus*. They are well adapted to cooler highlands of Ethiopia such as Sheno and Sinana. Lotus is highly resistant to frost and moisture stress and stays green during the dry season. Though their productivity is low compared to the introduced ones, the native species are also commonly found in many highland areas. The major problem in Lotus is its seed productivity. In most areas, it doesn't set flower and produce seed. However, at Sheno, *L. pendiculatus* produced seed, whereas *L. corniculatus* had limitations at all sites. It is well established from root splits. If sites for seed production are identified and adequate amount of seed is produced, it is a very promising perennial forage legume for the highlands.

SEED PRODUCTION

Despite the many desirable characteristics of selected and cultivated forages, they have not been disseminated to farmers because of seed scarcity. Most adaptable pasture species are capable of flowering and producing healthy seeds. As the field husbandry critical to herbage seed production is little studied, current seed quality and yield levels are mostly unsatisfactory. With the growing forage seed demand from the user's side, seed research is gradually growing. Few but valuable seed crop management studies have already been developed.

Adequate seed supplies of acceptable standards in terms of purity and germination of the important forage crops are very limited in most tropical countries. Thus lack of seed places a serious constraint on various national efforts to raise animal productivity quickly and effectively through increasing the land area under sown pastures and improving the species composition of existing natural grazing lands. The need for information leading to economic and efficient seed production and processing is acute.

Seed production methods for most forage crops are quite different from those used for cereal or large seeded legume crops. Each herbage plant has its peculiarities. It is important to know the proper rate, time and method of seeding and the best stage of plant development at which the seed is sufficiently mature to harvest. In addition, isolation requirements and post-harvest management under local situations are also important considerations.

Research and development of forage seed production is just beginning in Ethiopia, and some preliminary work has been conducted by different researchers. A trial was conducted at Holetta to determine the optimum maturity dates for higher quantity and quality of seed yields for four annual clovers on two soil types. The clovers gave better yield when harvested one week after flowering on red soil and two weeks after flowering on black soil. Yield declined on both soil types when harvesting was delayed as shattering was the most important problem in most clovers. Seed yield was in the range of 126-256 kg/ha in red soils and 215-298 kg/ha in black soils. The germination of the seeds was 14-24 and 15-19% in red and black soils, respectively (HARC, 1995).

Experiments done to assess seed yield potential of some forage crops in the mid-altitude environment indicated that *D. unicinatum, S. guianesis* and *L. purpureus* at optimum seed rate and row spacing on small plots could give up to 400, 350 and 1700 kg/ha seed, respectively (Alemu, 1990).

Annual forage crops such as vetch generally produce higher quantity and quality and larger sized seeds than perennials. Moreover, seed production technologies and pasture establishment techniques are easier in annuals than in perennials. Experimental results have shown that vetches gave good seed yield when planted at the rate of 20-30 kg/ha and row spacing of 60 cm. It has also been confirmed that it was possible to increase the seed yield of these species by providing some supporting structures (Lulseged, 1985).

Some forage crops such as lotus do not produce flowers and set seeds due to effect of day length.

However, they are well-adapted and produce high herbage yield. These can be propagated by vegetative means by their root splits.

Some important management practices in forage legume seed production include choice of seed production site, preparation of the seedbed, optimum seeding and fertilizer rates and supporting structures. After establishment, management practices such as weeding, and plant protection from diseases, insect-pests and birds and others are crucial. The mature crop should be harvested at optimum stage, favorable season of the year and with appropriate harvesting tools. The harvested seed should also be threshed, cleaned, packed and stored using appropriate procedures and techniques. In perennial forage legumes, there is a need to establish management practices for defoliating the re-growth for the following seed harvest.

SUGGESTIONS FOR FUTURE RESEARCH DIRECTIONS

Forage crops are most commonly cultivated for their herbage yield and seed production is often opportunistic. This, with the very low productivity and associated problems, make forage seeds very expensive, especially for perennial forage crops. Any forage development without availability of adequate amount of good quality seed is a futile exercise. Hence, seed production of forage crops should be encouraged at different levels, and should also be backed up with research results.

The forage legume research with limited resources and manpower seems thinly spread in the country. Although some potential species have been identified on the basis of preliminary results but these species have not been finally tuned for their varietal and agronomic performance, and are not yet ready for adoption by farmers. This calls for an immediate attention.

The ultimate goal of evaluating forage legumes is to identify species or varieties, which are productive, disease-resistant, easier to establish and manage, palatable and nutritious to animals, and preferably with multipurpose benefits. This requires very organized evaluation procedures at the national level. Until now, there is no such evaluation procedure in place. This should be given emphasis and evaluation procedures should be developed as a manual, and they should be implemented. Appropriate procedures for evaluation, selection and release of species and varieties are the means for efficient utilization of scanty resources and avoid duplication of efforts.

Forage crops in general and forage legumes in particular are highly diverse. However, most of the national research systems do not have much access to germplasm, which has limited evaluation of mostly the native species. There is a need for strong forage biodiversity conservation and research, which provides well-organized services in providing forage germplasm for evaluation. Only very recently, IBCR started dealing with forage and pasture crops. As conventional production of forage legumes are very limited, one option is through integration with food crops.

Forage legumes are more susceptible to diseases and pests than most forage grasses. Therefore, species and varietal evaluation with the different stress conditions including, diseases, pests, moisture (drought and water logging), frost tolerance, seed-setting ability and resistance to salinity are very important.

In the highlands, annual forage legumes are doing very well but there aren't any promising perennial forage legumes, hence there is a need for screening and evaluating more perennial forage legumes.

The end-product of forage legumes will eventually be measured by the amount of animal product such as milk and meat. Hence, any release and recommendation of the species and varieties needs to be based on animal performance. Most exotic and commercial varieties have information in feeding qualities, which could be adopted through adaptation trials. The Ethiopian farming and livestock production systems call for special efforts to evaluate the native as well as the exotic forage legumes for livestock feed to fit the Ethiopian livestock production system in the different agro-ecological zones.

REFERENCES

Alemayehu Mulugeta. 1997. Conservation based forage development for Ethiopia. Self Help Development International for Sustainable Development. Addis Ababa, Ethiopia.

Alemu Tadesse. 1990. The unexploited potential of improved forages in mid-altitude and lowland areas of Ethiopia. *In* Proc. PANESA/ARNAB Joint Workshop held in Lilongwe, Malawi, 5-9 December, 1988. PANEL/ARNAB, Addis Ababa, Ethiopia.

Allen, O. N., and E. K. Allen. 1981. The Leguminoseae: A Source Book of Characteristics, Use and Nodulation. McMillan Publishers, London.

AwARC. 1988-2002. Forage and pasture crops annual report. Awassa Agricultural Research Center (AwARC), Awassa, Ethiopia.

DZARC. 1995. Progress report. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

EARO. 2001. Forage and pasture crops research program research strategy. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.

Getahun Mulat, Getnet Assefa, Abate Tedla, Eshetu Janka, and Alemayehu Mengistu. 2003. Forage and pasture crops genetic resources conservation and research. Stocktaking for biodiversity conservation national strategy and action plan project. Ethiopia. Institute of Biodiversity Conservation and Research (IBCR). Addis Ababa, Ethiopia.

Gillet, J.B. 1952. The genus Trifolium in southern Arabia and Africa south of the Sahara. *Kew Bull.* 7: 367-404.

Hanson J., and J.H. Heering. 1994. Genetic resources of Stylosanthes species. *In* Proc. Regional Workshop on the Use of Stylosanthes in West Africa, held in Kaduna, Nigeria, 26–31 October 1992. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.

HARC. 1988-2002. Forage and pasture research program progress report. Holetta Agricultural Research Center (HARC), Holetta, Ethiopia.

Kahurananga, J. 1988. The screening of perennial Trifolium species mainly from the Ethiopian highlands and their potential for use in pasture. *In* Proc. Third Workshop held at the International Conference Center, Arusha, Tanzania, 27-30 April 1987. Pasture Network For Eastern And Southern Africa (PANESA). International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Lulseged Gebrehiwot. 1985. Undersowing of forage crops in cereals: Some achievements. *In* Proc. First National Livestock Improvement Conference, 11-13, Feb. 1987, Addis Ababa, Ethiopia.

MWARC. 2003. Summary of forage and pasture research activities progress report at Melka Werer. Ethiopian Agricultural Research Organization, Melka Werer Agricultural Research Center (MWARC), Melkawerer, Ethiopia.

ShARC. 1988-2002. Forage and pasture crops annual report. Sheno Agricultural Research Center (ShARC), Sheno, Ethiopia.

SnARC. 1988-2003. Forage and pasture crops progress reports. Sinana Agricultural Research Center (SnARC), Sinana, Robe-Bale, Ethiopia.

Solomon Demeke. 1989. Forage network in Ethiopia (FNE). No. 21. International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia.

Tarawali S.A., G. Tarawali, A. Larbi, and J. Hanson. 1995. Methods for the evaluation of forage legumes, grasses and fodder trees for use as livestock feed. ILRI Manual 1. ILRI (International Livestock research Institute), Nairobi, Kenya. 51 pp.

Tessema Zewdu, 1998. Forage yield and adaptability of vetch and alfalfa in northwestern Ethiopia. *Agritopia* 13. Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Thulin M. 1982 Legumes in Ethiopia: An illustrated guide. *Opera Bot.* 83.

Zinash Sileshi, Seyoum Bediye, Hailu Gebre, and Daniel Keftasa. 1996. Aspects of varietal development and release in forage and pasture crops in Ethiopia. *In* Proc. Fourth National Conference of Ethiopian Society of Animal Production (ESAP), 18-19 April 1996, Addis Ababa, Ethiopia.

Section VI. Research Extension and Socio-economics

Research on Food Legumes Processing, Utilization and Reduction of Toxic Factors

Mulugeta Teamir[1], Maaza Kerssie[2], Asrat Wondimu[3], Frew Tekabe[3], Senayit Yetneberk[1], and Shimelis Admassu[1]

[1] *Nazareth Agricultural research Center, P.O.Box 436, Nazareth, Ethiopia,* [2] *Holetta Agricultural Research Center, P.O.Box 2003, Holetta, Ethiopia,* [3] *Ethiopian Health and Nutrition Research Institute, P.O.Box 5654, Addis Ababa, Ethiopia*

ABSTRACT

Food legumes occupy an important place in the world food and nutrition by constituting a considerable portion of dietary protein. Survey results showed that the white haricot bean varieties fetched higher price for the export market. The colored varieties are for consumption and for local markets. The major dishes made from haricot beans are *nifro*, *kik shiro*, *shorba*, and *blandwaa*. It can also be used as mix for other dishes. Experiments on cooking time results indicated varietal differences and locations. Mean cooking time at Awassa, Bako, Jimma and Nazareth was an average of 23.86, 24.50, 22.65 and 14.99 minutes, respectively. Varieties grown at Nazareth showed the least cooking time. Laboratory analysis of nutritional composition of haricot bean and cowpea indicated that protein content ranged from 17.32-23.18 %, fat 1.38-3.46 %, fiber 2.40-10.13 %, carbohydrates 51.72-64.71 %, phosphorus 7.81-25.55 mg/100g, calcium 64.21-220.61 mg/100g, zinc 1.34-2.90 mg/100g, and iron 5.14-8.41 mg/100g. Among the varieties of lowland pulses tested, Roba-1 was found as a potentially good variety for *kikwot*, *shirowot*, soup and *samosa* making. According to the studies made, Roba-1 contained 20.55 % protein, 2.44 % crude fat, and 54.72 % carbohydrates. A total of 30 food samples were collected from Gojam (Bichena) and Gondar (Woreta) localities where incidence of lathyrism was reported to be high. The ODAP content of foods from Gojam ranged from 503.7 mg/100g (raw) to 337.7 (*shiro* flour) and 443.2 (*kik*). In the samples from Gondar, ODAP ranged from 480.9 mg/100g (raw) to 227.8 (*shiro* flour) and 221.7 (*kik*). The average ODAP content of raw grass pea from Addis Ababa market was 779.4 mg/100g, which was reduced to 412.4 in *shiro* flour and 71.5 in *shirowot*. The processing techniques for reducing ODAP have involved soaking and frequent removal of soaking water, boiling and discarding of the boiling water, dehulling and roasting.

INTRODUCTION

Food legumes constitute a considerable portion of dietary protein in the daily diet of people when consumed together with cereal grains. They also provide good quantities of vitamins. Legumes are consumed daily in Ethiopia in one way or another by large part of the population. They are eaten in the form of sauce to supplement the cereal-based staple diet. When fermented or made into paste, legumes are served as a side dish. They are served as snack, when made into bread, boiled or roasted.

There are, however, varieties of food legumes that contain toxins that are released in the body when consumed, depending on the methods of preparation. Those of concern are the two thermo-labile factors that exist in the form of enzyme inhibitors and haemagglutinins. These factors have ability to inhibit the action of the enzymes trypsin, chymotrypsin and alpha-amylase affecting the digestion, and thereby, absorption of carbohydrates and proteins. Haemagglutinis cause growth depression (Smartt, 1976). Besides, legumes contain goiterogens that cause goiter, saponins which inhibit growth, phytate that reduces calcium and iron absorption, cause lathyrism and flatulence that caused by long chain carbohydrates that are difficult to digest (Kordylas, 1990).

The correct application of heat in cooking pulses can eliminate most toxic factors without impairment of the amino acid composition that contributes greatly to the extent of their use (Smartt, 1976). Moistening the whole bean, or using the bean dehulled by wet or dry milling, soaking, fermentation and sprouting or germination are also good treatments to reduce the toxic factors.

In Ethiopia, with shortages of fuel wood for food preparation; cooking time and cookability are important criteria for domestic utilization. The main bottleneck for utilization of beans is their long cooking time that increases with storage at high temperature, humidity, genetic influences and type of soils they are grow in. Soaking beans in water for up to 24 hrs reduce cooking time. Water absorption is an important determinant of the rate of hydration and of cooking properties. Addition of alkaline salts, dehulling and using other chemicals assist in reducing the long cooking time (Smartt, 1976).

Lowland pulses reasonably satisfy the amino acid requirements for nutritionally adequate protein. Their protein content is twice as much as cereals. They are rich in lysine and tryptophan and can compensate the deficiency of these amino acids and they help to prevent anemia and protein energy malnutrition (PEM) diseases (Grasspeck et al., 1982).

Grass pea (*Lathyrus sativus*) is generally characterized by a relatively high content of protein, which is about 22.6% of the total nutrient content (Agren et al., 1968). However, the major restriction of grass pea consumption is a disorder called lathyrism in humans and domestic animals, which is caused by toxic constituent, β-N-oxalyl-L-α β-diaminopropionic acid (ODAP). The toxic effects become apparent during prolonged consumption. According to the study by Tekle-Haimanot et al. (1993) the disease affects the northwestern and central highland areas of the country, where the prevalence rate was reported to range from 1/10,000 to 7.5/10,000. Food legumes require proper processing before consumption so as to improve palatability and remove/reduce certain undesirable constituents present in them. This article attempts to summarize various activities done in Ethiopia in the past 10 years in the area of food science and technology.

UTILIZATION OF HARICOT BEANS

Haricot beans processed and converted into primary products are utilized in various ways after cooking or are processed to make different products at home or in commercial catering establishments. A survey was conducted in six selected haricot bean producing districts: Sidama, Wolaita, Alaba, Adamitulu, Adama, Boset and two boarding institutions (Kuyera and Akaki) (MIARC, 1994). Three hundred sixty households were interviewed in 24 sub-districts in 1992 in order to gather information on different food preparation methods and to identify processing constraints.

The survey results indicated that farmers grew different types of crops such as haricot bean, *tef*, maize, sorghum, potato, sweet potato, yam and taro. The farmers use these commodities for both home consumption and sale. In haricot bean, the white pea bean varieties fetch high price for the export market. The colored varieties are mainly for food consumption and some are sold in the local markets.

From the survey results, it was found that *nifro*, *shiro*, *kik*, soup and blend was as major dishes were prepared locally (MIARC, 1994), the last dish prepared in Wolaita area only. The most common dish in the Rift Valley is *nifro*. Large-seeded beans and different colored beans are preferred for *nifro* preparation. Red Wolaita variety is the most preferred variety in Wolaita area due to its taste and color. Results also indicated that flatulence was associated with haricot bean consumption that resulted when complex of sugars contained in beans were not digested before they reached the lower part of the intestine. These sugars are acted upon by naturally occurring bacteria in the intestine causing the release of gas and diarrhea, which is caused by the toxic manifestations such as hemagglutinins and constipation (MIARC, 1994; Senayit, 1995).

COOKING TIME

The major problem in the utilization of dry beans is their long cooking time, which increases with storage time especially at high temperature and humidity (Burr et al., 1968). Two types of hardness were described by Gloyer (1921). One is sclerema, a condition where the cotyledon portion of the beans does not imbibe water, and the second type is hard-shell or impermeable seed coat. The hard shell character is partly genetic (Lebedeff, 1943).

Cookability as applied to legume seeds is defined as the conditions by which they achieve a degree of tenderness during cooking, acceptable to the consumer. In most countries, legumes are commonly prepared for traditional consumption by soaking for varying periods and then boiling. A characteristic property of nearly all dried legumes is the long cooking time required to attain the required degree of softness and palatability (doneness). Cooking time is affected by the permeability of the seed coat to hot water, by the chemical composition of the cell walls, by the inherent hardness of the cotyledons and by the physical size of the seed, which governs the distance the hot water must penetrate to reach all the cells. Method of cooking also influences cooking time. Soaking of food legumes before cooking reduces cooking time significantly which also saves energy and lowers the cost. Cooking imparts a soft texture, improves palatability, enhances digestibility and also increases the nutritive value by destroying certain antigrowth factors and enzyme inhibitors. The long cooking time needed for softening beans may lower the nutritional value through destruction of vitamins, by the binding of lysine, or by leaching out the water soluble nutrients.

Three classes of beans (white pea beans, different colored beans and large-seeded beans) at three stages of varietal development (Nursery-II, PNVT and NVT) were tested at Melkassa Agricultural Research Center (MIARC) for seed weight, cooking time and interaction between seed weight and cooking time. A total of 147 genotypes were included in the experiment. The results indicated that the length of cooking time ranged between 12 and 35 minutes. The variation was found highest in different colored beans (DCB) in almost all cases indicating the possibilities that existed in variation in cooking time. In white pea beans (WPB) and large-seeded beans (LSB) the range of variation in cooking time was low with lowest variances. However, among the three classes of beans, the WPB, on an average, took shorter time to cook. Variations in cooking time among the three stages of varietal development within each class of beans were statistically non-significant (MIARC, 1994).

The influence of locations and varietal response on cooking time was studied by using 12 varieties at MIARC. These varieties covered a wide spectrum of seed types, size and color, i.e., LSB, DCB and WPB. Seed dimensions, 100-seed weight, % of non-soakers and cooking time were observed. The results indicated that the mean value of seed thickness, breadth, length, weight and % non-soakers of 12 varieties grown at four locations were 4.84-5.16 mm; 6.23-6.40 mm; 9.89-10.28 mm; 22.23-25.65 g and 2.5-7.5%, respectively (CIAT African Workshop Series No. 28). The physical characteristics such as seed length, breadth, thickness and weight showed significant differences among varieties and across locations. These variations might be attributed due to genetic and environmental effects.

Common beans grown at a high Ca^{++} site had long cooking time (Paredes-Lapez et al., 1989). In the absence of soil nutrient data, it is not possible to make such conclusive statements for the observations made in the present study. Among locations, the shortest cooking time was observed at Nazareth where the soil pH was high. The soil pH at Awassa, Bako, Jima and Nazareth was 6, 5.7, 5.2, and 7.6 with a soil texture of sandy, clay, sandy clay and sandy clay, respectively. The mean cooking time was 14.99-24. 50 min. Varietal differences in cooking time were also reported by others (Durigan et al., 1978; Morris et al., 1950. Sefa-Dedeh et al. (1979), studying the storage of beans, concluded that the inherent susceptibility of the starch granules and protein matrix to soften may play an important role in the degree of softening during cooking. According to Senayit (1993) data on the physical parameters appeared to indicate that the variations in the seed dimensions and weights were among varieties than across locations. Correlation of these parameters with cooking time did not show a consistent trend. Studies elsewhere demonstrated an association between cooking time and seed thickness in beans but the seed length, breadth, weight and density are unrelated to water absorption and cooking time (Phirke et al., 1982; Desphande et al., 1985). Nevertheless, they found seed thickness to be linearly related to cooking time of beans.

NUTRITIONAL COMPOSITION OF HARICOT BEAN AND COWPEA

Food legumes enjoy the distinction of being protein rich foods and form an important constituent of the diet of people living in poor countries. In addition, they contain soluble carbohydrates, and are low in crude fiber when dehulled. They also contain good amounts of vitamins and adequate level of minerals. The proteins of most beans are not complete because some of the amino acids are not provided in high quantities to provide the body with what is needed. When beans are eaten alone the body is in short of amino acids and cannot function properly. Fortunately, beans are usually eaten with cereals and their food products. Combination of protein units helps to provide higher amounts of protein and increases the quality of the protein mixture in the meal.

Anti-nutritional factors or anti-nutrients are substances found in most dryland pulses that are poisonous or in some way limit the nutrients available to the body. According to Abraham (1981) toasting at 210 ^{0}C for five minutes reduced the trypsin inhibitor content of haricot bean (Table 1) and improved the essential amino acid composition and amino acid score (Table 2).

Table 1. Trypsin inhibitor content of haricot beans as affected by toasting*.

No	Temperature(^{0}C)	Trypsin inhibitor concentration (g/kg)
1	Not toasted	12.81
2	150	1.77
3	210	0.79

*Samples were toasted for 5 minutes. Source: Journal of Food Biochemistry (1981).

Lowland pulses are reasonably adequate to the amino acid requirements. It is exceptionally rich in lysine and can compensate for the deficiency of lysine in animal proteins.

Utilization of more lowland pulses for human consumption should be a nutritional advantage as it helps to prevent anemia and protein energy malnutrition (PEM) diseases (Graspeck et al., 1982). In order to determine proximate analysis and to select the best varieties by comparing their nutrient composition 15 haricot bean and three cowpea varieties were studied by the MIARC in collaboration with the Quality and Standard Authority of Ethiopia (QSAE). There were significance differences in chemical composition of haricot bean and cowpea varieties tested (Table 3). Generally, cowpea varieties had better crude protein than haricot bean varieties. Haricot bean varieties Gofta, Ayenew, Melke, Beshbesh and Red Wolaita had higher zinc and energy value content than other haricot bean varieties (Table 4). The WPB (navy bean) types are high in crude protein but low in Zn content (1.52-1.79 mg/100g.) compared to the colored, food type beans.

Table 2. Essential amino acid composition and amino acid score of haricot beans in Faffa.

No.	Amino acid	Amino acid content (mg/g)		Amino acid score	
		Not toasted	Toasted	Not toasted	Toasted
1	Threonine	32.5	33.8	81.3	84.5
2	Valine	46.4	53.7	92.8	107.4
3	Leucine	75.3	76.4	107.6	109.4
4	Isoleucine	40.7	43.8	101.8	109.5
5	Phenylalanine + Tyrosine	116.0	98.5	193.3	164.2
6	Methionine + Cystine	20.6	22.4	58.8	64.0
7	Lysine	53.5	51.0	92.7	99.5

Source: Abraham (1981).

Table 3. Mean values of nutritional composition of different varieties of haricot bean and cowpea, 2001.

S.N.	Variety	Crude protein (% by mass on wet basis)	Crude fat (% by mass on dry basis)	Crude fiber (% by mass on dry basis)	Carbohydrate (% by mass)	Energy value (Kcal/ 100g)
1	Roba-1	20.55	2.44	7.36	54.72	309.36
2	Awash- Melka	17.32	1.67	8.76	55.50	292.44
3	Awash- 1	21.95	1.44	10.13	51.72	294.71
4	Mex-142	22.06	2.62	7.35	56.17	322.46
5	Atendaba	20.40	2.99	6.19	56.60	320.76
6	Ayenew	20.50	2.82	3.41	64.21	348.17
7	Red wolaita	19.37	2.66	3.27	64.70	344.05
8	Beshbesh	20.44	3.02	2.94	64.32	350.14
9	Melke	20.47	2.80	2.75	64.03	347.19
10	Gobe Rasha	17.95	2.81	3.36	64.71	339.75
11	Gofta	20.07	2.80	4.22	64.61	347.77
12	Brown Speckled	19.91	1.38	3.40	61.73	323.55
13	Tabor	19.62	1.28	3.40	63.10	326.63
14	Zebra	20.59	1.73	2.70	60.97	326.57
15	A-197	17.86	1.71	3.70	62.43	320.94
	Cowpea					
16	Black eye bean	23.08	1.67	2.40	59.22	329.43
17	TVU-1977	21.65	3.46	3.21	57.84	334.64
18	WWT	23.18	1.50	3.90	58.29	324.81
	LSD (p=0.05)	0.772	0.6589	0.7549	0.2945	0.8801
	CV (%)	5.23	42.08	24.84	0.13	2.15

Source: MIARC (2001).

Table 4. Mean values of mineral contents in different varieties of haricot bean and cowpea, 2001.

S.N.	Variety	Phosphorus (mg/100g)	Calcium (mg/100g)	Iron (mg/100mg)	Zinc (mg/100g)
1	Roba-1	15.75	90.56	6.34	1.59
2	Awash-Melka	12.49	154.03	7.13	1.52
3	Awash-1	16.58	163.17	6.96	1.72
4	Mex-142	16.44	165.41	6.43	1.79
5	Atendaba	20.33	198.05	7.40	1.35
6	Ayenew	17.22	116.73	8.32	2.38
7	Red wolaita	16.50	126.69	8.41	2.82
8	Beshbesh	16.14	112.66	6.27	2.80
9	Melke	25.55	108.85	6.35	2.90
10	Gobe Rasha	17.40	133.10	7.93	2.39
11	Gofta	16.79	167.85	6.21	2.76
12	Brown Speckled	15.77	132.08	5.14	1.55
13	Tabor	14.73	220.61	6.18	1.54
14	Zebra	15.18	90.66	5.40	1.52
15	A-197	15.28	179.57	6.43	1.34
	Cowpea				
16	Black eye bean	16.18	65.72	5.28	1.68
17	TVU-1977	7.81	66.45	6.38	2.05
18	WWT	14.26	64.21	5.26	1.77
	LSD (P=0.05)	0.32	0.92	0.73	0.62
	CV (%)	2.92	1.04	16.57	46.15

Source: MIARC (2001).

PROXIMATE ANALYSIS AND RECIPES FROM ROBA-1 BEAN

Depending on the survey of utilization and proximate analysis, haricot bean recipes were developed, promoted and popularized from var. Roba-1 for consumption as *nifro*, soup, *shiro*, *kik* and *samosa* at MIARC. The basic reasons for the acceptance of var. Roba-1 than others are its food making quality and taste. It also has small seed size and cream color, and is an intermediate bush-type haricot bean.

Studies were conducted on the nutritional evaluation of Roba-1 at MIARC in collaboration with QSAE. Results showed that the variety contained 20.55% crude protein, 2.44% crude fat, 54.72% total carbohydrates, 7.36% crude fiber and other minerals (Zn, 1.59 mg/100g; P, 15.75 mg/100g; Ca, 90.56mg/100g; and Fe, 6.34mg/100g). Test results showed that Roba-1 had 12957 J/g of food energy value (MIARC, 2001). The advantages of Roba-1 are: (i) it can be used for different food recipes, (ii) it has short cooking time (16 min), (iii) it has good taste and less pronounced bean flavor, (iv) it has reduced flatulence factors during different food processing methods, (v) it has relatively high protein content (vi) it has low fuel/ energy consumption during food preparation, and (vii) it can generate income at house hold level.

TRADITIONAL PROCESSING OF COOL SEASON FOOD LEGUMES

Pulses are consumed in different forms of dishes: breakfast, main and occasional snacks, and as weaning foods (Maaza, 1993). Traditionally, people process pulses in different ways for *shiro* and *kik* preparations. This might be because of the lack of appropriate methods to follow, and the available methods are drudgery and time and fuel intensive. To solve this problem, an experiment was conducted at Holetta Agricultural Research Center (HARC) to compare the traditional preparation methods that can minimize labor, fuel and grain losses (Maaza, 1993).

Faba bean, field pea and chickpea seeds were subjected to different processing methods as pretreatments for *kik* making. This included: (i) soaking overnight before roasting, (ii) boiling for 5, 5 and 10 minutes, respectively, before roasting, and (iii) direct roasting for 4, 5 and 7 minutes, respectively. Thereafter, the seeds were milled and then separated from the husk by winnowing. Three handfuls of *kik* for each pretreatment set were taken and the parameters fully dehulled and splitted, undehulled but splitted and broken. The raw-roasted beans and peas gave low *kik* yield of 63% being hard to split, and some of the seeds were undehulled and many more were unsplitted. On the other hand, the seed loss was very high in seeds roasted after soaking. These seeds were soft and difficult to split into equal halves, instead they turned into powder. As a result, the *kik* yield was only 54%. The boiled and then roasted seed splitted in equal halves gave better yield of 78% *kik*. Therefore, 5, 5 and 10 minutes boiling before roasting for faba bean, field pea and chickpea, respectively, was a better method for *shiro* and *kik* making and can be recommended for users and farmers. Moreover, the organoleptic assessment of the prepared *wot* from direct boiled and soaked-roasted beans showed that panelists first preferred boiled-roasted followed by direct-roasted and soaked-roasted (Table 5) (Maaaza, 1993). Preparation methods for important traditional dishes are given in Appendix 1.

Table 5. Test conducted on the pulses mixture *Shiro wot*

Preparation method	% yield	Evaluation score	General acceptance
Raw-roasted	63%	3P, 6F, 6 G, 5 VG	Very Good
Soaked-roasted	54%	2P, 5F, 9G, 4VG	Acceptable
Boiled-roasted	78%	-- 2F, 5G, 9VG, 4EX	Excellent

P = Poor; F = Fair; G = Good; V.G = Very good; EX = Excellent.

ASSESSMENT OF THE NUTRITIONAL VALUES AND ODAP CONTENT OF TRADITIONAL FOODS FROM GRASS PEA

Grass pea is one of the pulses commonly grown in Gojam, Shoa, Gonder, Tigrai, Wello and Arsi. Of these, Gojam is by far the leading producer of this legume in the country (CSA, 1987). More than 70% of the total production is produced in Gojam, Shoa, and Gonder administrative regions (Negere and Wolde Mariam, 1994). A considerable portion of the population in these areas depend on this pulse for their protein source, especially when all other crops fail due to drought, since it grows under adverse agricultural conditions such as moisture stress and water logging.

Surveys on the traditional processing method were conducted in two high producing localities in Gojam-Bechena and Gonder-Woreta, where the grass pea consumption and the incidence of lathyrism were reported to be high. The survey mainly concentrated on the utilization of grass pea and health conditions of the people who consume grass pea as primary source of their diet. The locally prepared 30 grass pea food samples were also collected from the households of these localities.

Processing

Raw samples of grass pea were purchased from the open markets in Addis Ababa (Merkato, Nifas Silk and Kazanchis) for processing and replications of the traditional foods. In the grass pea food replications, samples of *shiro, shiro wot, kik, kik wot, kolo* and *nifro* were prepared and analyzed for proximate nutrient compositions and ODAP contents. In processing *shiro, kik, kolo* and *nifro* the procedures consisted of soaking the whole seed for about 24 hrs with subsequent discarding and changing of water. The drained seeds were then sun-dried to lower the moisture content. On the other hand, the same processes were repeated but with slight changes in one of the steps such as roasting and slight boiling and removal of the boiling water with the whole seed or after the seed coat had been removed.

Chemical analysis (Proximate composition)

Moisture, protein, fat, ash and crude fiber were determined according to the standard method of AACC (1976). Carbohydrate was calculated by difference, and energy was calculated by multiplying protein, carbohydrate and fat by factors of 4, 4 and 9, respectively (Table 6).

ODAP Content

The ODAP content of the fresh and processed samples of the grass pea was determined according to the method described by Rao (1978). According to the survey, the ODAP (mg/100g) content of these traditional foods from Gojam ranged from 503.7mg/100g (raw) to 337.7 (*shiro* flour), and 443.2 (*kik*). In the case of Gonder, it ranged from 480.9mg/100g (raw) to 227.8 (*shiro* flour), and 221.7 (*kik*). These traditional recipes were replicated and modified to maintain their nutritional value to the maximum. The processing technique involved soaking and frequent removal of soaking water, boiling and discarding of the boiling water, drying, dehulling, roasting, etc.

Table 6. The nutrient composition and ODAP content of raw and processed grass pea.

No.	Product	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Fiber (%)	CHO (%)	Calories	ODAP (mg/100)
1	Whole (Raw)	10.2	0.9	28.8	2.3	1.9	59.3	346.9	779.4
2	*Shiro* (flour)	5.8	1.3	31.3	3.6	2.1	58.0	360.5	412.4
3	*Shiro* (wot)	72.9	3.5	5.9	1.4	1.6	16.3	113.9	71.5
4	*Kik*	9.1	1.1	27.6	1.8	1.4	60.4	356.3	447.6
5	Kik (*wot*)	58.6	3.5	9.5	4.5	1.7	23.9	158.3	275.4
6	*Qolo*	27.1	0.7	22.6	2.3	5.1	47.3	265.5	312.6
7	*Nifro*	61.9	0.4	11.9	0.8	3.7	25.5	136.4	201.8

Source: Ethiopian Health and Nutrition Research Institute, Food Science and Dietetics Team Laboratory.

The average ODAP content of raw grass pea from Addis Ababa markets (779.4 mg/100g) was reduced to 412.4 in *shiro* flour. The corresponding scores for *kik*, *kolo* and *nifro* were 447.6, 312.6 and 201.8 mg/100g, respectively (Table 6). The ODAP concentrations in raw whole grass pea from Addis Ababa markets (779.4 mg/100g) were found very high compared to the samples procured from Gojam (503.7mg/100g) and Gonder (480.9mg/100g) (Table 6). Nevertheless, the exact sources of the samples collected from the Addis Ababa market are not known. This calls for further investigations in future. It is evident that the proximate composition of nutrients does not show major variation. These results demonstrate that subsequent and appropriate processing substantially reduces the ODAP content.

FUTURE RESEARCH DIRECTIONS

The future directions will involve the following;

1. Development of legumes with reduced cooking time and anti-nutritional factors through breeding and/or new processing methods.
2. Analysis on the protein quality (amino acids) of bean/pea varieties.
3. Selected varieties that have highest nutritional composition must be studied for their food making quality.
4. The bioavailability of food legumes for indication of dietary recommendation must be analyzed.

REFERENCES

AACC. 1976. Approved methods. American Association of Cereal Chemists (AACC).

Abraham Besrat. 1981. Protein quality of Faffa, the Ethiopian infant formulas affected by pulse substitutions. *J. Food Biochemistry* 2 : 233-238.

Agren, G., and R. Gibson. 1968. Food composition table for use in Ethiopia, I ENI, Addis Ababa, Ethiopia.

Burr, H.K., S. Kon, and H.J. Morris. 1968. Cooking rates of dry beans as influenced by moisture content, temperature and time of storage. *J. Food Science and Tech* 22: 336-368.

CSA.1987. Time series data on area, production and yield of major crops. Statistical Bulletin No. 56 Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Desphande, S.S., S.K. Sathe, and D.K. Salunkhe. 1985. Dry beans of Phaseolus: A review. Part 3, Proc. CRC Crit. Rev. *Food Science and Nutrition* 21: 137-195.

Durigan, J.F., R.R.S. Faleiros, and A. Lam-Sanches. 1978. Determination of the technological and nutritional characteristics of several Brazilian bean varieties. 1. Technological characteristics. *Cientifica* 6: 215-223.

Gloyer, W.O. 1921. Sclerema and hard shell: two types of hardness of the bean. *Proc. Assoc. Official Seed Analysts* 13-160.

Grasspeck, R., J. Mjuri, I. Kovanen, and R. Thohunen. 1982. Spectral and other studies on the intestinal chemoreceptor of the pig. *Biochem. Biophys. Acta* 700: 137.

Kordylas, J.M. 1990. Processing and preservation of tropical and subtropical foods. Hong Kong. 375 pp.

Lebedeff, G. A. 1943. Heredity and environment in the production of hard seed in common beans (Phaseolus vulgaris). Agri. Exp. sta. Rio Piedros, P-R. Res. Bull 4.

Maaza Kerssie. 1993. Survey on pulse dishes in selected areas of Addis Ababa, Minjar and Ada. Paper presented at the Regional Coordination Meeting of Cool Season Food Legumes, 29 Sept-4 Oct 1993, Addis Ababa, Ethiopia.

MIARC.1994. Progress report of food science and post-harvest technology research program. Melkassa Agricultural Research Center (MIARC), Nazareth.

MIARC, 2001. Progress report of food science and post-harvest technology research program. Melkassa Agricultural Research Center (MIARC), Nazareth.

Morris, H. J., R.L.Olson, and R.C. Bean. 1950. Processing quality of varieties and strains of dry beans. *J. Food Technol.* 4: 247-249

Negere, A., and S. Wolde Mariam. 1994. An overview of grass pea (*Lathyrus sativus*) production in Ethiopia, Proc. Second International Lathyrus/Lathyrism Conference in Ethiopia, Addis Ababa.

Paredes-Lapez, O., C. Reyes-Moreno, R. Montes-Rivera, and A. Carabez-Trego. 1989. Hard to cook phenomenon in common beans. Influence of growing location and hardening procedures. *Intern. J. Food Sci. Technol.* 24: 535-547.

Phirke, A.V., J.K. Chavan, S.J. Jadhau, and D.K. Salunkhe. 1982. Physical properties, chemical composition, cookability and solubilization of proteins of dry beans (*Phaseolus vulgaris* L.). *Legume Research* 5: 91-96.

Rao, S.C.N. 1978. Sensitive and specific calorimetric methods for the determination of a-B-diaminopropionic acid and *Lathyrus sativus*. *Neurotoxin and Biochem.* 86:386-395.

Sefa-Dedeh, S., D.W. Stanly, and P.W. Viosey. 1979. Effect of storage time and conditions on the hard-to-cook defect in cowpeas (*Vigna unguiculata*). *J. Food Sci.* 44: 790-796.

Senayit Yetneberk, 1993. Hard-to-cook defects in beans (*Phaseolus vulgaris*): Influence of locations and varieties. p. 32-34. In Proc. Third Multidisciplinary Workshop on Bean Research in Eastern Africa, 19-22 April 1993, Thika, Kenya.

Senayit Yetneberk, 1995. Quality evaluation of lowland crops. p. 259-267. In Progress and Future Direction. Proc. 25th Anniversary of Nazareth Agricultural Research Center: 25 years of Experience in Lowland Crops Research, 20-23 September 1995. Nazareth/Melkassa, Ethiopia.

Smartt, J. 1976. Tropical Pulses. Longman Group Limited. 347 pp.

Tekele-Haimanot, R., Y. Kidane, E. Wuhib, A. Kassina, Y. Endeshas, T. Alemu, and P.S. Spencer.1993. The epidemiology of lathyrism in North and Central Ethiopia. *Ethiopian Medical Journal* 31:15-24.

Appendix 1. Different recipes for different preparations in food legumes

1. *Shiro Wot* (powder-sauce) – Stew:

The following ingredients are required to prepare *shiro wot* for lunch and dinner of five persons:

Ingredient	Quantity
Spiced *shiro*	150 g
Onion	200 g
Oil	100 ml.
Water	1200 ml.
Pepper (spiced and powdered)	50 g
Salt	to taste

Preliminary preparation procedure includes the following:

- Clean the seed by hand for removal of foreign materials
- Blanch for 10 min.
- Dry in sun
- Roast
- Dehull and winnow
- Wash, then dry
- Add spice and grind to powder

This spiced and ground powder called *shiro* should be packed and stored in clean and dry place

Preparation method:

- Peel and chop onion
- Put in vessel and cook till brown
- Add oil and fry for 5-10 min.
- Add pepper and cook for 15 min. by gradually pouring water
- Add the water and allow boiling
- Add the spiced *shiro* and stir frequently
- Cook for 1 hr. in moderate heat
- Eat with *Injera* (a leavened bread made from cereal *tef*) or with bread

Now, pack the spiced *shiro* in plastic bag and seal by candlelight or electric sealer.

2. *Kik Wot* (Split bean seed sauce)

The following are the ingredients required to prepare *kik wot* for five persons:

- Clean seed by hand to remove foreign materials
- Blanch for 10 min.
- Dry in Sun
- Roast
- Dehull (split) and winnow
- Wash, then dry
- Pack in plastic bag or in other packing

Ingredients	Quantity
Split beans	300 g
Chopped onion	200 g
Oil	100 ml.
Pepper	50 g
Water	550 ml
Salt	to taste

Preparation method:

- Wash split beans and boil for 30 min. in a pan
- Fry chopped onions with oil for 10 min. in another pan
- Add pepper to the chopped onion with oil and fry for 15 min.
- Add cooked beans to the sauce and boil for another 10 min.

3. Roba-1 Bean Soup

The following ingredients are required to prepare bean soup from variety Roba-1 for five persons:

Ingredients	Quantity
Beans	500 g
Chopped onion	100 g
Oil	100 ml
Chopped carrots	100 g
Sliced potato	100 g
Chopped tomato	200 g
Chopped garlic	50 g
Chopped pepper	50 g
Butter spiced (Ghee)	10 g
Salt	to taste

Preparation method:

- Boil beans to soft in pan
- Cook onion to brown in the second pan

- Fry onion with oil for 5 min.
- Add carrots into the onion with oil and fry for 10 min.
- Add tomato to the sauce and fry for 5 min. by stirring frequently
- Add potato to the sauce and cook for 10 min.
- Add boiled beans and water to the sauce and boil for 15 min.
- Add garlic, salt, butter and pepper, and homogenize by stirring

4. Bean Samosa

The following ingredients are required to prepare samosa for five persons:

Ingredients	Quantity
Bean (Roba-1)	500g
Wheat flour	500g
Onion (chopped)	150g
Carrot (minced)	200g
Garlic	10g
Green pepper	75g
Vegetable oil	312 ml
Salt	to taste
Spices	8g

Preparation method:

Sauce

- Soak clean beans overnight
- Discard water
- Cook to soft texture
- Fry the onion and garlic in oil
- Add carrot and continue frying for about 5 min.
- Add salt and spices
- Add the cooked beans and uniformly (ready for staffing).

Dough

- Prepare wheat flour dough (without starter culture)
- The dough is flattened on a wooden board using roller.
- Place it on a hot *"mitad"* (clay griddle) for 1min.
- Wrap it in polyethylene sheet to avoid drying.
- Roll the sheeted dough
- Cut the roll into pieces
- Wrap the pieces into a triangular shape and stuff the mixes.
- Deep fry it on frying pan

Generic Problems of Cool Season Pulse Crops Technology Transfer and Associated Attempts of Solutions

Elias Zerfu

AMAREW Project, P.O. Box 061, Bahir Dar, Ethiopia

ABSTRACT

The extension system or otherwise called the technology transfer in Ethiopia in the last 30-40 years was guided by the governing principles that varieties and practices that are developed by research centers will be passed onto farmers, which then be incorporated into their farming systems and thereby improve their productivity or output. As a result, most emphasis was given to develop varieties and technologies that could give better yields compared to what farmers are getting presently. Though this may have helped to develop number of varieties and associated technologies, most development workers including researchers agree that the intended change through cool-season pulse crops is far from being fulfilled. Because, in most cases technologies are less amenable to spontaneous diffusion due to their complexity, cost requirement for a specialized knowledge, inputs, or concurrent institutional or policy change (at local or wider level). The Problem may be related to the supply- or demand-side of technology transfer, which most of the times is over-looked. This article seeks to look into the demand-side, which is considered as the generic problems of pulse crops technology transfer. These relate to perceived ability to mobilize resources, perceived availability of skill and competence, perceived ability to control or accommodate risk, and perceived validity of the evaluative frame. Though most of these problems are unique to pulse crops, they are also shared by other crops. This article attempts to review the efforts made to tackle these problems. In this regard, activities related to diffusion of improved seeds through high school students conducted by Adet Agricultural Research Center, the vertical linkage experience with flour mills from Debre Zeit Agricultural Research Center (DZARC), promotion of sustainable community-based seed production by Agri-Service Ethiopia (ASE) the national extension intervention program and FFS (Farmers Field School) to transfer potato IDM are mentioned. Furthermore, the effort made to narrow the yield variation between farmers' and farming conditions, through Farmers' Research Groups (FRGs) and Food Legume Groups (FLGs) by DZARC is presented. Finally, some suggestions on how these could be integrated and scaled-up are presented.

INTRODUCTION

Ethiopian agriculture is facing a paramount challenge of feeding a population as big as 65 million, which is alarmingly increasing yearly by about 3%. Thus, projections indicate that the population will be 94 million by 2010 and 140 million by 2025 (Jones, 1990). It means that the production, in actual terms, should increase from the presently produced by two- to three-fold. This is to, at least, redeem people requiring emergency food aid and who have continuously been increasing since 1980/81 (Mulat, 2003), which in 2002/2003 rose to 14.5 million or over 20 % of the total population. The challenge is becoming more and more complex as result of the soil fertility decline, land degradation and associated yield decreases. Various attempts were made at different levels; most of them dealing with the best utilization of technology. The discussion in this article also revolves around technology and most specifically transfer of technology. This is partly based on the premise that the challenges of agriculture can only be tackled if the sector develops and uses -in timely fashion –better adapted knowledge information of various kinds (e.g. on localized agro-ecological processes, market development, risk market etc.) (Leeuwis and Van den Ban, unpublished).

Down the centuries and across the globe, technologies have been developed by some innovative farmers somewhere and taken from place to place which led to radical changes in the farming sector and agricultural economics of other countries (Garforth and Harford, 1995). However, the challenges that agriculture faces presently to fulfil the ever-growing demand for food, feed and fodder reliably and continuously has necessitated as Roling (1997) would like to call it a complimentary working Agricultural Knowledge Information System (AKIS). The AKIS includes knowledge generation, technology development, networking, dissemination, knowledge utilization, and decision making, etc. In other words, it deals with the elements for a well functioning agriculture production to utilization chain, which are essentials and accelerators of rural development. Technology dissemination is more frequently taken as synonymous to transfer of technology (TT) (Garforth and Harford, 1995; Roling, 1997) and is considered as one of the important functions of AKIS. Though TT activity is performed by most of the AKIS (Research organizations conduct TT; farmers involve in farmer-to-farmer extension; input agencies also perform TT, etc.) it is customary to associate TT with extension. This is partly based on the assumption that interventions that can be classified as TT are the main functions of extension. However, it may be misleading to totally equate extension with TT because in addition to TT, extension performs the functions of mobilizing farmers to help them organize themselves, and educates them to build their capacity at the local level. Hence, the part of activity performed as TT refers knowledge and information transfers without including input transfer. The extension practice, which can be termed as TT, can take many forms not only in terms of the methods and techniques that are being used, but also with regard to its wider intervention purposes, which again relate closely to the assumed nature of the problematic situation. If we try to look at the intervention purpose of TT in Ethiopia, the predominant governing principle in pulses, TT is mainly geared towards 'Farm Management Extension'. This assumes that the problematic situation is 'lack of adequate technology' or 'an individual farm management problem'. Thus, the response was development of new varieties. Furthermore, these new varieties and practices would pass on to the farmers and would be incorporated into their farming systems, and would ultimately improve their productivity or output.

Though, occasionally outputs from research are simple, cheap, versatile and easily understood (Pound, 2001), in most cases technologies are less amenable to spontaneous diffusion due to their complexity, cost requirement for a specialized knowledge, inputs, or concurrent institutional or policy change (at local or wider level). This calls for a thorough understanding of how farmers, the ultimate targets of the TT, make their decision to benefit from the TT interventions. Leeuwis and Van den Ban (unpublished) have derived a model to explain what farmers should or should not do (Fig. 1) . The model includes perceived social relations and pressure, perceived effectiveness of the social environment, perceived effectiveness of agro-support network and perceived effectiveness of inter-communication organization, and perceived self-efficacy and evaluative frame of reference. The last variable is a consequence of the former three variables or their outcome. Furthermore, if the former three of these variables are further classified in relation to the client influence on them, the first two can be considered as existing outside the farmer/client (can be termed as the supply-side), and the third one within the farmer/client (can be termed as the demand-side). All variables have a bearing in improving TT of pulses, however, this article intends to dwell on the perceived self-efficacy or farmer/client or demand-side, which is considered as generic or as given, at least in the short-run in the existing conditions in the country.

There are a couple of good reasons for selecting the demand-side for this article. First, they are over-looked by most people when discussing the problems of transfer of technology. Most authors have dealt more on the supply-side and mentioned problems like, extension agent to farmer ratio, poor linkage between research and extension, choice of extension approaches and methods, follow-up and technical support, relevance of technology packages, magnitude of task, dependency on wider policy and other agency functions, fiscal sustainability, etc. (Feder et al, 1999; Tesfaye, 1997; Elias and Agajie, 2001). In support of this, a report made by OAU/STRC-SAFGRAD (2000) identified that demand studies were generally an add-on and under-researched area. Second, it is reasonable to think that it would be relevant for a workshop organized by a research organization focusing more on technology development issues to discuss the demand-side because it will have a bearing on technology generation more than the supply-side, which is under the jurisdiction of other entities.

THE GENERIC (DEMAND-SIDE) PROBLEMS OF TECHNOLOGY TRANSFER

The things that need to be considered are the challenges that can be considered as the demand-side or user-environment or to borrow from Leeuwis and Van der Ban (unpublished) the perceived self-efficacy. The perceived self-efficacy comprises perceived ability to mobilize resources, perceived availability of skill and competence, perceived validity of the evaluative frame of reference, and perceived ability to control or accommodate risk.

However, to further help us understand the underlying cause of the perceived self-efficacy it would be relevant to be aware of our dominant user-environment which accounts for more than 85% of the population, and which is characterized by Chambers et al. (1989) as CDR (Complex, diverse and risk-prone) and which are targets of our development interventions. Therefore, in the sections that follow we will try to look at the perceived self–efficacy dimensions, which greatly affect the TT of pulses.

Perceived Ability to Mobilize Resources

Access to means of production: Applying a particular practice usually requires a mixture of resources in terms of land, labor, cash, etc. In Ethiopia, pulses are grown mostly by subsistence farmers under rainfed conditions. When listing the socio-economic constraints faced by these farmers in the process of producing cool season legumes, Hailu et al. (1994) mentioned shortages of arable land, seasonal labor and draft power as some of the problems that hindered cool season legume crop production. Furthermore, they also indicated how pulses would be affected more than other crops due to these problems as they received less priority in terms of land, labor and draft power allocation. The condition is further worsening due to the alarming increase in population. To substantiate this, Mulat (2003) pointed out that farm holdings had become smaller (now averaging less than one ha and fragmented, reducing farmers' ability to practice crop rotation and fallowing. Reduced crop rotation implies less land that can be allocated for pulses. With regards to labor, Hailu et al. (1994) reported that most crops were planted at the same time in most highlands of Ethiopia resulting in overlap of activities requiring labor. Obviously, pulses get less priority compared to *tef* and wheat. As a result, their planting is delayed, remain non-weeded and receive minimum crop management attention, which results in higher yield losses.

Access to information and market

Road infrastructure: Chambers et al. (1989) mentioned that many populations in the developing countries were widely dispersed and hard to reach, the case in Ethiopia being much worse. In 1998/99 the whole country was served by a total of 3,665 km of asphalt, 12,240 km of gravel, and 10,157 km of rural road. As a result, 75 % of farmers are located more than half-day walk from all weather roads (Wolday, 2003). Furthermore, the average road density in Ethiopia is estimated to be 21 km per 1000 km^2 of land or 0.43 km per one thousand of population, which is one of the lowest road densities in Africa.

Ironically, most of the agricultural development activities are now concentrated around roads or accessible areas. For example, more than 70% of NGOs operating in Oromia region are concentrated in Shoa and only 1% in Illu Ababora zone. If we look at the outreach TT activities of most research centers we will not find more than 30-40 *woredas* (districts), which have benefited (EARO Research Directory), and this is because of their inaccessibility to road transport. Also, as a result of this inaccessibility, the affected farmers are dissuaded from producing market-oriented crops, which include pulses. Furthermore, prices of their products are cheaper, when compared to the input prices which are expensive. Both discourage investment in production, and thus pulses are much affected since they are also grown for markets.

***Mass media*:** The usual mass communication methods used for agricultural TT are electronic (TV and radio) and printed materials. Nobody can claim that the Ethiopian farmers have access to these communication innovations. Moreover, the generic problem lies in the illiteracy level, purchasing power and the above-mentioned road inaccessibility. With the existing literacy level of 35.5%, it may be hard to think of using viable printed materials for agricultural TT.

If it is not leading us to the chicken and egg metaphor, based on the author's own knowledge and an earlier study to do inventories of extension publications (Elias, 1993), there is not even a single print medium that targets farmers not withstanding to some of the posters one may find here and there to create awareness about specific agriculture or any other issues.

With regard to radio transmission, the condition is not much different from what was mentioned for the printed medium. The three main local languages[1]; namely, Amharic, Afan Oromo and Tigrigna which have national radio transmission programs, have one program which dwells on agricultural issues. It may be way out of the intention of this article to make content analysis of these activities, but there are good reasons to believe that these activities will not reach the ears of the farmer, as the farmers have very limited number of radio transmitters (11.2%) (CSA, 2001). Above all this, what matters most is farmers' purchasing power. While conducting fieldwork in rural areas, the author of this article asked a farmer whether he listens to the radio. The answer which he got was one that shocked him and made him understand that the farmers' purchasing power had been reduced to its bare minimum. The farmer said 'I don't have the money to buy battery cells for my torch, which I need very badly, let alone for a radio'. The problem is further worsened by the inaccessibility problem mentioned above.

The implication is that farmers will be constrained by lack of market information to make pulse production market-oriented. Furthermore, the possibility of improving pulses production is highly hampered due to lack of awareness and inaccessibility of information about improved practices for production.

***Objectives for growing pulse crops*:** Farmers may consider all sorts of resources that they may mobilize and their consequences. Based on these, they decide what to grow and how. Similarly, a decision to grow pulses and their purpose will follow similar argument. Pulses in Ethiopia are grown for different purposes. Asfaw et al. (1994) cited four main uses of pulses, namely, human food, animal feed, cash source, and soil fertility restoration. Farmers may have one or more of the above objectives when deciding to plant any specific pulse in a certain year including the method of its cultivation. This has a bearing on the kind of practices he/she would follow in pulse production. Though it was not be possible to produce empirical result that could be cited here, from the information the author could gather during informal discussions with farmers it was learned that pulse crops when planted with an intention of soil amelioration received less attention and received less agricultural inputs and management. On the other hand, when planted as source of cash, due consideration was given in selection of variety e.g. large-seeded faba bean, white-seeded field pea, etc. (Hailu et al. (1994) and its uniformity e.g. mixed faba bean and field pea fetch lower prices in the local markets compared to the sole field pea.

Perceived Availability of Skill and Competence

As a result of the 35.5% literacy level the skill and competence of farmers is very much limited. This is highly relevant to pulses because they need skill and competence in commercializing the crop and value-adding. However, there is hardly any skill training being given to farmers by the government extension system, except some sporadic attempts made by some NGOs. Most training activities are given on production-related issues using demonstration as a dominant training method.

Variation or Diversity between Farmers and Farming Conditions

As we tried to observe in the model, a large variety of cultures, technical, economic, and relational aspirations and preferences may play a role in individual farmer's practice. Typically, such aspirations may vary across individuals and households. Surveys made to record farmers' practice in different areas have revealed that relevant differences in this respect existed even among farmers

[1] Though Afarigna also has national radio transmission, it is not having any program for agriculture.

of different regions (Table 1), and among farmers in the same region (Table 2).

As a result of this diversity between farmers and the associated practice differences between different regions and farmers in the same region yield of same varieties differed very significantly. For example, similar varieties of field pea planted in the same woreda in Wolmera but in different farmers' fields showed that yield differences range from -3 to almost 100 % (Table 3). A similar trend was observed between the different places. This may not be unique to pulses but the problem is very much prominent in them, and may be attributed to the difference in value given to different uses of the crops in different areas by different farmers. This is somehow unique to pulses.

Table 1. Summary of agronomic practices followed by different pulses in different areas.

Crop	No. of plowings	Seed bed	Seed rate (kg/ha)	Fertilizer rate(kg/ha)
Faba bean	0 – 4	Flat, Ridge and Furrow, BBF	60 - 200	0 – 100
Field pea	0 – 4	Flat	60 -132	-
Chickpea	1 – 4	Flat, BBF	28 - 97	0 - 40
Lentil	2 – 3	Flat, BBF	-	0 - 40

Source: Hailu Beyene et al. (1994).

Table 2. Variation in production practices followed in faba bean production around Holleta.

Production practice	Variability level	Percentage of practicing farmers
Crop mixture	Pure	28
	Faba bean x field pea mixture	72
Soil fertility status	Fertile	55
	Moderate	27
	Poor	18
Plowing frequency	1x	36
	2x	57
	3x	7
Fertilizer	No-fertilizer	89
	Fertilized	11
Weed control	No-weeding	44
	Weeded	56
Yield	Range (q ha^{-1})	2.6-30.2
	Average (q ha^{-1})	12.8

Source: HRC (2003).

Table 3. Grain yield results of field pea (Wolmera, Milki, Adi and Holetta varieties with their recommended practices) demonstrations in western and northern Shoa, 2001.

Farmers' code	Improved varieties used for Improved method	Woreda	Yield (q/ha)		Percent Increase
			Farmers' method	Improved method	
1	Wolmera	Degem	6.25	3.4	-45.60
2	Wolmera	Degem	3.3	5.8	75.76
3	Wolmera	Wolmera	16.3	15.0	-7.98
4	Wolmera	Wolmera	6.3	12.5	98.41
5	Wolmera	Wolmera	12.1	23.8	96.69
	Woreda mean		11.6	17.1	47.84
	Wolmera variety mean		8.2	10.9	32.79
6	Milki	Degem	10.8	22.9	112.04
7	Milki	Degem	3.7	3.3	-10.81
	Milki variety mean		7.3	13.1	80.69
8	Adi	Degem	3.3	8.3	151.52
9	Adi	Degem	1.7	1.7	0.00
10	Adi	Wolmera	14.6	17.5	19.86
11	Adi	Wolmera	11.7	24.6	110.26
12	Adi	Wolmera	16.7	20.4	22.16
	Woreda mean		14.3	20.8	45.35
	Adi variety mean		12.0	17.7	47.63
13	Holetta	Wolmera	12.9	15.8	22.48
14	Holetta	Wolmera	10.2	5.4	-47.06
15	Holetta	Wolmera	5.0	17.9	258.00
	Woreda mean		9.4	13.0	39.15

Source: HRC (2003).

EXPERIENCES IN OVERCOMING GENERIC PROBLEMS

Different efforts to directly or indirectly tackle the generic problems of technology transfer in pulse crops have been tried by government as well as NGOs in the country. The objectives set in their project documents may not exactly match to the generic problems discussed in the aforementioned sections, however, their ultimate goals are directed towards bringing positive change in one or more of these problems. The cases selected in this article are assumed to represent initiatives taken by different organizations to tackle the generic problems mentioned above. Thus, the intension was not to document all TT of pulses activities in the country.

Case I. Seed Multiplication and Diffusion of Varieties of Food Legumes through High School Students

Adet Agricultural Research Center (AdARC), which is located in northern part of the country, initiated an activity on TT of pulses with high school students. The assumptions and activities of the work were:

1. Due to resource limitation and inaccessibility of most of the districts, the effects of the usual/traditional type of demonstrations were limited in scope. Furthermore, level of education of the farmers had a significant effect in technology adoption.
2. Contrarily, there were quite a good number of high schools, at least, one in the majority of the districts, and most of their pupils originated from inaccessible rural areas. Taking this potential as an advantage, the center utilized these high school students to multiply and diffuse seeds of varieties of pulse crops to inaccessible and illiterate communities of western Gojam, eastern Gojam, southern Gondar and northern Gondar zones in 2002.
3. Six high schools representing six potential growing districts were selected, and 20-30 students were identified from each high school with the participation of biology/agriculture teachers of each high school. Two kg seed each of the improved varieties of each pulse crop were given for each student after one-day orientation on the production techniques and overall objectives of the work
4. Following this, students demonstrated and exchanged varieties of pulse crops to farmers, which were given to them from the Center.
5. Farmers requesting seed exchange at a given demonstration numbered 10-30.
6. On an average, a student exchanged about 5 kg seeds of a variety for a farmer for a –total of 10 farmers. The exchange ratio depended on agreement, mostly 1:2 with *tef*, wheat, local field pea or barley or seeds were sold at a price of 50% more than the market price.
7. The seeds returned were treated with chemical seed dressers and supplied for new grade IX students in each high school to establish a revolving seed system.
8. Evaluations of the demonstrations were carried out at different stages with the participation of farmers, students and development agents. Then students gave seminars at their high schools regarding their observations and reflections. (Wuletaw et al., 2002).

Looking at the activities conducted in this TT effort it could be said without doubt that the approach helped to tackle some of the demand-side problems. As a result of the improved seed availability, pulses got better priority in getting land and inputs. Furthermore, the effort also helped information dissemination to inaccessible rural communities. However, most of the effort was limited to increasing production, which was facilitated by direct contact between researchers and farmers.

Case II. Promoting Sustainable Community-based Seed Production

To tackle the problem of seed availability, organization, access to technology and inputs Agri-Service Ethiopia (ASE), a local NGO, initiated farmer participatory seed multiplication and diffusion through farmers' participatory organizations. The assumptions and activities of the work were:

1. Adopted a strategy that included selection of participants in seed multiplication program.
2. Conducted skill enhancement training, on-farm adaptation and demonstration trials.
3. Provision of seeds of adaptable, high yielding, pest- and disease-resistant varieties in collaboration with research centers and other seed suppliers. For all the problems, feed-back was requested on research areas and the technologies, especially performance of the improved crop varieties against the local ones.
4. Established Seed Grower Groups (SGGs) and apex committees at *kebele*-level and linked them to agriculture development and cooperative development offices at different levels,
5. Each group developed its own by-laws and received training on management and book keeping,
6. In the process, during the period of 1997-2000 a total of 954 project participants (8.8% females) were selected, organized into SGGs, and received benefit from the project,
7. As a result of this, the groups through their apex committees developed capacity and were able to purchase seeds of their own interest from Sinana Agricultural Research Center (SnARC) by mobilizing their own resources. (Haile et al., 2002).

Since most of the activities are planned and executed with the clients there were better chances of tackling the above-mentioned demand-side problems.

In addition, this TT activity developed a system to make the effort sustainable. This was made possible through creation of apex bodies for the SGGs, linking them with line bureaus and offices and offering leadership and group process skill training. However, the effort was limited to the SGG members and marketing and value addition were overlooked.

Case III. Use of Farmers Research Groups/Farmer-Extension Groups (FRGs/FEGs) in Transfer of Technology of Lentil and Chickpea

To form a strong alliance with farmers in the process of making the generation, development and transfer of agricultural technologies more demand-oriented, FRGs/FEGs were established at Debre Zeit Research Center. The assumptions and activities of the work were:

1. In the course of forming the FRGs/FEGs a series of meetings were held with farmers. In the discussions, farmers were allowed to enumerate their production constraints, elaborate upon them, and group them accordingly based entirely on their willingness.
2. A total of 84 farmers, 42 each in lentil and chickpea, participated in the lentil and chickpea production groups, frequent formal and informal meetings and workshops were held to strengthen the link within and between the FRGs/FEGs and researchers, Since there was a problem of marketing for the newly released lentil seeds, farmers were linked to businesses engaged in split-lentil processing mills. (Teklu et al., 2000; Fasil, 2001).

Also, most of the activities were planned and executed with the clients so there was a better chance for tackling the problems. However, the approach had no methodology to benefit farmers other than the group members. As a result, the impact was very much limited. Furthermore, it did not instal a sustainable marketing system.

Case IV. The Extension Intervention Program

Based on the experience of SG-2000 approach the Ethiopian Government adopted the program and launched it in July1995. The program included seed-fertilizer technology with other complementarities as a means to achieve food self-sufficiency. As a result, large-scale campaign with up to 4 million, 0.5 ha plots.

Table 4. Showing planned activities and their execution

Type of package	Plan	Execution	%
Food crops	604032	584343	96.7
Livestock development	32368	21511	66.5
Crops of economic importance	6507	22503	345.8
Post-harvest technology	850	141	16.9
Others	46407	128110	276

Source: MoA (1999). Report on the Package, 1997/98.

Moreover, pulses were not included in the program early in the inception period, and were included at a later stage due to the unavailability of seeds, and emphasis, etc.

With this approach, the greatest advantage was its wider coverage, as a result of which information was disseminated to a large number of farmers throughout the country. It showed that their perceived skills and competence were improved. However, pulses came late in the program and benefited the farmers less. Moreover, similar to earlier TT efforts it overlooked value-addition and markets. In addition, as it was a top down TT campaign and placed less emphasis on the farmers' objectives.

Commonalities of the Case Studies and their Practical Implications

1. Most of the interventions limited themselves on production
   - Calls for production, marketing, value-addition orientation
   - What new knowledge and institutional arrangements are required?
2. Variation or diversity is over-looked
   - Rather than moving for transferring finished products, going for their refinement with farmers may be an alternative.
   - Do targeting groups initiate group pressure for narrowing gap?
   - Should we continue with our mass marketing or go for targeted TT.
3. Objectives of growing pulses not addressed
   - Have we understood them clearly?
   - Can we target all the objectives of farmers?
   - Are the objectives transient, and do they really require focus?
4. Most of the interventions engrossed more on delivering and provided less time to observe, reflect and propose subsequent action(s).
   - What about adopting the action research/development approach?

CONCLUSIONS

1. The sporadic efforts by different organizations have remained unrecognized. Professionals of TT should create a forum to evaluate these activities and design means of scaling-up.
2. Seeking innovative method of mass media use is one that needs to be explored for TT of pulses.
3. If we don't descriptively understand the demand-side or user environment it is hard to develop effective supply-side of TT.
4. This is frequently mentioned but seldom performed.

REFERENCES

Asfaw Tilaye, Geletu Bejiga, and Alem Berhe. 1994. Role of cool-season food legumes and their production constraints in Ethiopian agriculture. p. 3-17. *In* Asfaw Tilaye et al. (Eds.) *Cool Season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR: ICARDA, Aleppo, Syria.

Chambers, R., A. Pacey, and L.A. Thrupp (Eds). 1989. Farmer first: Farmer innovation and agricultural research. Intermediate Publications. Shurt Punn Press.

CSA. 2001. Reprot on the year 2000 welfare monitoring survey. Statistical Bulletin 259. Central Statistical Authority (CSA), Addis Ababa.

Elias Zerfu.1993. Extension publication in transfer of agricultural technology in Ethiopia. M. Sc. Thesis, CCS Haryana Agricultural University, Hissar, India.

Elias Zerfu, and Agajie Tesfaye. 2001. The history, present challenges and future approach to technology transfer in Ethiopia. p. 334-349. *In* Proc. Third International Conference on Public Management, Policy and Development, 3-6 June 2001, Addis Ababa, Ethiopia.

Fasil Kelemework. 2001. Farmer research groups: the experience of Debre Zeit Research Center, p. 104-107. *In* Proc. Second Forum on Farmers' Participatory Research, 29 June-1 July, 2000, FARM Africa, Awassa.

Feder, G., A. Willett, and W. Zijp.1999.Agricultural extension: Generic challenges and some ingredient for solution. Working Paper No: 2129. Washington, DC: World Bank.

Garforth, C., and N. Harford.1995. Issues in agricultural extension. AERDD Working Paper 95/9.

Haile Kefene, Girma Sida, and Asfaw Tulu. 2002. Promoting sustainable community based production: experience of Agri-Service Ethiopia. p. 90-97. *In* Gemechu Keneni et al. (Eds.) *Central Highlands of Ethiopia: Towards Farmers' Participatory Research: Attempts and Achievements*. Proc. Client Oriented Research Evaluation Workshop, 12-18october 2001, Holetta Agriculture Research Center, Holetta, Ethiopia.

Hailu Beyene, Workneh Nigatu, and Shelemew W/Mariam. 1994. Smallholder production practices in Ethiopia. p. 19-30. *In* Asfaw Tilaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR, Aleppo, Syria.

HARC. 2003. Progress report for the period 2001/2002. Holetta Agricultural Research Center (HARC), Holetta.

Jones, H. 1990. Population Geography. Paul Chapman Publishing Ltd, London.

Leeuwis, C., and A. van den Ban. (Unpublished). Communication for innovation in agriculture and rural resource management: Building on the tradition of agricultural extension. Blackwell, Oxford.

MoA. 1999. Report on the package, 1997/1998. Ministry of Agriculture (MoA), Addis Ababa.

Mulat Demeke. 2003. An over view of agricultural production and land resource management in Ethiopia. Paper Presented in FCI Launching Workshop, 14-17 July 2003, Addis Ababa, Ethiopia.

OAU/STRC-SAFGRAD. 2000. Transfer of commercialization of agricultural technologies: Experience in West Africa. Final Report.

Pound, Berry. 2001. The uptake environment. p. 91-103. *In* Proc. Second Forum on Farmers' Participatory Research, 29 June-1 July 2000, FARM Africa, Awassa.

Roling, N. 1997. Extension, whether and whither: An attempt to anticipate and vision. p. 27-45. *In* R.K. Samanta and S.K. Arora (Eds.) *Management of Agricultural Extension in Global Perspective*. B.R. Publishing Corporation, Delhi.

Teklu Tesfaye, Fasil Kelemework, Milion Eshete, Yadeta Anbessa, and Teklu Erkosa. 2000. A client oriented research (COR) approach to technology transfer of an improved lentil production technology. NVRSRP Newsletter. 3&4: p. 31-32.

Tesfaye Beshah. 2003.Understanding farmers: Explaining soil and water conservation in Konso, Wolaita and Wello, Ethiopia. Ph. D. Thesis, Wageningen University, The Netherlands.

Wolday Amha. 2003. Linking agricultural production, processing, marketing and consumption to improve farmers' competence in Ethiopia. Paper presented in FCI Launching Workshop, 14-17 July 2003, Addis Ababa, Ethiopia.

Wuletaw Tadesse, Daniel Tilahun, Adugna Kassie, and Bekele Abiew. 2002. Seed multiplication and diffusion of varieties of food legumes through high school students. *Agritopia* 17: 2-4.

Agricultural Technology Transfer of Highland Food Legumes in Ethiopia

Fasil Kelemework[1] and Kiflu Bedane[2]

[1]Debre Zeit Agricultural Research Center, P.O. BOX 32, Debre Zeit, Ethiopia, [2]Holetta Agricultural Research Center, P.O. Box 2003, Addis Ababa, Ethiopia

ABSTRACT

Food legumes are very important soil ameliorating crops in addition to their usefulness as source of protein and cash to the growers. In spite of the fact that food legumes are second to cereals in terms of acreage and production in Ethiopia, but their production system is still mostly traditional and of low productivity. Although some technological progress has been made through the research system for developing improved varieties and management practices to avert this problem but generation of technology alone has not helped much. For ensuring adoption of technology, it must be complemented with an effective technology transfer system in order for the farmers to benefit from the fruits of research. This article, therefore, reviews the efforts made on the transfer of highland food legume technologies with particular emphasis on faba bean, field pea, chickpea and lentil.

INTRODUCTION

Legumes are the second most important crops in Ethiopia next to cereals, considering their acreage and production as well as their importance in the national diet. In many parts of Ethiopia, legumes are mostly cultivated and used for local consumption as a daily food and considered as important source of protein, especially for the majority of the farming community who cannot afford to purchase animal products. They are boiled, roasted, or included in stew-like dish known as *wot*, which is sometime a main dish or a supplementary food. In addition to food value, they serve as source of cash for smallholder farmers and provide additional benefits such as soil amelioration and pest control, when grown in rotation with cereals. The ability of legumes to fix atmospheric N_2 and thereby add external N to the crop-soil ecosystem and their residual effect on subsequently grown cereals is their distinct benefit. Pulses have also been one of the highest export commodities until 1975 ranking second to coffee but later their export share dramatically declined. The recent statistics show that they account for only about 2% of total exports from Ethiopia (NBE, 2002).

Although food legumes can grow in most parts of the country, they are more prevalent in the highlands of the central, north-western and south-eastern regions. These crops are grown on small area of land, accounting for about 13% of the country's area under crops compared to 80% of cereals. Of the total land under food legumes, faba bean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) take the greatest share of 78% (CSA, 2002) and are thus the dominant food legumes. A number of improved agricultural technologies for food legumes have been demonstrated and popularised on a number of farmers' fields particularly around the mandated areas of the respective agricultural research centres. Technology transfer efforts of food legumes up to 1992 were reviewed and presented at the first National Cool-season Food Legumes Review Conference (Asfaw et al., 1994). This article discusses the extension intervention aspects with regard to highland food legume technologies with particular emphasis on faba bean, field pea, chickpea and lentil after 1993.

TRENDS IN PRODUCTION AND PRODUCTIVITY

The bulk of food legumes production in Ethiopia generally comes from the fields of small farmers where the use of improved varieties and management practice are not largely exercised. Due to this, the obtained average yield of the crops in the farmers' fields remained much below the expected yield potential of the crops (Table 1). The major contributing factors for the low yields of food legumes are the susceptibility of the landraces to an array of disease and insect attacks, and abiotic factors such as drought, hail, frost and water-logging. Consequently, the food legumes production has been unstable and declined in some years due to adverse climatic conditions. For instance, the main season (*meher*) rains were late during 2001/02 and 2002/03, and in many areas stopped earlier than usual, leaving crops without sufficient moisture to prevent them from reaching their full potential as well as in some places causing losses to harvest. There have also been year-to-year variations in terms of area coverage and production. Although more land has been brought under food legumes in the last decade but their productivity has not increased as expected (Fig. 1 and 2).

Recognizing the fact that research and technology development have been the foundation for productivity gains, coordinated food legume research has developed a number of improved pulse crop varieties and agronomic practices since 1960's (Asfaw et al., 1994). However, the generation of technology alone is not a sufficient condition to ensure wider adoption and desired outputs. Thus, the need for forging an effective technology transfer system coupled with improving access of farmers to inputs and credit as well as improving the performance of the market and distribution system in order for the farmers to benefit from the fruits of research and enhance the production and productivity of the food legumes is of paramount importance. To this effect, various government and non- governmental organizations conduct several technology transfer activities.

TECHNOLOGY TRANSFER PROCESS

Currently, the national extension system used Participatory Demonstration and Training Extension System (PADETES) since 1995, to ensure the participation of farmers in the delivery of extension in the country. The system is based on demonstrating and training of farmers on proven technologies in a participatory manner using the demonstration plot approach, which was mainly adopted from Saskawa Global 2000. The extension intervention strategy in this system involves a package approach geared towards three different agro-ecologies (reliable moisture, moisture stress and nomadic pastoralists' areas). As part of implementing the extension strategy, the Ethiopian government also launched a National Extension Implementation Program (NEIP) in 1994/95 crop season. The program was mainly geared towards assisting small-scale farmers to improve their productivity through disseminating research-generated information and technologies on major food crops such as *tef*, maize, wheat, sorghum as well as potato and forage crops (MOA, 1996). The greatest advantage of this approach is its wider coverage and information, which it was able to disseminate to a large number of farmers throughout the country. This lead to improvement of farmer's perceived skills and competence. As a result of this strong extension intervention, actual yields of some crops (particularly maize, wheat, *tef* and sorghum) have been increased. However, the food legumes were not included during the earlier inception period of the national extension package programs. Moreover, though they were included at a later stage, satisfactory results were not documented for major food crops.

In an effort to foster research-extension-farmer linkage and enhance technology transfer and dissemination, Research Extension Divisions (REDs) were established in 1985 under the Agricultural Research Centers. The REDs ensure effective research-extension-farmer linkages and enhance technology dissemination using various mechanisms such as demonstrations, popularization, training, field days, workshops, extension materials, publications, etc. in order to create awareness, evaluate the performance of the improved packages, and collect feedback from participating farmers. In pre-extension demonstration activities, REDs conduct demonstration trials on selected farmers' plots to verify the advantage of the new technologies over the existing ones. The lay out of the demonstrations consisted of two adjacent plots, one planted with the improved technology package and the other with the host farmers' local practices. The area used for demonstrations were 1/8-1/4 of a hectare each for improved and farmers' practices. Farmers, extension agents, researchers and other relevant stakeholders then evaluated performances of the technologies during field evaluation and field days. Yield data were obtained from randomly taken samples of all demonstration plots and analyzed. The demonstration plots were also used to obtain feedback information from host farmers/others by conducting farmers' assessment about the performance of the demonstrated improved technology, which in turn help to incorporate some of the comments for future research improvements as well as refinement of the existing technology.

PERFORMANCE OF HIGHLAND FOOD LEGUMES TECHNOLOGIES

Faba Bean

Based on their adaptation, faba bean varieties have been released either for wide adaptation or for mid-altitude areas. Accordingly, Tesfa and Messay varieties were released for mid-altitude areas, while CS-20DK, Bulago-70 and Degaga for wide adaptation. Mid-altitude varieties were demonstrated in Weliso district and the widely adapted varieties in Ejere, Wolmera and Degem districts by Holetta Agricultural Research Center (HARC). The results of the demonstrations are shown in Table 2. Because of the differences in soil type, weather variation, crop rotation histories and management levels between farmers', the yield variations between farm plots and years have been very high. In general, yield improvement over the local varieties and management has been great although yields lower than the local varieties have been registered in rare cases. Yield improvement as high as 100% have been obtained from CS-20DK. However, variety Bulgo-70 was found to be very sensitive to water-logging situation and therefore may not be advised for planting on Vertisols. Farmers who hosted the demonstrations appreciated the technologies and were willing to continue growing faba bean. However, dissemination has not been very fast because access to the improved seed has been problematic.

CS-20DK was also demonstrated in Goncha Siso Enesse, Enesse Sar Mider, Huletju Enesse, Yilmana Densa and Farta areas by Adet Agricultural Research Center (AdARC). The improved technology showed a higher yield and a better economic return (Table 2).

Field Pea

Five improved field pea varieties were demonstrated around Holetta of which G22763-2C variety is an old recommended variety; and Adi, Milki and Holetta are recent releases. The varieties were demonstrated in Ejere, Welemera and Degem districts. All the improved varieties with their recommended management performed better than the local varieties and management (Table 2). The yield increase due to improved varieties and management ranged from 9 to 77%. Varieties like Adi and Milki were preferred more because of their white seed color and good *kik* making qualities. The performance of the variety Tegegnech was not as good on the lower side of the high-altitudes as it was on the upper side. Thus, it was advised that this variety be grown above 2700 m asl.

Around AdARC, the improved varieties Adet-1 and Sefinesh were demonstrated in Yilmana Densa, Fogera and Huletijju Enesse areas. Although the improved variety out-yielded the local varieties, the participating farmers commented that the seed rate of 150 kg/ha was very high, and suggested that an optimum seed rate should be considered in the future. Around Sinana Agricultural Research Center also an improved variety Mohanderfer was demonstrated in farmer fields in Ginhir and Goro areas. The results showed that the improved variety out yielded the local variety (Table 2).

However, the improved variety, G-22763-2C, was not satisfactory (Table 2).

Chickpea

Chickpea, which is among the most important food legumes in Ethiopia, is classified as either *desi* or Kabuli types. The *desi*-type is characterized by smaller, angular, and pigmented seeds, whereas the Kabuli types are characterized by larger seeds that are more rounded and lack pigmentation. The *desi*-type predominates in the country while the Kabuli types are not common and less wanted in the domestic market. In this regard demonstrations of the *desi*-type chickpea varieties (Mariye and Worku) were conducted. However, the Kabuli-type (var. Shasho and Arerti) were demonstrated through farmer research groups organized near the vicinity of the Debre Zeit Agricultural Research Center (DZARC). The improved varieties were demonstrated along the improved production packages in Ada, Akaki, Gimbichu, Inewari, Minjar and Tulu Bolo areas in different farmers' fields. The results indicated that the improved package out yielded the local practices in most of the cases (Table 2). However, most of the farmers reported that theft of green pods by the passers-by sometimes significantly reduced the expected grain yield.

Lentil

Similar to the chickpea, improved lentil varieties (Chalew, Alemaya and Adaa) were demonstrated on the above-mentioned areas by DZARC. The yield performance of the improved varieties was much better than the local ones (Table 2). Besides, through farmer research groups, it was possible to show farmers how the improved lentil varieties resisted the rust and gave higher yields, while the local variety was completely attacked during 1998/99 and 2000/01 around Chefe Donsa area. As a result, it was possible to produce more than 100,000 kg seed of the improved varieties from 700 kg through farmer-to-farmer seed exchange mechanism. Consequently, the area is now considered as a source of improved lentil varieties at the country level.

In general, the demonstration results revealed that the improved highland food legume varieties out yielded the local varieties in most cases. But the demonstration activities were limited to few research centers and varieties (Table 3). Hence, the majority of the pulse technologies do not reach the end users.

CONSTRAINTS TO FOOD LEGUMES PRODUCTION

Lack of Improved Seeds of Pulse Crops

Although a number of highland food legumes were developed and released by different agricultural research centers and demonstration efforts have shown that the performance of the improved varieties were better than that of the local varieties, only few of them have reached the farmers' hands. In this regard, the most important constraint that is mentioned frequently is unavailability of sufficient seeds of the improved highland food legume varieties to the farmers. As a result, farmers are forced to utilize their local varieties, which are highly susceptible to diseases such as wilt/root-rots, chocolate spot, powdery mildew, rust, Ascochyta blight, and insect-pests (the most important is aphid), etc. The severity of the diseases was very high in some periods of time, and total losses were also reported (Teklu et al. 2000) when there was favorable environment for the disease development.

Inadequate Agronomic Practices

So far, no cost effective recommended herbicide has been available for use on legumes. Farmers do not weed faba bean fields until the grassy weeds are well grown to be harvested for animal feed. Field pea fields are rarely weeded. Though fertilizer responses have been reported for faba bean and field pea, farmers rarely use fertilizers. Farmers also strongly desire determination of appropriate seed rate for some field pea varieties as the case documented by AdARC (AdARC, 2002).

In general, with regard to agronomic practices, the recommended packages have faced lots of problems. On one hand, there were fertilizer application recommendations but in most of the cases farmers were not convinced on their economic return. On the other hand, farmers have different planting dates for legumes at different locations starting from early-June to late-September so that it was difficult to stick with the recommended sowing date. As a result, most of the time the crops were affected by moisture stress especially after the early rain stopped.

Marketing Problems

Most of the time, the farmers knew that legume crops were marketable in foreign countries but they lacked clear marketing information (what legumes to produce, where to sell, and at what price, etc.), and were unable to get access to markets (other than their local markets), which inhibited farmers to be attracted to grow more pulses. In addition, farmers also reported that they needed the pesticide in small amounts/packages (where it is applicable under their conditions) and the right time when they needed it, i.e., when there was high infestation. But, most of the time they could not obtain the chemicals in the required amount and at the right time. Costs of the inputs were also high as well as the farmers also stated that some merchants supplied the wrong pesticides with different formulations. Consequently, productivity and production of legumes were very low at the farmers' fields, and even some had quit growing legumes.

Limited Extension Services

Emphasis of extension activities has so far been on cereal crops whereas less effort was placed on pulses. In places where some extension activities existed, technical extension messages concentrated more on the use of improved varieties with very little emphasis on proper agronomic practices such as appropriate sowing dates, seed rates, weeding, etc. In contrast, following the right agronomic recommendation would enhance the production and productivity of pulses both for improved and local varieties.

Environmental Constraints

The year-to-year climatic variation/fluctuation highly affects production and productivity of pulses in various locations. The adverse environmental conditions discourage the farmers to depend on pulses and these affect the wide adoption of their technologies.

Farmers' Selection for Demonstration Purposes

During field pea technology demonstration efforts, difficulty of finding enough farmers who could grow the field pea varieties in pure stands was encountered as the usual practice was growing faba bean and field pea in mixtures. In this practice, the faba bean plant supports the field pea resulting in reduced disease incidence. Thus, sometimes it was not possible to demonstrate the performance of one improved variety in terms of yield and other factors as compared to the already existing practices/varieties.

CONCLUSIONS AND RECOMMENDATIONS

Demonstration and popularization results have shown that improved varieties with their proper agronomic practices increased yields of highland pulses substantially. However, the yields of pulses have not improved much at the farm level, as several of the technology options are not adopted. It was also repeatedly said that the problem of seed availability had very much slowed the fast dissemination of the technologies. In this regard, the issue of seed availability as a constraint has to be addressed seriously, i.e., the problem of quality seed multiplication and distribution deserves special attention if farmers have to benefit from the already existing technologies.

The less extension emphasis given to pulse crops must not continue the way it exists now but should be taken more seriously. Extension advice should not concentrate on improved varieties alone but also on the use of proper agronomic practices, as management is the most important aspect of production, particularly for pulse crops. In this regard, it was observed that the farmers have not adopted most of the recommended production practices. Hence, farmers have to be continuously advised to follow the practices, and group extension approach has been found to be more successful as has been seen around Wolmera and Chefe Donsa areas.

The marketing aspect should also be given due attention. The low and unstable price of pulses does not encourage farmers to use inputs and the required labor. In this regard, different types of marketing information, particularly for export markets, should be easily available, and private sectors should be encouraged to participate both in exporting pulses as well as processed pulse products. Moreover, researchers have also to devote more efforts to improve the quality of pulse varieties in order to meet the desired grade particularly targeting for the international markets.

Results of a participatory group approach in pulse technology development and transfer were satisfactory (as it was seen in the work of lentil and other farmers' research groups). It is possible to develop appropriate technology on the basis of the client demands and reach as many farmers as possible within shortest possible time, using farmers' research groups wisely. Therefore, such approaches should be continued and strengthened. Further research on agronomic practices is needed to develop specific recommendations on seed rate, fertilizer application and rate, sowing date, etc. for different agro-ecologies in the country.

Availability of the inputs and their timely delivery needs to be increased, and due consideration should be given to the relative prices between the inputs and the prices of pulses in markets.

Intensive training should be given for the subject matter specialists (SMSs), development agents (DAs), farmers and other relevant stakeholders to further disseminate and transfer the pulse technologies.

Table 1. Mean yield potential (t/ha) of major pulse crops in Ethiopia, 1992/93-2000/01.

	Mean yield (t/ha)			
Crop	On-station	On-farm	On demonstration sites	National
Faba bean	3.0-4.50	2.21-3.86	1.61	1.01
Field pea	2.87-3.45	1.7-2.20	1.36	0.73
Lentil	1.7-2.48	1.44-1.82	1.82	0.60
Chickpea	1.69-3.58	1.59-2.71	1.80	0.76

Source: CSA (1997, 1999); EARO and Regional Agricultural Research Centres (1992-2002).

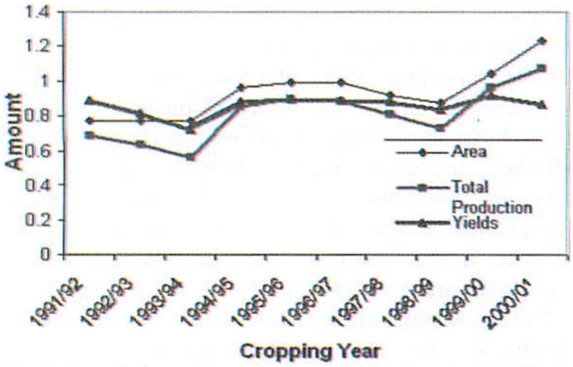


Fig. 1. Area (ha), total production (million t) and yield (t/ha) of pulses. Source: CSA (1995, 1997, 2001).

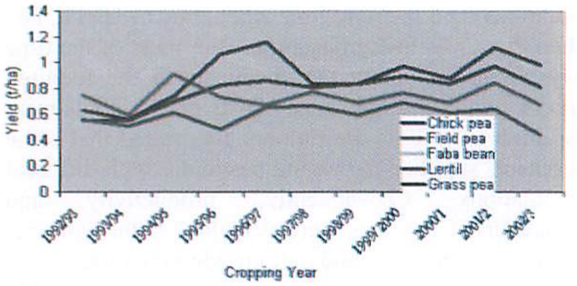


Fig. 2. National average yields (t/ha) of highland food legumes in Ethiopia. Source: CSA (1995, 1997, 2001, 2003).

Table 2. Mean grain yield of faba bean, field pea, chickpea and lentil varieties on pre-extension demonstration sites at different locations around Holetta, Adet, Sinana and Debre Zeit areas.

Crop	Variety	Demonstration site	Mean yield t/ha Improved	Local	Percent yield increment
Faba bean	CS 20DK		1.20	0.94	30
	Bulga 70	*Holletta (from1992-2002)*	1.60	1.42	13
	Tesfa		1.21	1.28	(5)
	Mesay		1.50	1.22	23
	Degaga		1.81	1.42	27
	CS 20DK	*Adet (from 1989-1999)*	2.03	1.07	90
Field pea	G22763-2C		1.50	0.70	114
	Tegegnech	*Holletta (from1992-2002)*	1.65	0.96	73
	Adi		1.82	1.30	40
	Milki		1.79	1.22	47
	Holeta		1.43	1.18	21
	Adet-1	*Adet (from 1989-1999)*			
	Sefinesh		1.56	1.25	25
	G-22763-2C	*Sinana (from 1986-1997)*	0.10	0.80	(88)
	Mohanderfer	*Sinana (from 1986-1997)*	1.90	1.20	58
	G-22763-2C	*Eastern wellega zone (from 1994-1995)*	*1.04*	0.46	126
Chickpea	Mariye		1.24	0.95	30
	Shasho		2.60	1.60	62
	Akaki	Debre Zeit	1.56	0.48	225
	Worku	(from 1989-2002)	2.26	0.48	371
			1.36	0.48	183
Lentil	Chalew		0.82	0.57	45
	Alemaya		2.75	0.70	293
	Ada		1.88	0.70	168

'The values in brackets represent decrease.
Source: HARC (1992-2002); AdARC (2002); SnARC; DZARC (1992-2002); Teklu et al. (2000); Abubeker and Tesfaye (1998).

Table 3. Highland pulse technologies demonstrated in Ethiopia, from 1992-2002.

Technology	Crop: Faba bean	Field pea	Chickpea	Lentil
Plowing	2-3 (LP)*	2-3 (LP)	3-4 (LP)	N/A
Planting time	Mid-June to first week of July	Mid-June to first week of July	End-August to mid-September	End-June to early-August
Seed rate	200-250 kg/ha	150-180 kg/ha	80-140 kg/ha	65-120 kg/ha
Fertilizer rate	100 kg DAP/ha	100 kg DAP/ha	Sometimes 100 kg DAP/ha	Sometimes 100 kg DAP/ha
Weeding	Two hand-weeding (25-30 and 40-45 DAS)**	One hand-weeding (25-30 DAS)	One or two hand- weeding (30-60 DAS)	Two hand- weeding (30-60 DAS)
Varieties	CS-20DK Bulga-70 Tesfa Mesay Degaga	G22763-2C Tegegnech Adi Milki Holetta	Dube Mariye Worku Akakai Arerti Shasho	Chalew Gudo Ada Alemaya

* LP = Local plough. ** DAS = Days after sowing. NA = Data not available.

REFERENCES

AdARC. 2002. Summary of Research Achievements, 1987-2001. Amhara Regional Agricultural Research Institute, Adet Agricultural Rresearch Center (AdARC), Adet, Ethiopia.

Asfaw Telaye, Geletu Bejiga, and Alem Berhe. 1994. Role of cool –season food legumes and their production constraints in Ethiopian agriculture. p. 3-17. *In* Asfaw Telaye et al. (Eds.). *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/Institute of Agricultural Research. ICARDA: Aleppo, Syria.

Abubeker Mussa, and Tesfaye Balemi. 1998. Demonstration and popularization of improved crop varieties to smallholder farmers in eastern Wellega and western Shewa. *In* Beyene Seboka and Aberra Deressa (Eds.) *Agricultural Research and Technology Transfer Attempts and Achievements in western Ethiopia*. Proc. Third Technology Generation, Transfer and Gap Analysis Workshop, 12-14 November 1996, Nekemt, Ethiopia.

CSA. 1997 and 1999. Statistical Abstract. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 2002. Federal Democratic Republic of Ethiopia Central Agricultural Census Commission Ethiopian agricultural sample enumeration, 2001/2002 (1994E). Report on the preliminary results of area, production and yield of temporary crops. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

DZARC. 1992-2002. Annual reports 1992-2002. Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia.

HARC. 1992-2002. Annual reports, 1992-2002. Holetta Agricultural Research Center (HARC), Holetta, Ethiopia.

MOA . 1996. The current extension strategy adopted by Ministry of Agriculture. Agricultural Extension Department, Ministry of Agriculture (MoA), Addis Ababa, Ethiopia.

NBE . 2002. Quarterly Bulletin, Fiscal Year Series, Volume 17, Third Quarter, 2001/02. National Bank of Ethiopia (NBE), Addis Ababa, Ethiopia.

SnARC. 1992-2002 Oromia agricultural research coordination service: A decade of research experience. Bulletin No. 4. Sinana Agricultural Research Center (SnARC).

Teklu Tesfaye, Fasil Kelemework, Million Eshete, Yadeta Anbessa, and Teklu Erkosa. 2000. A client oriented research (COR) approach to the transfer of an improved lentil production technology. NVRSRP Newsletter No. 3 & 4: 31-32.

Review of Technology Transfer of Haricot Bean in Ethiopia

Mathewos Belissa[1], Chimdo Anchala[2], and Aberra Deressa[2]

[1]*Bako Agricultural Research center, P.O. Box 03, Bako, Ethiopia,* [2]*Malkassa Agricultural Research Center, P.O. Box 436, Nazereth, Ethiopia*

ABSTRACT

Haricot bean (*Phaseolus vulgaris* L.) is among the major pulse crops contributing enormous protein that has a great role in complementing cereals and other stable foods in the Ethiopian diet. Besides, the crop can be grown with a minimum cost of production, and is of short maturity that enables the producers to harvest early for family consumption during the period when other crops are not yet harvested. It also has agronomic advantages over other crops in the farming system in that it improves the soil fertility. Despite its versatile use, the amount of household consumption is estimated to be low and the national average yield of the crop is estimated to very low (0.5–0.8 t/ha). This yield gap is attributed to a number of interrelated factors. Among these, the major one is the insufficient supply of improved seeds and inadequate extension services for the crop. However, different extension strategies and approaches were used to help increase the production and productivity of the crop as well as diversify the consumption by the farmers through inculcating haricot bean in their diets. The approaches used included pre-extension demonstrations, training and popularization. Community-based seed production, in-service training for front line extension workers and bean exporters, field days and workshops are the mechanisms for wider popularization of the technology. Thirteen improved haricot bean varieties with their full package of recommendation have been demonstrated by Melkassa, Bako, Awassa, and Jimma Agricultural Research Centers, and Alemaya University. The results obtained over years and across locations demonstrated that the improved haricot bean varieties gave higher mean yield when compared with the local ones. The average yield increment of the improved varieties with their management practices over the local varieties and traditional practices ranged from 74.8-83%, clearly showing better yields over the conventional production system. In general, through the attempts made in the transfer of haricot bean technology, good awareness has been created to most farmers in beans growing areas. Also, production and utilization of haricot beans has been demonstrated with frequent arrangement of field days and by conducting training programs on the same. In addition, community-based seed increases and dissemination activities have helped much in increasing farmers' access to improved seeds of the crop. As a result of the efforts made so far, haricot beans, particularly the white-colored ones (the export type) have become the potential source of income for the growers and private bean exporters in the Central Rift Valley of Ethiopia.

INTRODUCTION

Haricot bean (*Phaseolus vulgaris* L.) is the most important export pulse crop in Ethiopia, and contributes enormous protein that has a great role in complementing cereal-based Ethiopian diet. Besides, the crop has minimum cost of production and is of short maturity (IAR, 1990). Early maturity characteristics of the crop makes it the first food to become available soon after the seasonal 'food gap'. This entails the immediate use of the crop for family consumption during the period when other crops are in the field. In addition, particularly the white bean types are used as a source of income for producers especially in the central Rift Valley of Ethiopia where they are mainly produced for export purpose. Above all, the haricot bean is an ideal crop to fit in intercropping of various crops in the farming system, and in turn, contributes a bonus yield, increase land use efficiency, and mitigate the problem of land shortage, which is the current overriding problem for most growers. Despite the versatile use, the amount of consumption, particularly in the urban areas, is low as compared to faba bean and field pea. Moreover, the national average yield of the crop under traditional production system is estimated to be low (0.5-0.8 t/ha) (CSA, 1996a,b) when compared to the yield of improved varieties with full package of recommendation. A number of interrelated factors contribute to this among which lack of awareness on the food utilization of the crop, use of local seeds which are poor in quality and low in yield, poor crop management practice, lack of improved seeds and inadequate extension service are the major once. As a result, the majority of growers use the conventional production practices and low yielding and disease-susceptible local varieties. Research-extension divisions of Melkassa, Awassa, Bako, Jimma, Sirinka, Pawe, and Adet Agricultural Research Centers together with Alemaya University of Agriculture (AUA) have been participating in the haricot bean technology transfer activities in collaboration with bean research programs of the respective locations. Ministry of Agriculture (MoA) has also made efforts to transfer improved bean technologies through increased awareness on the production practices and consumption of beans. The participant stakeholders used one or combination of such methods and approaches as pre-extension demonstrations, popularization activities, and community-based seed production and dissemination, on-the-job-training for front line workers and users, and through organizing field days, workshops and conferences. Though massive attempts have been made in the past, the results and achievements were hardly documented. Besides, the merits and demerits of several extension methods used were not critically assessed, evaluated and presented in a way suitable for future modification and strengthening the activities. The main objective of this article is, therefore, to review the efforts, activities performed and achievements made in the transfer of haricot bean technology. In addition, it was aimed at identifying the success factors that enable further up-scaling of haricot bean production technologies.

METHODOLOGIES AND APPROACHES

Improved haricot bean varieties such as Awash-1, Awash-Melka, Mexican-142, Beshbesh, Robe-1, Red Wolaita, Brown Speckeled, Gofta, Ayenew, Atendaba, Zebra, Tabor, Goberasha and Melkee were demonstrated with their respective recommended packages of production. Different extension methods and approaches were used to effect the technology transfer efforts. Among the methods, pre-extension demonstrations were found to be the dominant. Popularization through seed supply and community-based informal seed production and disseminations are also notable. Furthermore, the training and workshops organized on this particular technology can never be overlooked. In most cases, demonstration plots and farmers traditional practices were established side by side for comparison purposes. The plot sizes used for demonstrations were variable depending on the availability of land and seed. The package used in the demonstration plots were the research recommendations, which included improved variety, optimum sowing dates, row spacing, optimum seed rate/plant population, frequency of weeding, and harvesting dates.

Field days were organized each year with which the host farmers, development facilitators and neighboring farmers together with other community members interacted in the form of evaluation of the seasonal production. The field days had provided an opportunity to the representatives of NGOs and private sectors to discuss the production systems of the crop under intensive extension.

ACHIEVEMENTS

Pre-extension On-farm Demonstrations

Pre-extension Demonstrations (PED) and popularization of improved haricot bean production technologies were implemented around 1986/87, after the formal establishment of research extension divisions in research centers in 1985. The main objective of the PEDs was to bring the technologies into the knowledge of the front line extension workers/agricultural expertise and awareness of farmers before the wide popularization. The PEDs of haricot bean technologies were further meant to minimize the knowledge gap between the traditional farming and the improved production practices. The major mandate of the research centers in the transfer of the technologies was to create awareness towards the production practices, and the utilization and the provision of marketing information. The wider and large-scale demonstration and popularization of technologies is usually under taken by the Bureaus of Agriculture under MOA. Therefore, the research center-based effort towards technology transfer, uses the pre-extension demonstrations. While attempting to create wider awareness about the haricot bean production technologies, both method and result demonstrations were used. As a result, farmers, development facilitators, private sectors (exporters) and consumers in different parts of the country were exposed to some of the improved haricot bean production technologies.

Even though a number of improved varieties were developed and released nationally, the extension services were inadequate. For instance, out of the 12 different varieties nationally released, only five are currently in the farming systems. Many of them are out of the knowledge of the development practitioners. The varieties such as Awash-1, Awash-Melka, Mexican-142, Robe-1, Red Wolaita, Gofta and Ayenew are among the released ones currently under aggressive demonstrations, and hence, are at good adoption level.

The major objective of the PEDs was not to cover large number of farmers, but create awareness on the improved production practices. Through the research center-based demonstrations, about 3583 farmers were reached in the year 1990-2002. This figure excluded the farmers who were reached through the package extension programs. The results from all the respective locations indicated that improved haricot bean varieties demonstrated to farmers gave higher mean seed yields as compared to the local varieties with traditional practice (Table 1 and 2). This revealed that improved haricot bean varieties with improved management practices provided better yield advantage. For instance, more than 74.8-83% yield increment was achieved in Bako and Malkassa areas, respectively, compared to the local varieties with farmers' management practices.

Under both improved and farmers' management practices, varieties such as Awash-1 and Awash-Melka gave stable mean grain yields compared to the other varieties. Yet there was some sort of fluctuation in yields across years. This was common to all the varieties. As indicated in Fig. 1, two varieties; Awash-1 and Awash-Melka maintained their potential yield, whereas Mexican-142 gave the least average yield.

Table 1. Mean seed yield (t/ha) of the pre-extension demonstrations of improved haricot bean as compared to local varieties with local practice on farmers' fields.

Location	Year	No. of demo. plots	Improved varieties	Mean grain yield (t/ha) Improved practice	Local variety with Farmers' practice	% Yield increment
Bako	1994-1998	25	Awash-1	0.63	0.35	79
		50	Robe-1	1.68	0.50	237
		30	Mexican	0.41	0.50	-18
		30	Red Wolaita	0.72	0.50	44
		30	B/ Speckled	0.66	0.50	32
Mean		***	***	***	***	74.8
Melkassa	1990-2001	133	Awash-1	1.57	0.85	84
		127	A/ Melka	1.58	0.91	74
		133	Mexican-142	1.54	0.85	81
		24	Beshbesh	1.53	0.84	83
		24	Atendaba	1.55	0.85	84
		15	Robe-1	1.20	0.63	92
Mean		***	***	***	***	83

Source: BARC and MIARC (1994-1998).

Table 2. On-farm yield (t/ ha) of five haricot bean varieties around Melkassa, 1990-2001.

Year	Varieties and yields in respective years				
	Awash-1	Awash- Melka	Mexican-142	Beshbesh	Atendaba
1990	1.80	1.60	1.75	---	---
1991	1.60	1.50	1.90	---	---
1992	1.60	1.75	1.68	---	---
1993	1.20	1.25	1.30	---	---
1994	1.60	1.80	1.20	---	---
1995	1.80	1.50	1.54	---	---
1996	1.50	1.40	1.20	---	---
1997	1.75	1.62	1.40	---	---
1998	1.90	2.10	1.80	---	---
1999	---	1.63	---	1.60	2.30
2000	---	1.75	---	1.60	1.36
2001	1.90	1.15	1.60	1.40	1.00
Mean	1.67	1.59	1.54	1.53	1.55

Source: MARC (1990-2001).

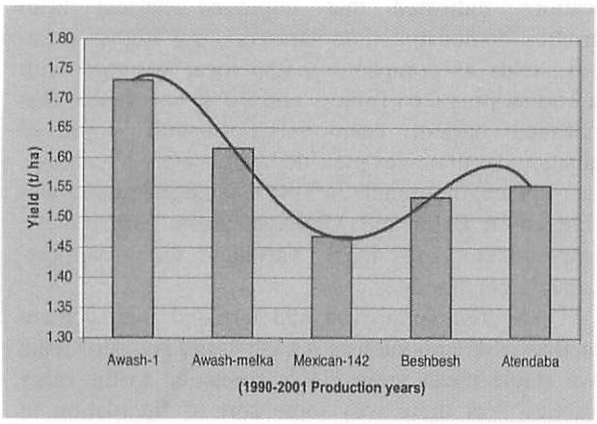


Fig. 1. Comparative average yield advantage of the five haricot bean varieties.

Popularization Methods

Through seed supply and advisory services: Improved haricot bean technologies are new to most of the farmers and other technology users. Hence, in collaboration with bean research programs and projects, efforts were made to popularize the technologies as per the availability of seeds. According to the past experience in technology transfer, popularization was done through supply of one kg of improved haricot bean seed per farmer each year in the bean growing areas. The number of farmers reached through seed supplies by the respective research centers is indicated in Table 3. As a result of such aggressive popularization efforts, the request towards the improved seeds of haricot beans has been increasing. However, because of limited availability of improved seeds it was not possible to provide the seeds as per the demand and likewise, no adequate number of seed agencies were observed participating in the seed production and marketing systems. Until the formal seed sector is ready to provide improved seeds adequately, it is advisable to continue popularization of bean technologies through seed supply for the benefit of the majority farmers.

Table 3. Number of farmers reached through seed supply as a method of popularization at five locations (1999-2002).

Year	Number of farmers at respective locations				
	Melkassa	Bako	Awassa	Jimma	Alemaya
1999	975	600	304	205	615
2000	692	2000*	415	114	214
2001	750	250	515	315	412
2002	700	150	402	110	420
2003	600	---	384	315	390
Total	3717	3000	2020	1059	2051

Seed supply as well as private purchase from the research centers. Source: AdARC, BARC, JARC, MIARC, and AU (1999-2002).

Through intercropping: The haricot bean is not only produced as a sole crop but also it fits well into intercropping systems. The yield and agronomic advantages of the crop make it most friendly in farming systems where it stands as a component. Here, intercropping experience in Bako area could be mentioned as an example. In this area, two improved maize hybrids (BH-660 and BH-540) were recommended for intercropping with any variety of haricot bean. A pre-extension demonstration of intercropping practice composed of two treatments (sub-plots) of sole maize and intercropping maize with haricot bean variety Roba-1, demonstrated for four consecutive years (1997-2000). The combined yield results indicated higher yield advantage of the intercropped plots compared to the sole maize planting. The yield increment was found to be 11 and 16% for BH-660 and BH-540, respectively. The lowest yield was obtained from sole maize planting (Table 4). This shows that intercropping haricot bean with maize could increase maize grain yield and without incurring additional labor/production cost. It rather enables to harvest extra beans with zero cost of production. In spite of such importance and double advantage of the technology, the intercropping practice was not much adopted by farmers in the area. The reason might be attributed to the problem of wild animals, which aggressively attacked the beans and the maize. This practice is however, strongly adopted and used in Hararge and Awassa areas of the country in which the haricot bean is used in intercropping with *chat*, maize, coffee and enset.

Through community-based seed schemes: One of the principal challenges that small-scale farmers and other private holdings are currently facing is lack of access to improved seeds. Because of this, in most cases farmers were forced to use local and unidentified seeds, which are poor in quality and low in yield. Even though most farmers have awareness through different on-farm activities, the limited seed source has restricted them for their large-scale production. There are no well-organized and formal institutions or agencies (governmental or private) responsible for haricot bean seed production and distribution. On the other hand, there always exists the problem of marketing if production increases. Recently, the Ethiopian Seed Enterprise (ESE) has made some efforts to produce seeds of haricot bean particularly the export-type bean varieties. However, because of high demand the Enterprise alone was not able to provide seeds as per the growers' demands. Hence, the chronic seed shortage has rarely been addressed.

In order to minimize the problem of seed shortage, research extension divisions of the respective centers and farming system research division of Alemaya University initiated the community-based seed production activities. The main idea behind this attempt was to make some farmers' seed as a source to other farmers in their community and introduce the farmer-to-farmer seed dissemination practices. Experiences reveal that farmers who have participated on the activity were found to be self-sufficient in improved seeds. Besides, they are able to market seeds on cash and in the form of exchange for other grains. Traditionally, selling seeds is a taboo and hence farmers provide seeds to their neighbors and peer groups in the form of gift. This taboo has negative impact on the success of the community-based seed system as it ignores the informal seed marketing. In any way, the approach helped much in mitigating the acute seed shortage.

Doss et al. (2003) indicated the four main seed sources of Ethiopian farmers were purchase from available sources, purchase from their neighboring farmers, supply by extension agents, and recycling their own seeds. In line with this, the community-based seed system was thus believed to contribute much to the farmers' seed demand; it is of course found to strengthen the seed acquisition through farmer-to-farmer means. The amount of seeds produced under the community-based seed increase scheme is indicated in Table 5. Similarly, the amount of seeds produced at MARC and dispatched to farmers in supplementing the on-farm seed production is indicated in Table 6.

Table 4. Mean grain yield of maize and haricot bean intercropping on farmers' fields in Bako area, 1997-2000.

Maize variety	Year	No. of plots	Mean yield (t/ha) Sole maize	Intercropped maize	Sole haricot bean (Robe-1)	% yield increment over the sole crop
BH – 660	1998	5	4.922	5.53	0.26	12
	1999	4	4.939	5.23	0.35	6
	2000	6	6.066	6.07	0.22	0
BH – 540	1998	3	2.463	3.40	0.46	38
	1999	3	4.858	5.06	0.33	4

Source: BARC (1997-2000).

Table 5. Grain yields obtained in community-based seed production.

Year	Variety	No. of sites	Total area (ha)	Total seed produced (t)
1995	Awash-1	36	9.00	10.00
1996	Awash-1	42	10.5	14.80
1997	Awash-1	51	9.86	9.60
	Robe –1	1	0.25	0.40
1998	Awash-1	33	8.25	10.60
	Robe – 1	33	3.33	4.10
1999	Robe – 1	22	5.50	7.20
	Awash-1	25	1.84	2.10
2000	Robe – 1	56	10.25	11.00
	Awash-1	21	2.62	2.10
2001	Robe – 1	26	5.60	5.40
	Awash-1	27	2.55	2.30
2002	Awash-1	25	3.50	2.90
	Robe – 1	28	4.20	4.10
Total	***	426	77.30	86.60

Source: MIARC (1995-2002).

In some cases, participant farmers were assisted to sale their extra seeds to potential NGOs and other private sectors at a better price than the local seed price. This has also motivated the host farmers to continue the production of haricot bean seeds. Unlike the western part, farmers of the Central Rift Valley got advantage of this arrangement. This approach contributed a lot towards farmers' access to improved seeds, but it does not mean that it totally solved the problem of seeds, which farmers and private producers are recurrently facing. An effort to encourage farmers to commercial farming and linking them to private sector seed dealers and government agencies is much recommended in order to sustain the production system of haricot bean. Similar recommendation by Mathewos and Chandargi (2003) revealed that for sustainable production and marketing of agricultural produces and effective extension system, integration and cooperation of public and private sectors is the immediate option.

From the experience of haricot bean technology transfer, it can be recommended that some sort of agreement as contractual farming, share cropping and product procurement arrangements can be made if sustainable agricultural production is to be thought of in which beans are no exception. Experience of Indian extension system indicated the same fact that private sectors had significant role in production and marketing of seeds through contractual arrangements with farmers (Mathewos and Sundraswamy, 2003), especially on cash crops, like the case of white beans in Ethiopia.

Table 6. Quantity of seeds produced at Melkassa and dispatched to users on sale-basis and/or free of charge (1990–2002).

Year	Quantity produced (t)	Quantity dispatched (t)
1990	41.40	34.50
1991	---	1.60
1992	27.30	18.00
1993	32.50	28.60
1994	30.60	24.80
1995	43.40	24.80
1996	48.20	34.50
1997	28.90	47.80*
1998	29.80	28.90
1999	46.80	2.90
2000	55.30	49.70
2001	37.80	47.50*
2002	38.40	29.86
Total	460.40	373.46

* Amount produced in the preceding year plus the closing stock of the same year. Source: MIARC (1990-2002).

Through farmer's research groups (FRGs): The main objective of organizing farmers in such FRGs is for the multiple advantages. One is to develop their indigenous skill and help the research to base on that; second is to evaluate the adaptability of released crop varieties with farmers' keen participation; and third is to disseminate the compatible technologies/selected varieties simultaneously with the location adaptability trials. This kind of participatory evaluation helps to develop location specific recommendations unlike that of the conventional blanket recommendation. Further, it helps to speed up the technology transfer activities.

Available data on bean technology promotion through FRGs in Bako show a good start and promising results on the recently released varieties. The FRG-based technology transfer and popularization system helps to shorten the time for wider coverage of the farming community. This approach is a simultaneous activity of technology evaluation, specific area recommendation, seed increase and popularization. Among the varieties demonstrated in six major bean growing districts, the variety Zebra and Atendaba have shown their optimum yield in east and west Wellega zones, respectively (Table 7). And therefore, these varieties were selected by the farmers' groups for large-scale popularization with full package of recommendations.

Table 7. Average yield of haricot bean varieties selected by Farmers' Research groups (FRGs) for large-scale popularization around Bako over years.

Location	Yield (t/ha)							
	Zebra	Gobe rasha	Tabor	Atendaba	Gofta	Ayenew	Robe-1 /(Std. ck)	Local
East Wellega								
Habe Dongoro	1.20	0.425	0.35	0.57	0.285	0.715	0.35	0.35
Wama Bonaya	3.20*	1.45	2.25*	1.85	2.05*	1.80	1.90	0.85
Gida Kiramu	1.00	1.10	1.60	0.70	—	0.30	0.80	0.90
West Wellega								
Gawo Dalle	---	1.225	1.500	1.65*	1.46	1.10	1.52	0.95
Jarsoo	---	0.93	1.35	1.45	1.30	1.15	1.26	1.075
Dalle Sadii	---	0.725	1.125	0.90	1.05	0.75	8.50	3.50

* Varieties selected for wider popularisation; Std. ck= standard check.

TRAINING

Training on Production and Management Practices: Training is one of the vital instruments used in technology transfer. It has significant effect to upgrade the technical competencies and production skills of the trainees. It is also a medium that creates interaction between researches, farmers, development facilitators and other technology users. Above all, training is used as a medium for introducing and popularisation of new technologies, exchange information and acquisition of feedbacks, and production constraints. Realising these facts, various training sessions were organised in different centres in collaboration with agricultural experts of the respective zones and districts.

Since 1990, a number of farmers, development agents (DAs), subject-matter specialists (SMSs) and other bean growers, research programs from NGOs and GOs engaged in haricot bean production and marketing were trained (Table 8). In most cases, farmers and other development facilitators were separately trained. Most of the trainings were organized to include both theory and practice, and study tours with production and distribution of leaflets.

Table 8. Training activities organized by research-extension divisions of various research centres (Melkassa, Bako, Awassa, and Jimma), 1990-2002.

	No. of trained individuals			
Year	DAs & SMS	Farmers	Private investors and others	Total
1990	25	29	-	54
1991	8	36	-	44
1992	106	48	25	179
1993	70	15	32	117
1994	307	25	40	372
1995	74	80	89	243
1996	94	51	66	211
1997	110	236	93	439
1998	198	226	104	528
1999	169	248	96	513
2000	243	272	215	730
2001	242	289	125	656
2002	197	485	146	828
2003	533	117	325	975
Total	2376	2157	1356	5889

DAs=development agents; SMS=subject-matter specialists. Source: AwARC, BARC, JARC, and MIARC (1990 -2003).

In general, a total of 5889 individuals were trained of which 2376 were farmers, 2157 DAs and SMSs, and the remaining 1356 were other private participants and consumers. This sort of training sessions enabled majority of them to get involved in the production and marketing of haricot beans. An experience from Bako area indicated that the haricot bean (Robe-1) growers were in the state of improving their diet, the "Roba-1" being the major component of their dishes. Yet, not much focussed training is being given on the food science aspects. This joint effort has currently increased the demand of haricot beans in type and variety; the color and yield potential together with resistance to pests and the desired major traits. These training forums, besides their impact in creating awareness, have also helped all the stakeholders in good link with each other.

Training on Food Preparation from Haricot Beans: Food preparations and utilization of Roba-1 and soybean have been popularized through the efforts of MARC and JARC to selected home agents, small grocery and hotel owners, schools, and other consumers in both urban and rural areas. Roba-1 is a lowland pulse that is grown mostly for home consumption, which is a good nutritional substitute as it is suitable for making dishes such as *kikwot*, *shirowot*, soup and *sambosa*. Both at MARC and JARC, awareness has been created as Roba-1 and soya beans are cheapest sources of protein for poor people who cannot afford to have meat (Fig. 2 and 3).

Fig. 2. Training on food recipe preparation of haricot beans (Robe-1) for women.

Fig. 3. Demonstration of the food prepared from haricot bean (Robe-1) at Melkassa Agricultural Research Center.

FIELD DAYS

The ultimate goal of research-extension divisions at agricultural research centers is to promote agricultural development by empowering small-scale farmers to enable them shift from low production level to the higher level. From the very nature, farmers are usually reluctant to improved production technologies unless they have clear idea of the technologies and are convinced of the benefits and risks involved. Organizing field days is, therefore, one of the important methods and approaches to convince farmers about the performance of the technologies and their expected outputs. Besides, field days are important forums where growers openly discuss their production constraints and argue about the elements they are dissatisfied with. It also provides an opportunity to researchers and extension workers to learn from farmers to have an understanding of their indigenous technical knowledge so as to help them incorporate into the research system.

To utilize all the options and opportunities, field days have been organized each year by MIARC, AwARC, BARC, JARC and AUA to evaluate the performance of the demonstration and popularization plots. These field days helped to convince the "follower farmers" (neighboring farmers), and provided opportunities for the policy makers, and relevant office representatives to evaluate the efforts of the research and extension sectors. The recently established Research Center Based-Research-Extension Advisory Council (RCB-REAC) has strengthened the on-farm activities and visits in an improved system than ever before. The suggestions and recommendations given during the council meetings and study tours are very much noted. The field tour made by the council members to visit the haricot beans seed increase plots is shown in Fig. 4.

Fig. 4. Members of the Research Extension Advisory Council visiting haricot bean demonstration plots.

According to the reports from different agricultural research centers the field days organized on haricot bean demonstrations and other technologies are found to be excellent forums to bean farmers in which they can practically visualize the performance of the improved haricot bean technologies in plots This approach also created awareness and would contribute much to the adoption and wider dissemination of haricot bean technologies.

WORKSHOPS AND CONFERENCES

The lack of appropriate forums for joint evaluation of the research and extension system by all relevant stakeholders was not only responsible for weakening technology transfer efforts but also constrained the client-oriented research approach. In order to suit the newer technologies in haricot bean production to the real situation of farmers, several workshops were conducted. The primary objectives were to evaluate the trends in haricot bean production system and technology transfer efforts, and formulate location specific package of recommendations on the same. Workshops held so far are indicated in Table 9.

Table 9. Evaluation of haricot bean technology transfer and gap analysis workshops (1995-1998).

Location	Year	Participating centres
Melkassa	December, 1995	Melkassa, Meiso, Arsi, Werer, Holetta, Kulumsa, Sinana, Alemaya
Nekemte	November, 1996	Bako, Jimma, Habobo, Gera
Bahir Dar	March, 1998	Adet, Srinka, Pawe, Sheno, Mekele, Kobo

Unlike the professional societies, these workshops were used to explore available research recommendations at each research center, assess farmers' technological needs, analyze and identify the technology transfer constraints and assess feed-backs in the respective zones with the active participation of all the stakeholders. The advantages envisaged in organizing such workshops with research centers included:

1. Researchers from each division had an opportunity to summarize and present their research findings for immediate use.
2. Community representatives, individual farmers and other users were encouraged to convey feedbacks on the types of technology they needed, prevailing production constraints, and problems in their mandate areas.
3. Formulation of location-specific extension recommendations and setting of client-oriented research agenda by a group of participating people.
4. An opportunity for interaction and sharing ideas among research and extension staff was created through these workshops. This in turn helped the research centers to redesign their researchable areas and methodologies.

A practical example of the advantages of such workshops and periodical advisory council meetings are the best observations and recommendation of the council members experienced in Bako and Melkassa to promote technology evaluation under farmers' environment. Towards this, the farmers' groups established are good platform for technology evaluation, verification and dissemination.

CONSTRAINTS TO TECHNOLOGY TRANSFER EFFORTS

So far, easy access to good quality seed has been a major limitation in haricot bean production. Till recently, public institutions were the only bodies responsible for production and distribution of seeds to farmers. Although some private companies are now entering the seed production and marketing sector, the impact is not sufficiently observed. In the past, the seed supply was constrained by inefficient public seed enterprises, poor seed promotion, poor transportation, and lack or inappropriateness (if any) of agricultural and pricing policies. In most cases, seeds in smallholder sector is produced by farmers (Hailu, 1992) and, of course, supported by the seed supply from research centers/universities. Thus, the access to seeds, limited and lack of market for the produces is complementary constraint to bean production.

The public seed enterprise, which was incorporated in 1979, is running as an Inter-ministerial Seed Board with an autonomous status to function as a profit-making enterprise (Doss et al., 2003). And it is on this very fact that the enterprise is emphasizing its business mainly on the profitable crops. The haricot bean in this regard is not much addressed, mainly because of lack of demand in the beginning, emanated from lack of awareness, or having low market value (specially the food bean types). Lack and limited opportunity of participating farmers in variety testing and verification for social acceptability has led to less attention being paid by farmers to the newly developed varieties.

CONCLUSIONS AND RECOMMENDATIONS

Efforts made in technology transfer of haricot bean during the last decade indicate promising results in both seed dissemination as well as demonstration of the production practices. The various extension methods and approaches like demonstrations, training and workshops were the best tools for the success in the transfer efforts. Seed supply and advisory works, community seed increase and dissemination, farmer-to-farmer seed exchanges and sales are the valid mechanisms utilized for the wider popularization of the improved haricot bean production technologies. Popularization through FRGs is also the current nationally appreciated approach under implementation in technology verification and transfer.

It is worth noticing that the technology transfer activities on haricot bean production in some areas of the country are rather efforts on the introduction of the crop. Realistic example is the case of Bako area. In the central Rift Valley area, the crop is currently a good income source for most growers and a promising cash crop. The white beans are widely exportable. Because of its market value and related agronomic advantages, haricot bean is the major component in today's farming. Haricot bean, in today's experience, is found to be the most important component of the local dishes. The versatile uses of the crop have made it most popular and hence the achievements through the research-center based transfer efforts are most remarkable.

From the experiences, it can be noted that the absence of seed production and marketing agencies both from the public as well as private sectors had a weakening effect on the wider technology transfer efforts. To this end, it is recommended to encourage the involvement of the private sectors in the seed system. Besides, some sort of agreement as contractual farming, share cropping and product procurement agreements can be made between private sectors and farmers for sustainable production. Also, village-based seed increases, and farmer-to-farmer diffusion systems need to be promoted. Furthermore, emphasis needs to be given for farmers' participation through FRG in technology development, variety verification, and transfer activities. There is also need to incorporate farmers' selection criteria on crops/technologies, and increase degree of compatibility of technologies/varieties to the farmers' situation. Thus, what is required is a good "client orientation".

Finally, the authors recommend the need for a strong national technology transfer network for up-scaling haricot bean production technology transfer with effective linkage between production and marketing/processing sectors.

REFERENCES

AwARC. 1990-2003. Progress reports for the periods 1995-2003, Awassa Agricultural Research Center, Awassa, Ethiopia.

AU (Alemaya University. 1999. Proceeding of the 16th Annual Research and Extension Review Meeting, Alemaya University.

BARC . 1990-2003. Progress reports for the periods 1990-2003. Bako Agricultural Research Center, Bako, Ethiopia.

CSA. 1996a. Report on area and production of *Belg* season crops for 1993/94 and 1994/95, Agricultural sample survey 1994/95, Volume V. Statistical Bulletin 141, Central Statistical Authority (CSA), Addis Ababa. 47 pp.

CSA 1996b. Report on area and production for major crops. Agricultural sample survey 1995/96. Vol. 1. Statistical Bulletin 152. Central Statistical Authotity (CSA), Addis Ababa, Ethiopia. 13 pp.

Doss, C.R., W. Mwangi, H. Verkuijl, and H. de Groote. 2003. Adoption of maize and wheat technologies in Eastern Africa: A synthesis of the findings of 22 case studies. CIMMYT Economics Working Paper 03-06. Mexico, D.F. CIMMYT.

Hailu, G. 1992. Availability and use of seeds in Ethiopia: Program Support Unit, Canadian International Development Agency.

IAR. 1990. Proc. of a National Workshop on Research on Haricot Bean in Ethiopia, 1-3 October 1990. Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia.

JARC. 1990-2003. Progress reports for the periods 1990-2003, Jimma Agricultural Research Center (JARC), Jimma, Ethiopia.

MIARC . 1990-2003. Progress reports for the year 1990-2002. Melkassa Agricultural Research Center (MIARC), Nazereth, Ethiopia.

Mathewos Belissa, and D.M. Chandargi. 2003. Models for public-private cooperation in agricultural extension as applicable to Ethiopian system. Paper Presented at Challenges and Prospects of Food Security in Ethiopia, a Food Security Conference, UNCC, August 13-15, 2003, Addis Ababa, Ethiopia.

Mathewos Belissa, and B. Sundaraswamy. 2003. Alternative methods in extension system: Indian experience of private extension service providers. Paper Presented at Reversing Vulnerability of Rural Livelihoods in Ethiopia: Options for Sustainable Development, 7th Annual Conference of the Agricultural Economics Society of Ethiopia (AESE), UNECA, Addis Ababa, Ethiopia.

Review of Adoption and Impact of Improved Food Legume Production Technologies in Ethiopia

Legesse Dadi[1] and Adam Bekele[2]

[1]Ethiopian Agricultural Research Organization, Addis Ababa, Etiopia, [2]Melkassa Agricultural Research Center, Melkassa, Ethiopia.

ABSTRACT

In the past, few studies have been done on the adoption and impact of food legume technologies, and thus information on the extent of adoption is scarce. This article attempts to review adoption and impact studies conducted with the objectives of assessing the extent of adoption and identifying constraints to improved faba bean, field pea, chickpea and lentil technologies in Ethiopia. Over the last 10 years, the number of improved faba bean, field pea, chickpea and lentil varieties released for farmers' use has increased. Despite this, the amount of seed produced for the improved food legume varieties and supplied to farmers through the formal seed distribution channel was insignificant. Food legume technologies particularly improved varieties were extended to farmers through outreach programs, and then expanded to more number of farmers through farmer-to-farmer seed exchange. Great variations were observed in the rates of adoption of food legume technologies reported by different studies. A study conducted in Lume and Ginbichu *woredas* (districts) of eastern Shoa zone showed that 57% of farmers who participated in on-farm trials and demonstrations of improved varieties continued to use the varieties. A study conducted in Bichena *woreda* showed that 5% of farmers adopted the improved chickpea variety in 1997. However, a monitoring survey of on-farm demonstration participating farmers in the same *woreda*, noted that only 34% of farmers continued to use improved variety of chickpea in 2000. The remaining farmers discontinued using the improved variety due to lack of seeds and low market prices. In lentil, improved varieties were widely adopted by farmers in Gimbichu *woreda*, but this was not the case in other lentil producing areas in the country. Though small, there has been an increasing trend on the adoption of faba bean and field pea technologies. Modern inputs such as fertilizer and herbicide have not been used on food legumes with the exception of the use of fertilizer on lentil by few farmers in Gimbichu *woreda*. Farmers also did not adhere to the recommended planting date, seeding rate and weeding practices. The major constraints to adoption of improved food legume technologies were found to be lack of improved seeds and awareness about the technologies. Therefore, policy to improve the formal and informal seed production and distribution mechanism is considered essential.

INTRODUCTION

Like many less developed countries, Ethiopia has difficulty feeding its rapidly growing population and is severely constrained in its ability to import foreign products for domestic consumption and capital goods for the development of the economy. Agriculture is the country's most important economic activity in terms of providing food, income, employment and foreign exchange. However, productivity on smallholder farms, which dominate agricultural production, is low, averaging 0.87 t/ha for food legumes, and 1.22 t/ha for cereals (CSA, 2001), and this low crop productivity at least partly explains why food availability per capita in Ethiopia is one of the lowest in the world.

It is proved beyond doubt that improved production technologies increase agricultural productivity. In view of this, a greater widespread use of appropriate technologies is essential to increase crop, livestock, land and water productivity. Cognizant of this, attempts have been made by the nation-wide extension activities and through agricultural research centres' outreach programs to increase the productivity of food legumes through promotion of new technologies. Despite these efforts, application of modern food legume technologies is very low at the farm level. The rate of adoption of new technologies is affected mainly by economic, institutional, technical and environmental factors, among which awareness and availability are very crucial. Profitability and the degree of risk and uncertainty associated with improved technology are important economic considerations in technology adoption. In addition, adoption of a new technology is highly influenced by the capital requirement, agricultural policies, and the socio-economic characteristics of farmers. Thus, an understanding of specific factors that affect adoption, and the effect of new technology on input demand and productivity is crucial for better understanding of potential diffusion of the technology among farmers.

Food legumes, namely chickpea, lentil, grass pea, faba bean and field pea are widely cultivated by smallholder farmers in Ethiopia. They play a significant role in the diets of many Ethiopians, soil amelioration, and generating cash income for rural households. Animal protein is expensive for most consumers while plant protein mainly originating from the consumption of food legumes is relatively cheaper. The objective of this article is to review studies on the adoption of improved faba bean, field pea, chickpea and lentil production technologies and their associated constraints in Ethiopia.

PRODUCTION OF FOOD LEGUMES

Food legumes cover about 10% of the area under crop production in Ethiopia, and share nearly 13% of total annual crops production (CSA, 2001). Area under faba bean, field pea, chickpea and lentil decreased between the early and late 1980's, but started increasing in recent years (Table 1). On the other hand, area under grass pea greatly increased between the 1980's and 1990's, although it is a less preferred food legume, and expansion in area under this crop reflects the deteriorating economic situation in rural areas. Farmers are responding to the deteriorating economic situation by shifting their production and consumption from preferred food legumes to less preferred crops such as grass pea (Legesse et al., 2003).

There was fluctuations in the average growth rates of area and production of food legumes over the last two decades. In the early 1980's, with the exception of grass pea, the average growth rate of area under food legumes was negative. This trend continued in the late 1980's until 1992. From 1992-2000, the average growth rate of area under field pea, chickpea, lentil and grass pea was positive (Table 2). Similarly, the average growth rates of faba bean, field pea, chickpea and lentil production in the early 1980's were negative as a result of decline in area under these crops. In the late 1980s and the first two years of early 1990s, with the exception of faba bean, the average growth rates of the production of food legumes were positive ranging from 0.05% for field pea to 12% for chickpea. The major reason for an increased production from 1992-2000 was not improved productivity, but it was due to an expansion in area cultivated to these crops as evidenced from the positive average growth rate.

YIELD POTENTIAL OF IMPROVED PRODUCTION TECHNOLOGIES

In view of the national significance of food legumes and problems faced with their production, several improved varieties and their recommended management practices have been developed by the research system (Table 3). These technologies have been verified and disseminated among farmers by research centers and NGO's through demonstrations, direct seed supply and farmer-to-farmer seed exchange systems. Grain yields of selected varieties on the experimental, on-farm and national average are shown in Table 4. Yields on both the experimental and on-farm plots are much higher than the national average for all the selected varieties. For instance, the yield gap between the experimental plots and farmer's fields for lentil variety is more than three-fold of the average lentil yield. This is also true for faba bean improved varieties. Thus, if adopted, the improved varieties along with their recommended management practices have the capacity to tremendously increase productivity of food legumes.

ADOPTION OF IMPROVED FOOD LEGUME TECHNOLOGIES

Most of the studies reviewed in this article are concentrated in areas where the outreach programs of research centers were undertaken. It was assumed that non-participant farmers could have access to improved seed through farmer-to-farmer exchange or purchase. The studies compared farmers who participated in the outreach programs (participant farmers) and non-participant farmers.

Table 1. Cultivated area and production estimates of the major food legumes.

Crop	Growing Season				
	1981/82	1985/86	1992/93	1998/99	1999/00
			Area ('000 ha)		
Faba bean	348.91	280.19	298.2	296.71	359.15
Field pea	174.09	130.74	139.10	141.95	152.20
Chickpea	138.09	132.00	109.70	167.70	184.79
Lentil	70.42	44.86	44.80	47.90	72.22
Grass pea	32.29	65.46	70.40	95.05	110.58
Haricot bean	25.06	45.53	39.80	129.50	166.04
			Production (t)		
Faba bean	469.94	233.33	312.10	285.82	388.68
Field pea	163.07	69.26	103.74	100.08	116.00
Chickpea	101.37	88.40	60.09	138.84	164.63
Lentil	51.60	25.87	25.03	28.38	49.77
Grass pea	21.37	41.73	44.16	78.62	107.48
Haricot bean	11.75	23.34	31.46	116.81	132.89

Source: CSA (1983-2001).

Table 2. Comparison of average growth rates (%) in cultivated area and production of the major food legumes.

Crop	Growing Season		
	1981-1985	1985-1992	1992-2000
	Area (%)		
Faba bean	-4.39	0.78	-0.07
Field pea	-5.37	0.78	0.29
Chickpea	-0.90	-2.31	6.06
Lentil	-9.02	-0.02	0.96
Grass pea	14.13	0.94	4.29
Haricot bean	11.94	-1.68	16.85
	Production (%)		
Faba bean	-0.14	3.63	-1.26
Field pea	-0.17	5.05	0.05
Chickpea	-0.03	-4.82	11.96
Lentil	-0.14	-0.41	1.79
Grass pea	13.38	0.71	8.24
Haricot bean	13.72	3.73	18.74

Table 3. Improved varieties of food legumes under production.

Crop	Released varieties
Faba bean	Shallo, Tesfa, Messay, Bulga-70, NC-58, Kassa, CS-20DK, Kuse, Holetta-2, Degaga, Wayu, Selale, Lalo, Dagm
Field pea	Welmera, Tullu-dimitu, Holetta, Adi, Milky, Markos, Hassabe, Tegegnech, Mohanderfer, FPDZ, G22763-2C, Hursa, Adet-1, Dadimso, Tulu, NC-95 Haik, Weyyitu, Sefinesh,
Chickpea	Arerti, Shasho, Mariye, Worku, Akaki, DZ-10-4, DZ-10-11
Lentil	Alemaya 98, Chalew, Assano, Gudo, Ada, Checole, EL-142, R-186
Haricot bean	Mexican 142, Awash, Roba, Red Wolaita , Atandaba, Wedo, Ibbado, Omo-95, Nasir, Dimtu, Tabor, Zebra-98, Gobe Rasha-1, Melka Awash-98, Beshbesh/Melk 97, Melke/Areka 97, Ayenew, Gofta

Source: NAIA (2003).

Table 4. Yield potential of selected food legume varieties under experimental and on-farm conditions.

Legume	Variety	Yield (q/ha)		National average (q/ha)
		Experimental field	On-farm	
Faba bean	Mesay	40-45	30-35	13
Field pea	Markos	27-35	15-20	9.7
Chickpea	Worku	19-40	19-29	11
Lentil	Gudo	18-25	16-24	6.56
Haricot bean	Awash-1	23	16	6.8

Lentil

Results of a survey of 140 farmers in Lume and Gimbichu *woredas* showed that 71% of the farmers who participated in the demonstrations and on-farm experiments adopted an improved lentil variety Chalew in 1997/98 crop season (Teklu, 1998a). In the same year, only 29% of the non-participant farmers adopted the said variety. Despite the merits of participation in outreach programs, unavailability of seed and poor performance of the variety were the two most important factors that affected the adoption of the improved variety. Absence of market outlet was also indicated as a reason for not growing the improved lentil variety Chalew. Those farmers who participated in the demonstrations but did not grow the improved variety reported that the improved variety poorly performed, and there was no market outlet. About 67% of the non-participant farmers did not grow the improved variety due to unavailability of seed, and 29% of them due to lack of awareness about the improved variety. A study conducted in Ginbichu in 2001 showed that 28% of the farmers surveyed adopted the improved varieties.

Chickpea

A survey of 140 participant and non-participant farmers in the demonstration of chickpea variety Mariye in Lume and Gimbichu *woredas* indicated that 71.4 % of the participant farmers grew the improved variety on an average area of 0.13 ha. Participant farmers did not plant the whole chickpea field to the improved variety because of the unavailability (68%) and expensiveness (25%) of the seed. As documented by Teklu (1998b), 66% of non-participant farmers did not adopt the improved variety Mariye because of the unavailability of the seed. Substantial proportion of farmers (28%) had no awareness about the existence of the improved variety at the time of the study. Farmers preferred the improved chickpea variety Mariye because of high grain yield (16.3%), large seed size (16.3%), and good food quality (16.3%). Frost resistance was reported by 14% of the respondents as a criterion while resistance to disease (9.3%), seed color (9.3%) and resistance to insects (9.3%) were also reported as criteria.

In the same study, the mean seeding rate used by farmers was higher than the recommended seed rate. Thirty-three percent of the farmers did not adopt the recommended seed rate due to lack of awareness, and 66.7% of those who were aware of the seed rate believed that the recommended rate was low. The sowing date for chickpea practiced by farmers coincided with that of the recommended sowing date (Teklu, 1998b). It is possible to say that sowing date is fully accepted or the recommended date can be taken as integral part of farmers' practice. About 75% of participant and 72% of non-participant farmers weeded their chickpea fields once at the recommended time of 4 weeks after planting. None of the participant and non-participant farmers reported using any herbicide to control weeds.

Results of two surveys in Bichena *woreda* in eastern Gojam zone, by Workneh (1997) and Kenea (2000) showed that the level of adoption of improved chickpea variety Mariye was quite low among non-participant farmers in extension demonstrations and popularization activities of research centers. Workeneh (1997) randomly sampled 80 farmers, and only 5% of them grew the improved variety in 1997/98 crop season. The average area allocated to the improved variety accounted for 47% of the average area allocated to chickpea. The major constraints to adoption of the improved chickpea variety were lack of awareness about the improved variety (53% of respondents), unavailability of seed (30%), and 7% of the sample farmers were not convinced of the yield superiority of the improved variety (Workeneh, 1997).

A farm survey of 54 participant and non-participant farmers in demonstrations in Bichena *woreda* showed that the use of the improved chickpea variety Mariye was much more accepted among participant farmers in demonstration and popularization activities than the non-participants farmers (Kenea, 2000). There was a considerable difference in the adoption of the improved variety in the villages where popularization activity took place. This variation might be attributed to differences in extension activities and access to markets. Extension workers and participant farmers were the major source of information for awareness about the existence and performance of the improved variety Mariye, whereas farmers and agricultural offices were the major sources of seed.

Attributes of a given variety are important factors in enhancing or deterring its adoption (Table 5). Kenea (2000) assessed perceptions of farmers regarding the improved chickpea variety Mariye. He identified attributes of improved varieties that farmers found important and used as criteria in adopting the varieties. As he reported, farmers perceived that the improved variety Mariye was better than the local variety in seed size, cooking time, taste of green peas, germination capacity, moisture stress tolerance and damage by boll-worm, cutworm and Aschochyta blight. However, they noted that the variety was inferior in terms of amount and quality of straw, and in market demand.

Table 5. Adopters' perception of some aspects of the *Mariye* variety as compared to the local chickpea variety.

	Number of respondents		
Trait	Mariye	Local	Equal
Big seed size	59	0	0
Less cooking time	36	6	2
Requires intensive cultivation	28	3	20
Requires higher seeding rate	28	21	6
Germinates well	33	21	6
High tillering capacity	38	7	11
Tolerance to moisture stress	22	16	1
Resistance to weed	15	9	19
Lodging resistance	24	5	22
Resistance to boll-worm	26	2	9
Resistance to cutworm	23	2	14
Resistance to Aschochyta blight	19	7	14
Early maturity	12	19	18
More straw	9	29	8
Desirable color	21	27	1
Better *Qolo*	23	21	1
Better *nifro*	40	2	0
Better *shiro*	25	1	1
Better *kiikki*	39	0	0
Marketability	11	25	2
Better straw quality	9	18	13
Taste of green peas	14	1	0

Source: Kenea (2000).

As identified by Kenea (2000), factors that constrained adoption of improved varieties included unavailability of seeds and susceptibility to diseases (Table 6). Lack of awareness about the improved variety was also one of the problems limiting adoption. Specific attributes (seed size and color) of the improved variety that affected market acceptance and price also influenced its adoption.

Faba Bean

In Wolmera area, Hailu (1996) studied rates of adoption of faba bean technologies, namely improved variety, fertilizer type and rate and recommended seeding rate from 1989 to 1995 (Table 7). From 1989 to 1995, the number of farmers who adopted the improved variety had increased, but the rate of increase was much higher for fertilizer than that of the improved variety. The low adoption rate for the improved variety, as noted by Hailu (1996), was due to shortage of seeds as reported by 66% of farmers. About 64% of improved variety adopters used seeds from the previous harvest. Large proportion of farmers knew the recommended sowing date (80%) and the recommended weeding time (73%). Few farmers (15%) were aware of the recommended fertilizer rate. About 44% of farmers applied diammonium phosphate (DAP) fertilizer on faba bean at the average rate of 76 kg/ha. The adoption of recommended weeding practice, frequency of plowing and fertilizer rate had increased in 1995 compared to adoption rates of these practices in 1989.

Table 6. Reasons for discontinuing growing improved variety Mariye in Bichena *woreda* in eastern Gojam zone.

Reason	Number of farmers	Percent of farmers
Lack of seed	16	42.1
Theft by bypassers	7	18.4
Low market price	2	5.3
Disease	12	31.6
Water-logging	4	10.5
Land shortage	5	13.2

Source: Kenea (2000).

Table 7. Comparison of adoption rates of faba bean technologies in 1989 and 1995 in Wolmera *woreda* (percentage of farmers reported).

Technology	1989 (N = 54)	1995 (N =73)
Improved variety	30	34
Fertilizer (DAP)	9	44
Recommended weeding time	59	80
Recommended plowing frequency	4	51

Source: Hailu (1996).

Haricot Bean

Survey conducted in Adama, Boset, Dugda-Bora and Adami-Tulu *woredas* showed that 60% of the farmers adopted the improved varieties on 30% of the total haricot bean fields. As identified by different studies, availability of seeds was the critical factor that affected adoption of the improved varieties of faba bean, field pea, chickpea and lentil. The amount of the improved seeds of faba bean, field pea, chickpea and lentil produced and distributed were quite insignificant (Table 8). Also, the amount of seeds of the improved varieties distributed by the Ethiopian Seed Enterprise (ESE), the sole formal seed producer and distributor of food legume seeds, was very small. There was no continuous supply of seeds, and in some years improved seeds of food legumes were not distributed at all.

IMPACT OF FOOD LEGUME RESEARCH AND TECHNOLOGIES

Impact assessment is one of the tools to help ensure better management, planning, and priority setting for raising the efficiency of agricultural research programs. It evaluates whether research and development programs produce intended effect or not. The food legumes research program has generated a number of improved varieties and better crop management practices. Impact assessment of food legume technologies has not been done in the past, and a system was not put in place to follow track effect of technologies. Thus, sufficient data are not available to measure the impact of food legume technologies.

Here, *ex ante* analysis was employed to evaluate the potential impact of food legume technologies. Comparing the net benefit from improved varieties and local cultivars, the improved varieties showed great potential to increase productivity of food legumes (Table 9). Application of these technologies would have a great impact in improving the income and well being of small-scale producers.

CONCLUSIONS AND RECOMMENDATIONS

A number of technologies, particularly improved varieties, have been developed over the past two decades. The technologies have great potential to increase productivity and income of farmers. In view of this, they were extended to farmers in areas close to research centers. As depicted from a review of the past adoption studies, adoption of food legume technologies in Ethiopia is very much localized and extremely low. The low level of adoption is mainly because of the unavailability of seeds and lack of awareness of the existence of the improved food legume technologies. Seed multiplication and delivery mechanisms have not been well developed. Special attention should be given to seed multiplication in order to increase the level of adoption of food legume production technologies and income of farmers. One possible way to enhance seed multiplication and their availability is to establish contract growers scheme. Commercial farms and cooperative unions can manage such a scheme. Possibly the ESE may also develop contract growers by paying premium prices. In addition to intervention in seed multiplication, there is a need to expand promotion of the improved food legume technologies to increase the awareness of the farmers on the existence and performances of technologies.

Table 8. Amount (in quintals) of faba bean, field pea, chickpea and lentil seeds distributed by the Ethiopian Seed enterprise (ESE).

Year	Faba bean	Field pea	Chickpea	Lentil	Haricot bean
1990/91	576	105	5	-	1872
1991/92	556	0	492	0	576
1992/93	452	1006	387	0	2653
1993/94	67	28	4172	780	1506
1994/95	135	0	1060	0	579
1995/96	0	0	0	0	1133
1996/97	223	6	0	12	385
1997/98	59	16	0	0	93
1998/99	0	342	3	0	32
1999/00	26	120	67	0	156
2000/01	152	38	254	4	376

Source: Extracted from ESE reports of various years.

Table 9. Expected impact of selected improved food legume varieties under on-farm conditions - partial budget analysis.

Description	Faba bean		Field pea		Chickpea		Lentil		Haricot bean	
	Improved	Local	Improved	Local	Improved	Local	Improved	Local	Improved	Local
Yield* (q/ha)	30	13	18	9.7	29	11	18	6.56	16	6.8
Prices of legumes at harvest time (birr/q)	78	78	80	80	119	119	190	190	150	150
Expected Gross benefit (birr/ha)	2340	1014	1440	776	3451	1309	3420	1246.4	2400	1020
Costs that vary										
Seed rate (kg/ha)	212	144	125	100	100	101	70	100	120	100
Price of improved seeds and local seeds at planting time (Birr/kg)	3.27	1.56	3.27	1.99	2.98	1.16	3.83	1.57	3.27	1.6
Total variable costs that vary (Birr/ha)	693.24	224.64	408.75	199	298	117.16	268.1	157	392.4	160
Expected net benefit (Birr/ha)	1646.76	789.36	1031.25	577	3153	1191.84	3151.9	1089.4	2007.6	860

Note: *Yield of improved seeds are from on-farm trials, while the yield of the local cultivars is obtained from CSA (1994 E.C.) yield estimates. One quintal is equal to 100 kg.

REFERENCES

CSA. 1983-2000. Area and production for major crops. Agricultural sample survey 1982/2000. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

CSA. 2001. Crop production forecast sample survey. Report on forecast of area and production of major crops. Statistical Bulletin No. 257. Central Statistical Authority (CSA), Addis Ababa, Ethiopia. 20 pp.

Hailu Beyene. 1996. Impact of faba bean technologies on the production of faba bean in selected Wolmera areas, 1996/97. Holetta Agricultural Research Center Report. (Unpublished).

Kenea Yadeta. 2000. Adoption of improved chickpea variety *Mariye* in Bichena *woreda*, eastern Gojam Zone. Research Report, Debre Zeit Agricultural Research Center Research Report. (Unpublished).

Legesse Dadi, Hailemariam Teklewold, Aden Aw-Hassan, Ali Abdel Moneim, and Geletu Bejiga. 2003. The socio-economic factors affecting grass pea consumption and incidence of lathyrism in Ethiopia. Integrated Natural Resource Management Research Report Series, No. 4. ICARDA, Aleppo, Syria.

NAIA. 2003. Crop Variety Register, Issue No. 6. National Agricultural Input Authority (NAIA). EDM Printing Press, Addis Ababa, Ethiopia.

Teklu Tesfaye. 1998a. Adoption of improved lentil production technologies in Lume and Gimbichu woredas of Ethiopia. Nile Valley and Red Sea Regional Program on Cool-Season Food Legumes and Cereals Regional Networks Annual Report 1997/98. NVRSRP, Cairo, Egypt.

Teklu Tesfaye. 1998b. Adoption of improved chickpea production technologies in Lume and Gimbichu woredas of Ethiopia. Nile Valley and Red Sea Regional Program on Cool-Season Food Legumes and Cereals Regional Networks Annual Report 1997/98. NVRSRP, Cairo, Egypt.

Workeneh Negatu. 1997. Adoption of improved chickpea production packages in Bichena woreda. Debre Zeit Agricultural Research Center Research Report. (Unpublished).

Socio-economic Studies in Lowland Pulses in Ethiopia

Adam Bekele[1] and Legesse Dadi[2]

[1]*Melkassa Research Center, P.O. Box 436, Nazareth, Ethiopia*
[2]*Ethiopian Agricultural Research Organization, P.O. Box 2003, Addis Ababa, Ethiopia*

ABSTRACT

In spite of its importance, research on socio-economic aspects of lowland pulses has been limited. This article attempts to review socio-economic and related studies that were done in the past 10 years; generally focussing on participatory technology development, local seed systems, role of gender and profitability of haricot beans. Results of a 4-year trial (1998-2001) in Melkassa (Adama and Boset areas), Awassa and Alemaya on participatory technology development indicated that farmers' participation was efficient in terms of empowering farmers in using their own variety selection criteria or making free choices and of improving farmers' acceptance of new varieties that would in turn facilitate better adoption. However, it was observed that even though participatory approaches were less costly when done on farmers' fields that were found around research centers, they did not substitute the conventional variety development method. Different studies made between 1996 and 2000 on local seed systems in eastern, southern and central Rift Valley areas described the system, and recommended the necessity of adopting both formal and informal seed systems and observing important seed diffusion mechanisms to ensure availability of seeds to the farmers. Regarding gender, it was observed in a study made in 1999 that there was no productivity difference among male and female-headed households in Boset area. However, differences were observed in the degree of involvement of household members in different farm activities among household types. All farm decisions were generally made by the household head (male or female). A study on comparative economic profitability of haricot bean with other competing crops in wet and dry zones of the central Rift Valley revealed that haricot bean was a very important and efficient user of scarce resources.

INTRODUCTION

Ethiopia stands among the three principal lowland pulses (commonly identified as beans) produced in east African countries (Kirkby, 1999). Haricot bean is the most important pulse crop grown by smallholder farmers particularly in moisture-deficit areas of Ethiopia. Haricot bean, occupying 129.5 thousand ha of land, is the third among all pulses and first among lowland pulses (CSA, 2000). In dry areas where rainfall is relatively low or medium, the crop functions as the most important cash-generating crop following tef. In dryland zones where rainfall is relatively good, it is grown for food (Teshome and Dereje, 1993). It is also used as a security crop in times of failure of major cereal crops (Shimelis et al., 1990). On the other hand, haricot bean possesses the highest share in the volume of export of pulses.

Cognizant of the importance of haricot bean over the past two decades, the national lowland pulses improvement program in collaboration with sister research institutions in the country and abroad has developed and released three export-type and 10 food-type haricot bean varieties for regional and national production purposes. The improved varieties have a potential of increasing the yield attainable by farmers by 4 -10 fold.

Some other studies have also been conducted to assess the performance of haricot bean in different parts of the country. Therefore, this article reviews and presents so far unreported socio-economic research work done after 1990 as prior works were reviewed in the First National Bean Workshop held in 1990.

PARTICIPATORY RESEARCH IN NEW TECHNOLOGY DEVELOPMENT

A 4-year (1998-2001) study funded by the Department for International Development (DFID) was conducted at Melkassa, Awassa and Alemaya sites to find out the merits of the participatory plant breeding (PPB) approach over the conventional approach in variety development among small farmers (CIAT, 2002). The study focussed on two different approaches in crop variety selection; individual farmer participation at Melkassa and Awassa, and participation of a group of farmers at Alemaya. Each site identified a number of user groups. At Melkassa, male and female bean selectors were identified. Further analysis revealed four types of user preferences, namely, pea beans for export, medium-white beans for *nifro* (a local dish), medium-red beans for food and sale, and *shirpo* and *kik*-type beans. Two user groups were identified at Awassa on the basis of fertilizer use; those who regularly applied and needed cultivars responsive to fertilizers, and those who did not and therefore, required genotypes tolerant to low fertility. At Alemaya, three user groups were identified, namely, resource-poor farmers, resource-rich farmers, and women farmers. A total of 50 male and female farmers were purposely selected for Melkassa, 44 for Awassa and 50 for Alemaya areas. At all sites, breeders and smallholder farmers (selectors) evaluated and then selected lines on-station from a diverse germplasm pool of 273 lines at Melkassa, 147 at Awassa, and 250 at Alemaya. They were then made to evaluate and select these lines on their own farms for three consecutive years. Results of the study indicated that there was a better advantage with participatory approach at least in the short period of time in agricultural research and development system. The following major advantages and challenges associated with participatory breeding were observed.

Increased Genetic Diversity

Farmers and communities were exposed to a wider range of bean genetic diversity at all sites. In general, farmers tended to select and retain a larger number of lines than the conventional breeding programs. At Melkassa, farmers selected between five and 38 cultivars individually. At Alemaya, the different user groups selected 12 to 52 lines. The average number of varieties planted by farmers also increased from one to four. Women farmers informally took seeds of their interest during on-station visit for sowing in their farms. In Awassa, the number of lines farmers retained for planting increased from one to six. Number of small- and medium-sized bean lines retained by farmers increased from one to two and that of the large-seeded from 0 to four. Overall, farmer-held bean diversity increased at all project sites. Farmers selected and maintained a larger number of lines to meet their needs.

Farmers' Selection Criteria and Preferences Adopted

Farmers' selection criteria are now better understood. Such selection criteria as seed color, seed shape, seed size, vegetative yield and pod clearance were included as additional criteria in breeding programs at Alemaya and Melkassa (CIAT, 2002). Farmers requested researchers to initiate similar programs for other important crops such as maize at Melkassa and sorghum at Alemaya. In Awassa, the program objectives were revised to include red-kidney and red-mottled lines in breeding program to meet the farmers' demands. Thirty farmers requested for support to start their own PPB trials. The programs at Alemaya and Awassa are now targeting more micro niches. At Alemaya, farmers selected more bush-type cultivars rather than the climbing types.

Improvement of Farmers' Acceptance of New Varieties

As opposed to the conventional method, farmers and other end-users were directly involved in the selection process. Consequently, farmers' access to improved varieties increased due to improved awareness about and capacity to get seeds. In this program, farmers were empowered to get seeds of the varieties they selected through informal seed increases and dissemination, and become main or initial source of information. In addition, their interest to adopt the varieties was easily obtained. In Alemaya, for instance farmers were observed to regard PPB lines as their own and expressed interest in multiplying and disseminating seed of XAN 314 and DICTA 105. Five farmers in Awassa, and 32 farmers in Melkassa expressed their interest to increase seeds of the selected lines on bigger plots. This study also showed that male and female farmers had different preferences. In Awassa region, women showed greater interest in large-seeded bean lines which are destined for home consumption, while men preferred small- to medium-size because of the higher demand in local markets. In Melkassa, female farmers were inclined more to market types than the male farmers.

Farmers' Production and Income

The participating farmers recorded production increases at the three sites. In Awassa, grain yields of participating farmers increased on an average by 38%. It was interesting to note that one of the participating farmers sold the small amount of seed he obtained from the research plot at a price higher by 2 Birr/kg (about US$ 2.5) compared to the local variety. This may be good indication for acceptance of lines by other farmers who bought the lines. PPB lines possessed acceptable seed characteristics. Most of the participating farmers showed willingness to increase the allocation of land to the newly selected varieties. Wider dissemination and adoption of these lines would contribute to increased production, food availability and income.

Capacity Building

Farmers' variety selection and trial management skills were enhanced through practical training during the on-station and on-farm visits. Participatory approach enhanced farmers' skills in identifying biotic constraints and superior genotypes. Communities got wider access to information, selection skills and better agronomic practices during the participatory rural appraisals (PRAs) and meetings, and during visits to the stations. In Awassa, Melkassa and Alemaya, farmers also learnt to evaluate a new variety and compare it with the local one on a research plot. Farmers could differentiate several beans for different quality traits. Farmers raised many issues on diseases, fertility and cropping systems. In Awassa, a farmer designed his own trial to study the effect of different fertilizer rates on a bean variety. Farmers also disseminated seed of the PPB lines. About 30 farmers requested for assistance in conducting PPB trials.

Empowerment

Internal capacities of communities to make wise decision and to work together were strengthened. Farmers were able to decide independently under individual approach and to listen to each other and argue positively in group work. Crop lines were selected based on farmers' own decisions and the lines selected were given names by the farmers. Relations and attitudes between communities and formal researchers improved because of regular contacts, sharing of experiences and materials. In Alemaya, farmers decided the number of lines they could accommodate in future PPB trials for effective selection: six to eight lines for women farmers, and 10-15 lines for resource-poor farmers. In Awassa, lines selected were given names such as '*Ibada Ado*' (i.e. fresh milk), '*Bussuke*' (i.e. a well-fed calf), 'meat without blood' – a name given to large-seeded types which tasted like meat when eaten with a local dish known as '*wassa*'. Other farmers reported some of the lines tasted like fish when cooked. Fast cooking varieties were described as 'food for the hungry' (children). In Melkassa, farmers named their lines as '*gera nema gnata*' (i.e. highly attractive), '*lefe guta*' (with good ground cover), '*diga guta*' (blood replenishing), 'lottery' (a fortune), '*konjit*' (the beauty), '*diniche*' (my potato), '*oda*' (the oak tree, i.e. equating the stem strength, pod load to that of the oak tree and its fruits). Rejected lines were described as '*gerjef gerjef jeaa*' (does not cook well), '*gera inkebu*' (has no belly), '*hinkeleti*' (it has lost weight), '*fon hinkebu*' (it has no flesh) and '*ake bishani*' (it is tasteless).

Shorter Time to Release Varieties

Under the classical breeding system it takes 8 to 11 years to develop and release cultivars. Results of this study showed that the period could be reduced by more than half implying that farmers could access new materials with desirable seed and plant characteristics faster than with conventional approaches, and an option in improving food availability and food security particularly for the poor and marginalized people.

Running Cost

During the 4-year period, conventional breeding was more costly than the participatory breeding at Melkassa and Awassa (Table 1). This could be attributed either to the large number of activities carried out, operational efficiency, program design, personnel costs and other operational costs involved at comparative stages or to the accessibility of farmers' plots to research centers.

Table 1. Running cost comparisons (US $) of conventional (CB) and participatory plant breeding (PPB) programs

	Melkassa		Awassa	
Year	CB	PPB	CB	PPB
1	18.6	0	971.3	4939.0
2	78.3	18.6	6192.0	3688.0
3	2626.6	1030.2	10320.0	4546.7
4	3830.5	1030.2	10320.0	1040.0
5	5214.4	1030.2	-	-
Total (US$)	11,768.4	3,109.2	27,803.3	14,213.7

Source: Adam and Tilahun (2003); Getahun et al. (1995).

Major Drawbacks of PPB

Major drawbacks associated with PPB program particularly among small farmers include: farmers difficulties in selecting from large number of germplasm accessions due to lack of training or missing exposure; participatory programs competing with farmers' time and resources set for other immediate-income-generating activities; farmers expectations of compensation for participation; and lack of official recognition for farmers selected varieties and of supportive policy environment. Participatory programs may not be economical if participation of farmers from distant, inaccessible areas is perceived and this may require incurring additional resources and development of new facilities which may be much more expensive. However, this statement should be verified by another study. On the other hand, individual farmer evaluation as opposed to group evaluation resulted in the selection of large number of lines altogether. As choices of individual farmers did not reflect the common interest of the community or even the participant farmers, the lines selected by each farmer became unmanageable for further selection and narrowing down the number to few lines for release in the production system to meet wider user needs. Chances of commonly selected lines were remote. For instance after 3-4 consecutive years of selection at farmers' fields around Melkassa more than 50 varieties were recommended by farmers for release into the production system of two peasant associations. Therefore, the individual farmer approach may not be good if full participation (participation with no external influence) of farmers is required, particularly under poor and small farmers' conditions.

Analysis of Local Bean Seed Management System

Local bean seed system was studied during the 1996-98 period in the eastern (eastern and western Hararge), southern (Sidama and north Omo zones), and central parts (east Shoa zone) parts of the country where haricot bean is dominantly grown. These areas are situated within altitude range of 800 and 2300 m asl and mean annual rainfall range of below 700 mm in the lowlands up to 1200 mm in the intermediate altitudes. Average land size and family size of the sample farmers ranged between 2.5 and 3.1 ha and 6 people, respectively. The objectives of the study were to analyze the existing local seed system and provision of policy recommendations of issues emanating from the study. Aspects covered included for the most part haricot bean genetic diversity, seed sources, seed management, and seed diffusion. A random sample of 176 farmers was drawn from eastern, and 140 farmers each were selected from central and southern parts of the country. Secondary data and interview using structured questionnaires were used to collect historical information.

Genetic Diversity

The average amount of land allocated to haricot bean compared to other major crops is given in Table 2. Based on the available data, farmers living in the southern part allocated more land to different crops than those living in the central part of the country. However, both allocated the least to haricot bean.

Table 2. Average amount (ha) of land allocated to major crops by a household in the different study zones, 1996.

No	Crop	Southern part	Central part	Eastern part
1	Haricot bean	0.8	0.5	N.A
2	Maize	0.9	0.6	N.A
3	*Tef*	1.4	1.2	N.A

NA Data not available.
Source: Adam and Tilahun (2003); Frew (2001); Getahun et al. (1995).

Haricot bean is grown as a sole crop, inter-cropped with maize or sorghum or alley-cropped with perennial crops, enset or coffee. Study results also showed that in the three sites farmers unanimously grew white varieties mainly for sale, and colored varieties mainly for home use. In the southern zone, most of the farmers grew colored beans whereas in the central zone most (94%) of the farmers grew the white varieties (Table 3). The latter grew mainly small-seeded white varieties followed by medium-seeded cream varieties. The varieties available in the hands of farmers in the southern zone included Awash 1, Mexican 142, Robal, Brown speckled, *Wajo*, *Red Wolaita*, *Baro* and *Dume*. Those available with the farmers in the central zone included Awash 1, Mexican 142, Roba 1, Lemat, Israel, Bora, Red (*Dima*), Black and Mottled. Those in eastern Ethiopia are named *Fosolia*, *Dima*, *Bure*, *Kacha* and *Jiner*. In general, the data in Table 3 does not show any major reduction in growing each crop individually. But farmers in the eastern and central parts seem to move from growing both bean types to one type. Also, few farmers seemed to quit growing haricot bean as the percentage indicated for presently growing farmers in the southern and eastern part went a little bit to a lower level than the farmers used to grow.

Even though farmers grew different types of haricot bean they lost some of their varieties over the past. In the south, between 1974 and 1996, farmers stopped growing such local varieties as "*Kolisho*" (black), "*Barro*" (brown and/or black mixed), "*Koke*" (brown mixed) and "*Logomma*" (red mixed) due to low yield, low market demand, and poor appearance (Getahun and Yeshi, 1989). The major factors determining farmers' preference of the local cultivars were high price, high yield, and good taste. During the same period, farmers in the central part lost their (local) varieties due to poor harvest, low output price and replacement of the old varieties by the improved (new) varieties. Here, most farmers lost the local variety known as "*Lemat*", Israel ("*Chore*") and "*Bora*" varieties mainly for shortage of land, poor food making quality and seed shortage, respectively. Thus, the incidence of loss of haricot bean seed experienced by sample farmers is deliberate.

Seed Sources

There was no uniformity in the type of seed sources across the three locations (Table 4). However, when considering the percentage distribution of farmers it could be generalized that the major initial sources of seeds of both white and colored bean types were purchased from other farmers, traders and NGOs or were gifts from parents and relatives. But giving seed in the eastern part is limited to some extent as some farmers did not give seeds because of the traditional belief that giving fresh crops to others would reduce the productivity of the crops, and some others did not give to those who used it for home consumption and to very weak farmers.

However, in most years farmers got seeds (in descending order) mainly from their own stock, other farmers, traders and NGOs (Table 5). This indicates that the role of the formal system/sector in supplying seeds and influencing farmers has been weak. Another study also indicated that once farmers obtained seed they were more inclined to use their own seed they were cheap and accessible (Almekinders et al., 1994). Seed Management/Seed Replacement

In the three locations, farmers undertook their own seed sorting. In eastern Ethiopia, farmers sorted seeds while it was in the threshing ground, immediately before planting, and by selective uprooting using such marker as pod color, while sorting seeds they looked for soil and sand particles, discoloration of seeeds, damaged seeds, undersized seeds, immature and shriveled seeds. Also, they rejected seeds of other varieties such as Guratti and Sara while leaving some other varieties such as Kenya, Jiner, Bure, Dima and Kacha in the mixture. In eastern Ethiopia, unlike the other locations, women played dominant role in sorting beans. Intra-varietal seed replacement was done mainly when there was seed shortage and for maintenance of the original seed. Seed replacement was not exercised in the southern part of Ethiopia. This showed that farmers used indigenous method of sorting seeds although the methods were labor consuming. Hence, there is a need to develop and/or introduce advanced methods that save labour and are within farmers' capacity.

At all sites, most of the farmers (more than 70 %) were found to store both grain and seed of haricot bean varieties for deferred uses. The major storage structures used were sacks or locally known as *madaberia*, followed by local *gotera* and *dibignit*. Similarly, the majority of farmers did not use any measure to protect their bean stock. The remaining (less than 30%) farmers used chemicals, botanical plants, sunning and cover them with straw, leaves and seeds and mix with ash. These entail launching strong promotional activities towards improving farmers' indigenous technical knowledge and capacity of using better methods of protecting their seeds.

Table 3. Percentage of sample farmers growing different haricot bean types.

	Southern (n=140 farmers)		Central (n=140 farmers)		Eastern (n=176 farmers)	
Bean type	Presently growing	Used to grow	Presently growing	Used to grow	Presently growing	Used to grow
White beans	2.2%	3.35%	96.0%	94.2%	29.9%	28.3%
Colored beans	92.0%	94.05%	4.0%	0.7%	28.8%	26.6%
Both	2.95%	2.6%	0.0%	5.1%	37.7%	44.8%
Overall	97.15%	100.0%	100.0%	100.0%	96.4%	99.7%

Source: Adam and Tilahun (2003); Frew (2001); Getahun et al. (1995); and Personal calculations.

Table 4. Percent distribution of farmers for initial seed sources.

	Southern zone		Central zone		Eastern zone	
Initial seed source	White	Colored	White	Colored	White	Colored
Purchase	100.0	94.6	65.6	61.4	47.3	38.2
Research Center	6.2	-				
MOA			3.4			
Trader	12.5	40.0	42.9	39.8		
NGOs	25.0	2.3		1.1		
Farmer	56.3	52.3	19.3	20.5		
Loan			2.5	1.1	6.1	8.5
Exchange			2.5	21.6	9.8	4.5
Gift			29.4	15.9	26.1	44.0
Other/combinations	-	5.4			4.8	10.7

Source: Adam and Tilahun (2003); Frew (2001); Getahun et al. (1995).

Table 5. Percent distribution of farmers against usual seed sources (in most years).

	Southern zone		Central zone		Eastern zone	
Initial seed source	White bean	Colored bean	White bean	Colored bean	White bean	Colored bean
Own Stock	23.3	26.6	74.1	79.4	N.A	N.A
Purchase from farmer	37.9	27.9	10.0	6.7	N.A	N.A
Purchase from trader	24.6	19.5	14.0	8.7	N.A	N.A
Purchase from MOA	3.6	6.5			N.A	N.A
Purchase from NGOs	10.7	19.5			N.A	N.A
Exchange			0.2	4.2	N.A	N.A
Gift			1.1	0.5	N.A	N.A
Loan			0.6	0.5	N.A	N.A

N.A.=Data not available.

Source: Adam and Tilahun (2003); Frew (2001); Getahun et al. (1995).

Seed Diffusion

The seed diffusion mechanisms identified in all of the study areas included sell/purchase, gift and exchange. Sell/purchase and exchange were prominent. The practice of giving seed was not a regular channel of seed diffusion. Gifts and sales depended on the color of the varieties. In central Ethiopia, usually seeds of colored beans were given as gift whereas the white beans were sold as they fetched better price. The seed diffusion relied mainly on the informal system (Frew, 2001; Adam and Tilahun, 2003). This supports the argument given by Almekinders et al. (1994) for own sources of seed that the activity of the formal seed system has been unsatisfactory, and the informal system has been both cheaper and accessible to farmers.

In countries like Ethiopia, where local bean genetic diversity is very low, it is not sustainable to rely completely on informal seed diffusion. The informal system has to integrate itself with the formal seed system for infusion of better varieties (Frew, 2001). The amount of seed purchased by farmers for different purposes ranged from 1 kg to 200 kg. This implies that attempts to sell bean seed should focus on different packages that meet the heterogeneous interest and capacity of the farmers.

Gender Analysis in Bean Production

The study on gender was conducted in Boset Werda, which is one of the major haricot bean growing areas in the central Rift Valley of Ethiopia with the objective of identifying gender differences in bean production across households. The study was done on a sample of 160 households constituting 88.3% land owning and 11.7% landless (but renting) farmers (Dawit, 2002). Gender wise 92.3% were male and the remaining either widowed or divorced female-headed farmers. Nearly all (96%) of the sample farmers grew improved varieties, and only 4% grew the local varieties. The study investigated differences among households mainly in land allocation, agronomic practices, productivity, in sale of produce, and in decision making.

Land Allocation

Haricot bean is important to males as cash source and as food crop but is generally a cash crop for females. Female-headed (FH) followed by male-headed land renting households (MHL) allocated higher proportion of their cropland to haricot bean as compared to other households (Table 6). The proportion of total cropland allocated to haricot bean ranged form 30% for male-headed to 40% for female-headed households. Mean difference in land allocation was statistically significant for male-headed with one wife (MHoW) and male-headed with many wives (MHmW) and MHmW and FH at P=0.1. Mean difference in proportion of land allocated to haricot bean was significant for MHmW and FH and MHmw and MHL at P=0.05 level (Dawit, 2002). The MHmW households allocated larger cropland for haricot bean as compared to the other household types. On the other hand, FH followed by MHL households allocated higher proportion of their cropland to haricot bean as compared to the other households. It can be inferred that the results in both cases entail the direct and indirect influence of females as there is an indication that females benefit from sales (obtaining better price) and less labor requirement for haricot beans. However, further study is required to establish this statement.

Agronomic Practices

The data on agronomic practices indicate that male-headed households did most of the hard works (Table 7). Female-headed households usually employed outside labour in doing most of the farm activities. However, as opposed to those in the female-headed households, females in male-household head families did such activities as weeding and winnowing themselves.

Productivity

The data on productivity showed that female-headed households obtained lower average yields (3.4 q/ha) than male-headed farmers (4.1 q/ha). However, both attained more than 43% lower yield than the national average yield of 7.92 q/ha (CSA, 2000). On the other hand, the study identified plot size allocated for haricot bean, ox ownership, off-farm activity and the dummy variable for landless households as statistically significant determinants of the haricot bean yield. These variables had a positive effect on the yield achieved per unit area implying that higher yield of haricot bean was achieved with the increase in the level of each variable. Those farmers owning relatively better land and oxen and those involved in additional off-farm activities, i.e., MHL households achieved highest productivity.

Sale of Haricot Bean

Significant difference was observed in the involvement of family member groups among household types in selling beans (X^2 =122.1). In both male and female cases, the head of the family got involved more in selling beans than the other members. The involvement of females in male-headed households was remote. However, considering the form of land acquisition, the non-resident farmers unlike the residents, selling of haricot bean was done jointly by adult females and males. Considering all cases, household members (such as children) did not undertake the activity (Table 8).

Table 6. Cropland allocation for haricot bean in Boffa area, 1998/99 crop season.

Family type	Haricot bean land area, in ha	Share of haricot bean land in cropland
Male-headed (one wife) owning land	0.57	0.33
Male-headed (many wives) owning land	0.74	0.3
Male-headed renting in land	0.69	0.39
Female-headed owning land	0.54	0.40

Source: Dawit (2002); Personal calculations.

Table 7. Household and gender difference in agronomic practices

	Household types		Gender	
Agronomic practice	Male-headed households (MHH)	Female-headed households (FHH)	Males	Females
Seed cleaning	Yes, but more than FHH	Yes	Yes	Yes
Ploughing	Yes	No (Recruit)	Yes	Not at all
Sowing	Yes	No (Recruit)	Yes	Not at all
Fertilizing	Yes, but more than FHH	Yes	Yes	Yes
Weeding	Yes	Not at all	Yes	Yes
Harvesting	Yes	Yes	Yes	Yes
Transporting	Yes	Yes	Yes	Yes
Piling	Yes	Yes	Yes	Not at all
Threshing	Yes	Yes	Yes	Yes
Winnowing	Yes	Not at all	Yes	Yes
Storing	Yes	Yes	Yes	Yes

Source: Dawit (2002); Personal modifications.

On the other hand, female-headed households sold their produce at higher prices (on an average 10% higher) as compared to the other household types (significant at a P≤ 0.1) (Dawit, 2002). The reasons were those females, who practiced retail selling had higher bargaining ability and were capable of predicting the price variation even within a single market day.

Decision Making

Results of the study showed that all decisions of bean production starting from the choice of the variety for planting up to the use of income from haricot bean sale were generally made either by the household head alone or in consultation with his spouse(s) (Dawit, 2002). In female-headed households decisions are made by the HHD, except in few cases where either adult family members or relatives were consulted.

The implication of these findings is that in addressing the issue of transferring improved haricot bean technologies efficiently both the household head and the wife should be first consulted and be convinced in male-headed with one wife and non-resident farmers' households, whereas the household head alone in female-headed and male-headed with more than one wife households.

Production Constraints

Lack of oxen followed by lack of improved haricot bean seed were the major constraints across households. Shortage of oxen affects farmers severely to the level that farmers fail to perform farm activities timely. The problem of seed is another challenge for farmers as they are either unable to save seeds for the next season or there is no sustainable seed supply. Differences were observed in the degree of importance of the other constrains across households as shown in Table 9.

Comparative Profitability of Haricot Bean

A comparative crop profitability study was conducted during 1990-1992 in the wet and dry zones of the central Rift Valley of Ethiopia where haricot bean is grown as one of the major crops. The target zones were identified based on differences in the degree of moisture stress, crop mix, soil type, and importance of livestock. A total of 90 sample farmers were selected using two-stage random sampling technique. The study was meant to determine the major inputs and outputs, costs and benefits, and comparative profitability of the crop to justify the contribution of the crop and the allocation of resources among crops. The crops considered were maize, haricot bean, *tef* and potato for wet zone, and maize, haricot bean, *tef* and sorghum for the dry zone. Results showed the profitability of crops from two approaches. The first pertained to individual farmer's perspectives where market prices were used and taxes and interest were treated as costs. Using the 1992 prices and labor valued in cash the costs associated to haricot bean were generally lower than the other crops. However, component wise costs associated with other variable inputs than labor (i.e., seed, fertilizer and service costs) were higher for haricot bean than for maize in wet zone and sorghum in dry zone. Lower yields were obtained for haricot bean and *tef*. However, the net return for land and management was greater for haricot bean than for the other crops in both dry and wet areas. Analysis of the rate of capital turnover also suggested that haricot bean was the most efficient crop in utilizing capital (Table 10).

Table 8. Involvement of household members in selling beans (% of bean growing households).

	Household by gender types		Household by form of land acquisition	
Member group	Male-headed* (N=95)	Female-headed (N=23)	Land owning, occupant (N=87)	Land renting in, non-occupant (N=31)
Adult male	53.7	4.3	49.4	29.0
Adult female	2.1	91.3	26.4	-
Adult female and male	34.7	-	14.9	64.5
Adult male and children	2.1	-	2.3	-
All family members together	2.1	-	2.3	-
Do not undertake the activity	5.3	4.3	4.6	6.5

* Include non-resident male farmers also.

Source: Dawit (2002); Personal calculations.

Table 9. Production constraints and their priority among household types.

	Ranking by household types				
Constraint	Male-headed (monogamous, resident)	Male-headed (polygamous, resident)	Female-headed (resident)	Male-headed (non-resident)	Total
Lack of improved seed	2	2	2	2	2
Shortage of land	-	-	4	3	*
Shortage of oxen	1	1	1	1	1
Lack of fertilizer	4	3	5	4	*
Shortage of rainfall	3	4	3	5	*

Source: Dawit (2002); Own modifications.

Table 10. Costs and returns analysis of haricot bean and other major crops among small farm holders of wet and dry zones (labour valued in cash, 1992).

	Haricot bean		Tef		Maize		Potato	Sorghum
Item	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Yield (kg/ha)	1040	963	1041	962	1473	1324	9880	1213
Gross benefit (Birr/ha)	1404	1300	1770	1635	1134	1020	2964	691
Labor cost (Birr/ha)	241	220	805	748	389	361	775	345
Labor (wd/ha)	48	48	150	139	82	82	166	78
Other variable input (seed fertilizer and service) costs (Birr/ha)	384	175	456	229	243	190	1667	114
Fixed costs (Birr/ha)	22	22	24	24	24	24	22	24
Cost of capital (Birr/ha)	22	14	64	50	44	38	44	32
Total cost (Birr/ha)	669	431	1352	1051	700	613	700	515
Net returns to land and management (Birr/ha)	735	869	488	548	453	407	434	176
Rate of capital turnover (%)	210	302	131	156	131	166	162	134

Source: Senait (1993).

Table 11. Economic profitability of haricot bean and other major crops in wet and dry zones (1992 prices).

	Haricot bean		Maize		Tef		Sorghum
Item	Wet	Dry	Wet	Dry	Wet	Dry	Dry
Yield (kg/ha)	1040	963	1473	1324	1041	962	1213
Gross benefit (Birr/ha)	1473	1364	1547	1390	1997	1847	1203
Labour cost (Birr/ha)	241	220	393	361	808	748	345
Labor (wd/ha)	48	48	83	82	150	139	78
Other variable input costs (Birr/ha)	345	180	202	166	639	222	116
Fixed costs (Birr/ha)	2	2	4	4	4	4	4
Total cost (Birr/ha)	588	402	599	531	1451	974	465
Net returns to land, labor and management (Birr/ha)*	1126	1182	1341	1220	1354	1621	1083
Net returns to land and management (Birr/wd)	23.4	24.6	16	15	9	12	14
Net returns to land and management (Birr/ha)	887	962	948	859	546	873	738

*Labour not valued in cash. Source: Senait (1993).

The other aspect considered was the society where costs were made to reflect social or economic values. Shadow prices of haricot bean were calculated following the method of Gittinger (1982). Free-on-board (FOB) prices at port Assab and at US Gulf and transport and insurance costs required to obtain cost-insurance-freight (CIF) expenses at port Assab were taken for maize and sorghum as these crops were internationally traded crops. Thus, after considering all fees and charges included in the price of each crop shadow prices of haricot bean, maize and sorghum at Nazaret were determined as Birr 1416/t, 1048/t and 993/t, respectively. The remaining inputs were valued at market prices as these were assumed to reflect true economic values. As in the survey area maize was an important substitute for *tef*, the world price of *tef* was calculated based on the world market value of maize that could be bought by cash switched from *tef*. The analysis of costs and benefits showed that using the 1992 prices and labor valued in cash, the costs associated with haricot bean were also generally lower than the other crops. However, component wise, cost related with other variable inputs than labor was higher for haricot bean than for maize in both zones, and sorghum in dry zone. The net return per unit of land and management was greater for haricot bean than for the other crops in the dry zone only. In the wet zone, haricot bean followed maize (Table 11). Overall, in spite of the very little attention given to haricot bean field management, the crop was found to generate the highest net return for individual farmers. However, from a national (society as a whole) perspective, haricot bean was found to generate higher net return than the other major crops in the dry zone only. The profit earned by haricot bean emanated mainly from the gain in haricot bean price. The study verified that haricot bean was an efficient user of scarce resources such as labor and capital. On the other hand, haricot bean was most liked by farmers as it fetched them good price, and as it matured early it served them as the most immediate means of covering their financial needs. Therefore, the crop is a very important enterprise in the farming communities and requires the attention of policy-makers in solving problems of haricot bean production.

CONCLUSIONS AND RECOMMENDATIONS

Preliminary results on participatory research in new technology development showed that there were a number of advantages from both conventional and participatory approaches. The gains of the participatory system and other indirect gains that were possible to arise out of these emphasize that previous effort were either overlooked or were not geared to address most important, probably, the corner stone of agricultural transformation elements. On the other hand, the irreplaceable merits of the conventional breeding system in identifying suitable and outstanding technologies (crop varieties in this case) that are not possible through simple work (i.e. simple selection that is within reach of farmers' indigenous technical knowledge) cannot be relegated to the ground. Lines selected under the classical method are not necessarily adapted to local environments. These situations suggest further investigation in delineating either a boundary or policy option beside the complementary relationship that exists between the two approaches. There is a need for further strong effort to place a demarcation on the nature and degree of involvement of different stakeholders in technology development, and to institutionalise participatory approaches in the research system. However, the merits of participatory approaches in terms of their applicability for much wider environments and the associated resource implications should be further studied before any policy is to be drawn. The seed system studies made in the past indicated that farmers' sources of haricot bean were the indigenous seed diffusion mechanism including barter/exchange, sale, gift and loan and farmers' own stock. The indigenous system has been a major means for haricot bean seeds to survive as seed and germplasm. However, this system is disorganized and incapable of meeting the requirement for seed of market demand. It is also variable in its function particularly in eastern Ethiopia. The operation of the formal seed system has failed to reach the small farmers in complex environment. It focused on specific crop varieties, and discriminated few and resource-rich farmers. In view of the shortcomings of both the informal and the formal systems, it is recommended that institutional transformation of the former system be given priority and thereby facilitate the complementary role of the two systems if immediate action to promote efficient seed supply system is desired. The informal system allows for various diffusion mechanisms, flexibility in operations and simple access to seed. The formal seed sector could organize the diffusion of new cultivars and supply of good quality seeds to the farmers. The integration of the two systems through participatory approach and secondary seed multiplication scheme and infusion of new and acceptable varieties will play a major role in ensuring the availability of quality seed to the farmers at reasonable prices.

From the results of gender analysis it can be inferred that farm size, land tenure system, oxen availability, improved seed availability and the degree of involvement of family members have been the most important factors creating differences in the productivity of farmers. Therefore, besides further studies to refine the facts obtained from the study regarding farm size and land tenure system, it is recommended that a favourable credit system is created to help farmers obtain farm inputs including oxen, organize the complementary operation of the informal and formal seed production and dissemination of improved seeds, and identify the right household heads for promoting effective extension message. These would be very important to mitigate differences in productivity of farmers.

Results of a study on comparative profitability of haricot bean showed that the crop was more profitable than the other major crops (*tef*, maize, sorghum and potato) both in the wet and dry zones of the central Rift Valley of Ethiopia and it was the most efficient user of capital. Since labor was the main limiting factor in the survey area, especially during weeding and harvest (peak periods), and haricot bean requires less labor and earns higher net return (Birr/ha) which indicates that its cultivation should be encouraged. However, haricot bean production suffers from impure seeds, which affect its price competitiveness and the demand at the world market. Hence, suitable measures should be taken to produce and distribute pure and clean seeds.

REFERENCES

Adam Bekele, and Tilahun Mulat. 2003. Haricot bean seed management in the central Rift Valley of Ethiopia. Research Report No. 50. Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Almekinders, C.J.M., N.P. Louars, and G.H. de Bruijn. 1994. Local seed systems and their importance for an improved seed supply in developing countries. Euphytica 78: 207-216.

CIAT. 2002. Participatory plant breeding with women and small farmers in Africa and Latin America (Draft report), January 2002. Internacional de Agricultura Tropical (CIAT), Colombia.

CSA. 2000. Area and production for major crops. Agricultural sample survey 1999/2000. Statistical Bulletin No. 227. Central Statistical Authority (CSA), Addis Ababa, Ethiopia.

Dawit Alemu. 2002. Productivity difference in bean production among household types in the Central Rift Valley of Ethiopia. *In* Proc. 10th Biannual Conference of the Crop Science Society of Ethiopia. June 19 - 21, Addis Ababa, Ethiopia.

Frew Mekbib. 2001. Local bean seed systems study in Eastern Ethiopia: Implication for establishment of sustainable seed system. *In* Proc. Ninth Annual Conference of the Crop Science Society of Ethiopia (CSSE), 22-23 June 1999, Addis Ababa, Ethiopia *Sebil* 9: 127-140.

Getahun Degu, Soniia David, and Shiferaw Tesfaye. 1995. An assessment of the local seed systems in bean growing areas of Sidama and North Omo Zones, Southern Ethiopia. Unpublished Report.

Getahun Degu, and Yeshi Chiche. 1989. Evaluation of farmers' preference for haricot bean varieties: Shebedino farming systems zone, Sidamo Region. Working Paper No.6, Institute of Agricultural Research (IAR), Addis Ababa.

Gittinger J.P. 1982. Economic analysis of agricultural projects. Second Edition. EDI Series in Economic development. World Bank, Washington

Kirkby, R.A. 1999. Evolution of the eastern Africa bean research network and objectives of the workshop. *In* J.B. Smithson (Ed.). Proc. Third Multidisciplinary Workshop on Bean Research in eastern Africa, 19-22 April 1993, Thika, Kenya, Network on Bean Research in Africa. Workshop Series No. 28. CIAT, Kampala, Uganda.

Senait Regassa. 1993. Comparative profitability of haricot bean production in Ethiopia. p. 256-263. *In* J.B. Smithson (Ed.). Proc. Third Multidisciplinary Workshop on Bean Research in eastern Africa, 19-22 April 1993, Thika, Kenya. Network on Bean Research in Africa. Workshop Series No. 28 CIAT, Kampala, Uganda.

Marketing of Pulses in Ethiopia

Gezahegn Ayele[1] and Dawit Alemu[2]

[1]DebreZeit Agricultural Research Center, P.O. Box 32, Debre Zeit, Ethiopia, [2]Melkassa Agricultural Research Center, P.O. Box 436, Nazareth, Ethiopia

ABSTRACT

Pulses provide an important economic advantage to small farm holders in providing alternative source of protein, cash income and food security. It is known that the availability of pulses have never been in surplus in the subsistence farming community of Ethiopia. There is, however, marketing of pulses at a limited scale both in domestic and export markets. It is often claimed that internal market seriously competes with the external market. Although, marketing pulses evolved traditionally in a village market and expanded to urban market economy, studies indicate that the share of export market is still limited by external demand for quality like any other primary commodities. The domestic prices are often related to the seasons of sale, the distance of flow and size of the market. Prices of pulses in the central highlands appear to fall rapidly during February to March following major harvest and then start to increase gradually from May to August. Recent studies on marketing indicated that prices of lentil and chickpea were highly influenced by quality factors. Grain color, seed weight, percent of foreign (inert) material, protein content and percent of shriveled seeds affect significantly the performance of domestic markets. The export market, although seems to be increasing, fluctuates every year and is limited by market demand and also supply. Haricot bean covers the dominant part of the country's pulses export. Recent trend shows that there are more potential markets opening up for certain pulse groups. The major constraints for the expansion of pulses export are related to the production problems (poor seed system, limited surplus production, poor quality, lack of producer incentives during low price), capacity of exporters (poor bargaining power, poor marketing skills, lack of finance, absence of certification for the organic nature of the product), limited export trade support (poor market information and dissemination, poor marketing infrastructure), and international trade barriers. Thus, a concerted effort is required for improving the pulses production through improvement in quality and productivity, generation of pulse technologies, through improvement in the capacity of pulse exporters, and provision of appropriate pulse exports trade promotion.

INTRODUCTION

Pulses are the second most important crops next to cereals and are mainly grown by small farm holders in the highlands of Ethiopia. The four major highland pulses in Ethiopia are fababean (*Vicia faba* L.), field pea (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.) and lentil (*Lens cultinaris* Medik.). The major lowland pulse is haricot bean (*Phaseolus vulgaris* L.), which is produced all over the country although the major producing area is the central Rift Valley of lowlands. It is where the dominant part of the exported haricot bean is usually produced and the varietal selection under small-scale farmers' conditions is determined by the demand in the export market. All the major highland pulses are believed to have domesticated in the Southeast Asia, from where the geographic distribution occurred to the temperate as well as tropical regions of the world, including the Ethiopian highlands. Ethiopia is considered as the secondary center of diversity for the highland pulses which provide an important economic advantage to the small farm households in providing alternative source of protein, cash income and soil amelioration as a break crop in the cereal dominated farming system. In spite of its importance, the productivity and marketable surplus has remained very low. The major constraints contributing to low productivity are low yielding potential of land races and their susceptibility to biotic and abiotic stresses, and poor cultural practices.

Food legumes serve as a mean of food security and source of cash. Smallholder farmers have hardly produced enough for the market except haricot bean and the market is limited by its supply. However, it is evident that whatever surplus is in the market, it is marketed either in the local market or exported to distant markets. The objective of this article is, therefore, to examine the structure of pulse crops markets, both local and international, and analyze the constraints of the markets.

MARKET STRUCTURE

Domestic Market for Pulses

It is believed that the domestic market for pulses seems less organized as compared to cereal markets. Market chains are absent and interaction for dealers and brokers are less visible compared with cereals like *tef.* Pulse marketing in Ethiopia still remains predominantly a characteristic of village markets where the quantities involved in transactions are relatively small. Large markets are radiated in Addis Ababa terminal or central markets. However, it would be difficult to estimate the volume of transaction entering into Addis Ababa market. Among the pulse crops, the haricot bean market is relatively organized as the production is linked with the international markets.

In 1990 and consequently 1992, the marketing and pricing policy was deregulated after heavy criticism of the uniform producers price and quota levying policy of the military regime. Following the market liberalization policy of the government, the measures have been taken by the Transitional Government of Ethiopia (TGE) to improve the role of the private sector in grain marketing. The reform policy included: (a) abolition of grain quota levies and fixed grain prices, (b) lifting of all inter-regional grain movement control, and (c) allowing the private sector to operate in grain marketing as determined by market forces. The role of the state was confined to a regulatory role. Since 1975/76, the Ethiopian Oilseeds and Pulses Export Corporation (ETOPEC), a marketing organization, has been responsible for the export of oilseeds and pulses in the country with a market share of about 70-75% of the nation's export of pulses.

Unlike the controlled market, which used to exist pre-1991, market for pulses now operate on the open market regime. The private traders have been active in the open markets after 1991. On the part of the public, the government established the Ethiopian Grain Trade Enterprise (EGTE) that operates in the market parallel to private traders. However, following the economic reform in the country, ETOPEC was merged with EGTE in 1999. Currently, EGTE has its own modern and big stores at various places of the country with a capacity of storing more than 600,000 t. It also has its own seed cleaning and grading machine, and undertakes hand-picking to separate the mixture using women labor force. The share of EGTE in pulses marketing in general and haricot bean trade in particular has been declining from year to year mainly due to the increasing active participation of private exporters. The amount of grain purchase was limited due to the limited capacity of ETGE. It is estimated that only about 2% of the total grain sold is purchased by EGTE. The grain marketing in Ethiopia and particularly of pulses is characterized by the seasonal nature changes from time to time depending on production level in the area. It is even less than the total in the case of pulses. Out of the total production it was estimated that about 26% of the pulses was marketable surplus (Girma, 2003). Producers of chickpea, faba bean, field pea and lentil often sell their surplus directly to consumers or traders. EGTE purchases are often targeted for export in the case of pulses. The amount of local purchase capacity by ETGE for pulses is provided in Table 1.

The intermediaries buying grain from farmers are retailers, wholesalers, assemblers, and processors or in some cases farmers who themselves are grain traders. Assemblers or part time traders collect and bag the produce and then deliver to processors and/or interregional traders. Based on the informal survey made in 2001, the most important haricot bean market participants are producers (small-scale farmers, private and state farms), village collectors, wholesalers, brokers, processors, EGTE, private exporters, and foreign buyers (Demelash, 2003). In the central Rift Valley, which is the major haricot bean producing area in the country, the crop is mainly produced for the export market and the selection of the varieties under small-scale farmers' condition is determined by the demand in the export market. As most farmers produce export-type of haricot bean, they usually purchase from the market food types (Dawit and Yeshi, 2003).

Small-scale producers usually sell their produce in local markets, and to village collectors and local consumers. Village collectors buy mainly from farmers (rural markets) and sell to wholesalers in the same place and/or urban centers. They mostly receive cash from wholesalers and get commission (2-3 *Birr*/kg) based on the total quantity purchased. None of the village collectors are either licensed or own the grain storages. But, they do have weighing scales (owned or rented).

The marketing chain also differs among the individual pulses commodities depending on the market share of the respective commodities. Wholesalers receive haricot bean from village collectors and producers, and some of them supply the produce to other wholesalers whereas others supply to exporters with or without the assistance of brokers. Some wholesalers receive advance payments from exporters, which serves as a pre-condition that the wholesaler should supply the product to the money providers. Most of the wholesale traders are licensed, however, due to the influence of the emerging unlicensed traders in the business, some of the traders returned their licenses and started operating unlicensed. Almost all the wholesale traders own storages. No wholesale trader is specialized in chickpea, lentil or haricot bean trade, rather they are involved generally in the grain trade and allocate their resources according to crop harvest period and profit motives. Some wholesalers go down to rural markets with their trucks and collect the crop purchased by village collectors. Besides, in some cases they are also involved in direct purchase from producers.

In the case of haricot bean, almost all big and experienced haricot bean exporters are also owners of seed processing machines. The processors also process the seeds of other exporters on payment of 5 *Birr/kg*. Ethiopian standard and quality authority approve the seed processing certification. The purpose of the processors is to clean and separate mixtures to the accepted export level. The typical case of lentil marketing for processing is located around central Ethiopia (Sendafa/Alelitu). It is labor intensive kind of processing based on the manual labor. Retailers can be in some cases small-scale processors selling the lentil after processing to consumers. Often, lentil varieties with red cotyledons are preferred for processing. Splitting is the main processing activity for lentil.

Urban wholesalers buy grain and sell it to retailers, processors and also consumers. In some of the major towns of the country of surplus areas the wholesalers also transfer grains to other towns and areas. Descriptive quality standards are often applied in the grain marketing of Ethiopia to fix the price. It is equally true that this descriptive quality is also applied to determine prices visually in the market date. These standards are mostly based on variety, color and origin. According to Gezahegn and Tekalign (2003), the quality characteristics of chickpea and lentil are affected by seed sizes, color preferences, inert materials and protein quality would affect prices of pulses at any market date. Some of the evident quality characteristics were verified using laboratory analysis and using hedonic price analysis found out to confirm to the evident quality. This indicates that domestic market would move also spirally with relevant quality characteristics of pulses. Some of the quality characteristics are evident in the market and easily observable by the consumers on a given market date. The quality characteristics should be systematically and cautiously identified.

Price Movements in Domestic Marketing

Grain prices in Ethiopia have increased almost more than 100% following the devaluation post-1992 reforms and other input prices. It is equally true for chickpea and lentil. Nevertheless, the advantage with the price increase is not spirally seen as in other grains with input prices. The price change caused by devaluation had no significant effect on pulses since they are low input crops and rather serve as input for other grains in terms of ameliorating soil depletion through crop rotation. In the domestic market, it was clearly found out that quality characteristics determined the prices of cool seasons food legumes particularly chickpea and lentil.

Export Marketing of Pulses

Generally, the Ethiopian structure of export market is uniquely determined with a single agricultural commodity, i.e., coffee. Of all the export markets or export earnings generated through agriculture coffee accounts for 62% of foreign exchange followed by skin and hides (EEPA, 2003). The overall export performance in the past three decades also witnessed the same trend as only one or two crops dominated the market. The indication is that the Ethiopian export remains so rigid that no diversification has taken place as major source of exchange earning. It is true that without diversification of the export market, export earnings would remain highly volatile. Pulses can be one of the potential crops to play the diversification role although their share in the overall export market remains insignificant. The share of pulses was 4.38% in 1982 and 0.93% in 1991 (Hailu et al., 1995). This trend did not show significant change although Ethiopia is being considered as a major producer of pulses in Africa (Table 2).

For exporting pulses there are certain minimum requirements that exporters should fulfil. First, certification of agricultural products cleanliness and quality from seed cleaning houses; and second, sales contract that contains details about seller, buyer, commodity type, quality, quantity, price, packaging, shipment and payments. Then, exporters present their request with the above-mentioned documents to the Ethiopian Quality and Standards Authority (EQSA) for inspection. The EQSA inspectors go immediately to the storage house and undertake inspection as per the sales contract and within the limits of Ethiopian standards. For processing, the exporter should submit the bank permit, commercial invoice, phytosanitory certificate from Ministry of Agriculture (MoA), custom declaration from the Ethiopian Customs Authority (ECA), and service charge payment for EQSA so that the exporter will get export authorization certificate from EQSA. The export process from the sales contact to the sale takes on the average about 10-15 days, and to receive money it takes about two months. The domestic exports process is not bureaucratic and takes about three to seven days. However, some exporters responded that ECA does not pay attention to exports as it does to imports, and it lacks human resources in MoA to provide phytosanitory certificate.

Recent statistics showed that pulses accounted for about 2% of all the exports but had a growing trend in the near future with the world demand in the Middle East and Far East countries (NBE, 2002). The types of product included in the pulses group consist of field pea (shelled or unshelled, fresh or chilled dried and shelled), chickpea (dried and shelled), black or green gram (dried and shelled), haricot bean (small red dried and shelled), lentil (dried and shelled), faba (broad) bean and horse bean (dried and shelled) and soybean. They are often graded and assorted to meet the export market requirements.

Table 1. Prices of major pulse crops per 100 kg in Ethiopian Birr.

Crop	1989	1990	1991/92	1992/93	1993/94	1994/95	1995/96
Chickpea	85	76	79	125	116	172	185
Lentil	149	88	92	187	190	212	223
Pea	104	92	76	77	144	135	208
Faba bean	73	81	68	61	110	109	173

Source: Girma (2003).

Table 2. Volume of exports of pulses commodity (in metric t).

Commodity	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Pulses Total	23,354	14,759	1,398	1,527	9,894	25,783	28,969	30,468	30,909	40,649	23,527	25,247
Growth of total pulse export (%)		-58.23	-955	8.44	84.5	61.6	10.9	4.9	1.42	23.96	-72.77	6.8
Lentil	97	30	-	7	-	-	-	5	-	180		
Horse bean	-	100	1,397	-	-	-	3,199	1,233	196	161		
Haricot bean	23,257	14,434	-	1,493	3,094	-	-	-	-	-		
Others	0	195	1	27	6,800	25,783	25,770	29,230	30,713	40,309		

Source: NBE (2002).

Diversification could take place with pulses, oilseeds and spices of the traditional crops of Ethiopia. In recent times, pulses and oil seeds have become one of the major export earning commodities of the country, and one of their comparative advantages in the export market is their value since they are produced organically. Major groups of pulses for export include haricot bean, field pea, faba bean, chickpea, and lentil. The major market partners for the export of Ethiopian pulses are the Gulf States, Saudi Arabia, Yemen, Algeria, Morocco, Israel, and more recently Pakistan and Afghanistan.

In 2000/2001, Ethiopia exported 111,857 t of pulses which valued 286 million Birr, and was by far the largest portion compared with spices and oil seeds (Table 3 and 4). The major share of export contribution of pulses to the foreign exchange earning can be explained by looking at the share of export earnings in 2000/01. It was found that the export-earning share of pulses accounted for 8%, while in the same period oilseeds and spices contributed 7.7% and 0.8%, respectively, and the total share of the three almost added up to 16% of the total export contribution of foreign exchange earnings. This trend appears to increase between the periods 2000-2002. The quantity of export pulses, oilseeds and spices showed an annual average growth rate of 102%, 22% and 7.3%, respectively.

Haricot bean comprises the major export share of pulses. Ethiopia has been exporting haricot bean to more than 68 countries found in all the continents for more than 40 years. The share of Ethiopia's haricot bean exports by geographic area for the period 1966-2001 is presented in Table 5. Over the periods under consideration, Europe on the average consumed more than 76 % of Ethiopian haricot bean export (48-92 %). It reached the peak level in 1976/80 (92%), but soon after, it exhibited a decline until 1996-2000 (except 1991-95), however, showed an improvement in 2001. Actually, this reduction was not associated with the absolute figure, but with significant import improvement by African and Middle East countries. According to Canadian Bi-weekly (2002), the Middle East and North African countries collectively imported 6 % of the world's total haricot bean.

Export to Africa and Middle East started to improve from 1995, this is especially due to Algeria, Morocco, and Yemen. Yemen is Ethiopia's traditional importer, moreover, North African countries, like Algeria and Morocco are becoming new markets. In addition, India, Pakistan, and Thailand are also potential new markets. Algeria is known as a traditional haricot bean consumer in the world, though it is a new market for Ethiopia. Algeria has become a major importer of pulses since independence in 1960. According to EEPA (2002), in the earlier periods Ethiopia's exports to Europe were in several cases re-shipped to other countries mainly to Algeria. The recent direction of Algerian import from Ethiopia probably is related to geographical proximity compared to other countries. The International Pulse Conference in 2001 also noted that it was expected that the Middle East and North Africa needed to increase protein supply significantly over the next quarter century (150-170%), however, the list of trade barriers existed such as import permits, labeling requirements and confusion about variety differences.

Table 3. Quantity of Ethiopia's export of pulses, oilseeds and spices (actual and projected) in t.

Product	1998/99	1999/00	2000/01	2001/2	2002/3*	2003/4*	2004/5*	1998*	Annual average growth rate (%)
Pulses	29,832.6	23,527.3	26,742.7	110,856.6	78,690.8	121,942.3	146,330.	190,230.0	54.72
% growth		-26.7	12.02	75.8	-40.8	35.46	16.66		
Oilseeds	51,312.8	42,915.2	54,764.3	85,440.7	104,091	93,984.7	112,781.	146,616.2	18.48
% growth		19	21.6	35.9	17.9	.-0.7	16.6		
Spices	2,687.9	3,284.9	2,696,9	3,167.9	4,617.2	3,484.7	4,181.6	5,436.1	13.29
% growth		18.17	-21.8	14.86	31.8	-32	16.6		

* - Projection. Source: EEPA (2003), and estimates.

Table 4. Value of Ethiopia's export of pulses, oilseeds and spices in thousand Birr (actual and projected)

Product	1998/99	1999/00	2000/01	2001/2	2002/3*	2003/4*	2004/5*	1998*	Annual average growth rate (%)
Pulses	101,658	80,021	74,384	285,990	201,811	314,589	377,506	490,758	47.51
% Growth		-27	-7.5	73.9	-41.7	35.8	16.6		
Oilseeds	271,235	253,735	268,507	318,475	476,026	350,322	420,387	546,503	13.01
% Growth		-6.8	5.5	15.68	33.9	-35.8	16.67		
Spices	23,704	28,554	31,356	31,863	42,323	35,050	42,060	54,677	13.93
% Growth		16.98	8.93	1.59	24.71	-20.75	16.67		

* - Projections. Source: EEPA (2003).

Table 5. The share of Ethiopia's haricot bean export volume (t) by geographic areas, 1966-2001.

Geographic area	Period				
	1981/85	1986/90	1991/95	1996/00	2001
Europe	78.24	76.15	89.66	48.08	53.87
Africa & Middle East	18.25	9.51	10.32	51.36	39.23
Asia	-	-	0.02	0.08	1.85
Others	0.29	14.34	-	0.47	5.06

Source: Demelash (2003).

Future trends of export market portrays that the pulses export would increase in terms of both volume and value. According to EEPA (2003), Ethiopia's export of pulses is projected to grow at the rate of 10% for the period between 1996-1998 Ethiopian financial year (EFY) or 2004-2006 from the base year of 1994 EFY, considering the past monthly average performances of export figures. The future trend of growth in export performance can also be explained by the comparative advantages of production of pulses in Ethiopia. Demelash (2003) quantified the profitability of haricot bean export business. He indicated that, on an average, the highest cost component (62%) of the total cost was purchasing cost in the haricot bean export business. The gross profit from haricot bean export trade in 2002/03 was estimated at 15.57 Birr/q (≈1.81 US dollar). A study by Gezahegn (2002) indicated that there was a comparative domestic advantage of producing chickpea, lentil, faba bean and filed pea with a better technology. Using Domestic Resource Cost (DRC) approach the four cool-season food legumes enjoy a comparative advantage (<1) of their profitability, which tends to increasingly favor domestic production than to import. It is clear from the analysis provided that production of cool season food legumes or pulses would be very profitable using the improved technology. Nevertheless, the demand in the local markets for improved technologies of most of the pulses is lower than the local varieties. This might be probably attributed to the quality related to the varieties than any other characteristics. It appears that breeders and agronomists have to work and devote more efforts to improving the quality of the varieties particularly targeting export markets.

MAJOR CONSTRAINTS

Pulses are generally highly demanded by smallholder farming systems. However, there are serious problems affecting the performance of marketing for cool season food legumes. These crops are severely affected by pests and diseases, which result in a substantial reduction of their productivity, and hence less availability of their supply for marketable surplus. Small farm holders have not yet developed the practice of producing pulses for the markets.

Lack of standards and grades in the local market has been a continuous threat to the improvement of the marketing system. Traders in most of the village markets do not have weighting scale (Eleni, 2001). Prices of pulses are fixed using different sizes of tins and bags. This affects the efficiency of grain marketing in the assembly markets and implementation of marketing information system. Among the most important constraints related to the production are lack of required quantity and the quality, supply instability, and poor incentive for farmers to produce. Major market-related constraints are poor bargaining power and marketing skills of exporters, poor market information and dissemination, absence of certification for the organic nature of the product, poor marketing infrastructure, and international barriers to trade.

Poor quality standards, particularly in the export market, hinder the performance of export diversification. Improvement on the production side requires structural changes in the production, harvesting, storing and processing. Particularly export quality is sub-standard in the case of chickpea and lentil. The awareness of producers and traders on this aspect is important for producing value added commodity and increasing the competitiveness. Research ought to work in this direction to target improvement of market-oriented production of pulses. This has to go also in line with the world demand for quality standard of pulses. Huge amount of subsidies in European markets for agricultural products is another problem creating export barrier for pulses. Despite the fact that Europe is a stable and very developed import market, there are trade barriers, especially non-tariff barriers (NTBs) and domestic subsidies to producers. Although, it is claimed to be a comparative advantage on the supply side this has not been significantly enjoyed in the world market. In general, some of the major constraints continue to be production, increased domestic consumption and higher domestic prices in some years. Such factors coupled with natural calamities such as drought and culminated export market are very unstable.

CONCLUSIONS

One of the major important factors in the transformation of the Ethiopian agriculture into market-oriented and competitive is the existence of good performing marketing system. In general, the performance of agricultural marketing system in the country is constrained by many factors which perform poorly at the domestic and international markets. The same is true with the marketing of pulses. This is due to the production-side problems (poor seed system, limited surplus production, poor quality, and lack of producer incentives during low price), capacity of exporters (poor bargaining power, poor marketing skills, lack of finance, absence of certification for the organic nature of the product), limited export trade support (poor market information and dissemination, poor marketing infrastructure), and the international trade barriers. Thus, appropriate measures are required to improve the pulse marketing system in particular and the grain marketing system in general.

REFERENCES

Dawit Alemu, and Yeshi Chiche. 2003. Gender analysis in bean production: The case of Bosset area. *In* Socioeconomics Research in Ethiopia: Its Role in Technology Generation and Policy Implications. EARO, Addis Ababa, Ethiopia.

Demelash Seifu. 2003. Ethiopia's haricot bean exports: Patterns, market share, constraints and prospects. M. Sc. Thesis, Alemaya University, Alemaya, Ethiopia.

EEPA. 2002. Ethiopia's pulses and oilseeds. Ethiopian Export Promotion Agency (EEPA), Addis Ababa, Ethiopia.

EEPA. 2003. Export projection: Pulses, oilseeds and spices. Ethiopian Export Promotion Agency (EEPA), Addis Ababa. (Unpublished report).

Eleni Gabre-Medhin. 2001. Market institutions, transaction costs, and social capital in the Ethiopian grain markets. International Food Policy Research Institute (IFPRI) Research Report No. 124. Washington, DC.

Gezahegn Ayele. 2002. Technological options, competitiveness and export potentials of some of the selected crops in Ethiopia. Paper presented at the 5th Annual Conference of the Ethiopian Agricultural Economics Society of Ethiopia, Addis Ababa, Ethiopia

Gezhagn Ayele, and Tekalign (2003). Market quality characteristics of chickpea and lentil in eastern Shewa. DZARC (Unpublished report).

Girma Bekele. 2003. The state of grain marketing in Ethiopia: A paper prepared at the EDRI/IFPRI 2020 network policy forum on ""Toward Sustainable Food Security in Ethiopia: Integrating the Agri-Food Chain:" May 15-16, 2003, Addis Ababa, Ethiopia.

Hailu Beyene, Gezahegn Ayele, and Berhanu Lakew. 1994. Marketing of cool-season food legumes. *In* Asfaw Telaye et al. (Eds.) *Cool-season Food Legumes of Ethiopia*. Proc. First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Ababa, Ethiopia. ICARDA/IAR, Syria: ICARDA.

NBE. 2002. National Bank of Ethiopia (NBE) Quarterly Bulletin. Volume 16, No.4, Fourth Quarter 2000/2001.

About ICARDA and the CGIAR

ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR). ICARDA serves the entire developing world for the improvement of lentil, barley and faba bean; all dry-area developing countries for the improvement of on-farm water-use efficiency, rangeland, and small-ruminant production and the Central and West Asia and North Africa region for the improvement of bread and durum wheats, chickpea, and farming systems. ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national agricultural research and development systems.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs is offered, from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.

CGIAR

The CGIAR is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work. The CGIAR receives support from many country and institutional members worldwide. Since its foundation in 1971, it has brought together many of the world's leading scientists and agricultural researchers in a unique South-North partnership to reduce poverty and hunger.

The mission of the CGIAR is to promote sustainable agriculture to alleviate poverty and hunger and achieve food security in developing countries. The CGIAR conducts strategic and applied research, with its products being international public goods, and focuses its research agenda on problem-solving through interdisciplinary programs implemented by one or more of its international centers, in collaboration with a full range of partners. Such programs concentrate on increasing productivity, protecting the environment, saving biodiversity, improving policies, and contributing to the strengthening of agricultural research in developing countries.

The World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the International Fund for Agricultural Development (IFAD) are cosponsors of the CGIAR. The World Bank provides the CGIAR System with a Secretariat in Washington, DC. A Science Council, with its Secretariat at FAO in Rome, assists the System in the development of its research program.

ghazaldesign@gmail.com