Cool-season Food Legumes of Ethiopia

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editors

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Cool-season Food Legumes of Ethiopia

Proceedings of the First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Abeba, Ethiopia

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Citation
Asfaw Telaye, Geletu Bejiga, Saxena, Mohan C. and Solh, Mahmoud B. (eds.) 1994. Cool-season Food Legumes of Ethiopia. Proceedings of the First National Cool-season Food Legumes Review Conference, 16-20 December 1993, Addis Abeba, Ethiopia. ICARDA/Institute of Agricultural Research. ICARDA: Aleppo, Syria. vii + 440 pp.

AGROVOC descriptors
Grain Legumes; plant production; technology transfer; Ethiopia; plant breeding; faba beans; lentils; peas; *Vicia faba*; *Cicer arietinum*; *Lens culinaris*; *Lathyrus*; agronomy; soil fertility; plant protection; plant diseases; pest insects; quarantine; research.

ISBN: 92-9127-020-2

Language editor: Linda J. Sears

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Foreword

Cool-season food legumes are major food crops in Ethiopia where they provide a considerable portion of the daily diet of the people and constitute an important component of its cropping systems because of their role in improving soil fertility through biological nitrogen fixation. The productivity of these crops in Ethiopia is, however, far below their yield potential. Constraints to increased production include unsuitable cultural practices and low-yielding landraces susceptible to biotic and abiotic stresses. Moreover, the transfer of improved production technology to the farmers has been inadequate in recent years.

The collaborative research between the Ethiopian Food Legume Improvement Program and ICARDA, which aims at finding solutions to problems facing the farmers who grow these legumes, has led to considerable achievements in food legume improvement. The work was carried out by a team established under the Nile Valley Regional Program (NVRP) currently supported by the Swedish Agency for Research Cooperation with Developing Countries (SAREC) and previously by the International Fund for Agricultural Development (IFAD) and the Italian Government. All partners in this program appreciate their contributions which have made their work possible.

The NVRP has brought together and streamlined the efforts of three countries —Ethiopia, Sudan and Egypt—and ensured the participation, in each country, of all governmental agencies concerned at the policy, planning, extension and implementation levels, as well as the full involvement of farmers. The undoubted success of the effort owes much to this collaborative approach and the rigor with which it was pursued. The proceedings of the workshop reported upon in this volume are a record of some of the achievements of this cooperative undertaking.

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Preface

Cool-season food legumes have a major role in the diet and economy of Ethiopia. Research on the major cool-season food legume crops (faba bean, chickpea, lentil and field pea) has been extensive, as reported here. Because of its unique adaptation to waterlogged situations and farmers' preference, grasspea deserves much more attention although some work is currently underway. For lupin and fenugreek, research has been minimal, owing to their lesser place in the economy. However, as the population of Ethiopia increases and land resources are increasingly strained, it is clear that a major effort in improvement of all cool-season food legumes in the country is required if the supply is to meet local demand.

The Ethiopian component of ICARDA's Nile Valley Regional Program (NVRP) on Cool-season Food Legumes has received support from SAREC (Swedish Agency for Research Cooperation with Developing Countries) since the 1989/90 crop season. Research scientists from the Institute of Agricultural Research (IAR) in Addis Abeba and its associated Agricultural Centers, and from Alemaya University of Agriculture (AUA), particularly the Debre Zeit Agricultural Research Center, have conducted research in a variety of agroecological zones of Ethiopia to determine the requirements of legume producers on both large and small farms. The overall objective is to develop and transfer improved technology to farmers to increase productivity and yield stability of the major cool-season food legumes and thereby ensure the sustainability of production systems in the country.

The Workshop on cool-season food legumes research brought together Ethiopian researchers and their cooperators to review and assess the research accomplished and to identify future priorities. The challenge to agricultural researchers is to halt the genetic erosion of indigenous landraces, develop improved cultivars suitable for traditional and new production practices, and to improve the economic returns of legume production. It is our belief that the recommendations reported in these proceedings will guide researchers in their efforts to solve some of the important problems facing the farmers.

The Workshop was sponsored by IAR and ICARDA/NVRP with the financial support of SAREC. We with to thank Dr Tadesse Gebre/Medhin, General Manager and Dr Getinet Gebeyehu, Deputy General Manager for Research at the Institute of Agricultural Research, Addis Abeba for their input and continued support. The Workshop was organized primarily by a National Organization Committee. In this regard, we thank the members of the

Committee, namely Dr Asfaw Telaye, Dr Geletu Bejiga, Ato Kemal Ali, Ato Rezene Fessehaie, Ato Hailu Beyene, Ato Gebrehiwot Hailemariam, Ato Amare Ghizaw and Ato Workneh Negatu for their hard work which contributed greatly to the success of the Workshop. To Ms Linda Sears, editor in the Communication, Documentation and Information Services department of ICARDA in Aleppo, we express our thanks and appreciation for preparing this volume for publication. Mr Zakariah Eteck of the same department prepared the graphs.

Last, but not least, the Editors would like to express great appreciation to SAREC for their support of food legume research and transfer of technology to farmers in Ethiopia between 1989 and 1994. Without such support, the achievements documented here would not have been attained.

The Editors

Chapter 1
Cool-season Food Legumes

Role of Cool-season Food Legumes and their Production Constraints in Ethiopian Agriculture

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Abstract

Production constraints under abiotic and biotic factors are briefly summarized. Under abiotic factors other than production ecology, the role of institutions and government policies is discussed. Research outputs include agronomic studies and screening and selection of high-yielding cultivars for release. The targets of emphasis in future improvement programs include development of effective production packages to support high-yielding cultivars adapted to several agroecological zones.

Introduction

The cool-season food legumes (CSFL) belong to three tribes, the Vicieae (*Lens*, *Pisum*, *Vicia faba*, *Lathyrus*), the recently separated tribe Cicereae (*Cicer*) and the Genisteae (*Lupinus*) (Summerfield and Bunting 1980; Hebblethwaite 1983). All are of Mediterranean and West Asian derivation and domestication, with Turkey to Iran as major centers (Simmonds 1976).

Several genera extend to East Africa (*Lens*, *Lupinus*, *Lathyrus*). *Lupinus* has evolved separately also in the Americas, which is a major center of diversity, and where it was domesticated in Peru (Pate *et al.* 1985). Species of *Vicia* and *Lathyrus* are indigenous in the Americas (Buddenhagen 1990).

All of the CSFL are ancient domesticates in the lands from Iran-Iraq to the Mediterranean and most were associated, along with the primitive wheats and barley, with the rise of civilizations in the Eastern Mediterranean and Fertile Crescent (Buddenhagen 1990). Peas (Davies *et al.* 1985) may be from that area but they are now mostly grown in more northerly climates. Many found their way to India and Ethiopia, which became a secondary center of diversity, especially for *Cicer* (Smithson *et al.* 1985).

Status of Cool-season Food Legumes

Area and Production

Ethiopian agriculture is decisively subsistence farming where all the field pea (*Pisum sativum* L.), lentil (*Lens culinaris* Medik.), chickpea (*Cicer arietinum* L.), grasspea (*Lathyrus sativus*) and faba bean (*Vicia faba* L.) are cultivated predominantly by the traditional and undeveloped farming community who use outdated methods of production. As a result the yields are extremely low: for field pea 0.6-0.9 t/ha, faba bean 1.0 t/ha, lentil 0.88 t/ha and chickpea a little over 1 t/ha. Grasspea is similar to chickpea in yield (CSA 1989, 1990, 1991, 1992).

Even though Ethiopia is the world's second largest producer of faba bean, next to the Peoples Republic of China, its share of world production is only 6.96%; within Africa, its share is 40.5%. Ethiopia is a major producer of these five CSFL with production being distributed throughout nearly all its provinces. Specific zones of production are mainly functions of elevation and, to a large extent, of humidity and temperature.

However, in terms of major agroecological zones, the major production area is roughly between 9 and 16° longitude. The area includes the central highlands of Shewa, all the highlands of Gojam and Gonder, northwest Wello, Tigray and Eritrea. The provinces of Welega, Arsi and Bale constitute the second major important production zone.

Nutritional Value

Human food

Although the livestock population of Ethiopia outnumbers its owners, animal protein is somewhat of a rarity in the human diet in both the urban and rural sectors. The amino acid profiles of CSFL satisfy the requirements of human nutrition when mixed with cereals. Most of these food legumes are also used as snacks, either roasted or fried, in the daily food of the poor sector. Furthermore, the consumption of fresh green faba bean, pea, chickpea and lentil is also substantial, although only for a short period when the green materials are available in the field. In the Ethiopian highlands, legumes as a curry with cereal *injera* (a pancake bread) are consumed at least twice a day. In most regions the flour of one or the other of these food legumes is mixed with the flour of small cereals and used in making bread. Considerable use is made of grasspea as a curry in the highland grain-producing regions, particularly in low-rainfall years when other crops fail.

Animal feed
Livestock are fed the haulms of these legumes, and stalks are a good source of fuel for cooking purposes. In faba bean, all the aboveground parts, other than grain, may contain 6-17.6% protein, depending on the stage of growth (Li-Juan *et al.* 1993). Faba bean and field pea plants are highly palatable to livestock and if faba bean is fed to a lactating cow, milk increase is considerable.

Economic Value

The availability of the major food legumes has never been in surplus in the subsistence farming communities of Ethiopia. In fact, it has often been said that internal markets seriously compete with the external ones. And yet the Ministry of Finance, Customs Authority publications (1987, 1990) show that a substantial tonnage of these food legumes is exported from the country every year (Table 1). Field pea, lentil, chickpea and faba bean are the major exported commodities of which faba bean is the most important as an export food legume.

Legumes as Soil Fertility Restorers

In the subsistence farming system one of the major characteristics of farm practice is an almost total absence of fertilizer use for soil fertility replenishment. The depleted soil is normally fallowed for 3-5 years. However, this practice is not always possible, particularly in the dominantly grain culture of Ethiopian highland agriculture. Thus, as an alternative to fallowing for soil fertility restoration, the cropping of dry pea, lentil, chickpea, faba bean and grasspea is highly desirable to improve both soil fertility and structure. These food legumes predominate in marginal agriculture zones where other crops such as wheat, tef and barley fail to grow because of repeated cropping of these cereals or serious soil erosion during the rainy seasons (June to October). In the absence of research in relation to their contribution to soil fertility restoration, it is difficult to quantify the amount of soil nitrogen replenished by legumes.

Table 1. Quantity and value of Ethiopian faba bean, lentil and chickpea exported compared with cereals and haricot beans (1986-90).

	Faba bean	Lentil	Chickpea	Haricot bean	Cereals
1986					
tonnes	75	206		10,651	
Birr†		29		10,341	
1987					
tonnes	20	1,632		9,798	62
Birr	18	2,074		17,826	69
1988					
tonnes	588	296	34	14,777	4
Birr	386	342	26	20,126	12
1989					
tonnes				9,708	3
Birr				12,786	9
1990					
tonnes	100	127		30,333	31
Birr	26	144		43,087	87

† 1 Birr = 0.48 US$.
Source: Central Statistical Authority, Addis Abeba.

Major Constraints to High Returns

Abiotic Factors

Agronomic practices

In the less developed agricultural systems the crop species that survive the vagaries of unpredictable weather and other destructive agencies over time must be those naturally selected for their ability to exist in natural hazards and calamities. Food legume species of the Ethiopian highland regions are those types, sometimes referred to as primitive landraces, on which human technological pressure has had little effect.

In Ethiopian agriculture, food legumes are grown with a single plowing with a pair of oxen or without plowing prior to broadcasting of the grains which are then covered in a single plowing. With this type of agriculture the common practice is to plant field pea and faba bean in June or early July and harvest in late October to early December. The seeding rate is low, varying from 75 to 150 kg/ha for faba bean and 70 to 100 kg/ha for field pea, although research recommendations for seeding rates are 200-250 kg/ha for faba bean and 100-203 kg/ha for field pea. Chickpea, lentil and grasspea are planted in late August to mid-September and harvested in late January to mid-February without weeding at any stage of crop growth. Seeding rates are also extremely low: 30-35 kg/ha for lentil and 30-40 kg/ha for chickpea and grasspea. Research recommendations are a minimum of 50 kg/ha for lentil and 50-95 kg/ha for chickpea. In this type of agriculture fertilizer is never used in food legume production. Instead, these crops are used as restorers of soil fertility for the following cereal crops.

The freshly harvested food legumes are stacked in piles in the field to dry for 4-6 weeks after which they are transported to the threshing floor. Threshing is done either through trampling by cattle or horses or in some sectors by groups of men or women who beat the dried plants with sticks. Winnowing is done by throwing the chaff in the air on a windy day with a long (1.5 m) wooden fork or by hand. As a result, the returns from the above agricultural practices for food legume production are very low (Tilaye 1988).

Temperature stress and yield instability

Faba bean and field pea are always vulnerable to frost damage in the highlands. This usually occurs at the prime vegetative or early anthesis stage and damages are often irreversible.

High temperatures, particularly at altitudes of 1800 m asl or less, are deleterious to faba bean at the reproductive growth phase and can result in considerable flower and pod drop. To increase production in these zones, there is a need to understand this phenomenon better and to identify and develop genotypes tolerant to high-temperature stress.

Low-moisture stress results in considerable reduction in grain yield. Thus, yields of all five food legumes are low and always variable from year to year compared with small cereals. The reasons for such fluctuating low yields have not yet been determined through research.

Agroenvironmental situation
Production zones in Ethiopia can be grouped according to three major rainfall patterns (Fig. 1).

Region I comprises all those places west of the central highlands, which have one rain season. It includes the administrative regions of Kefa, Ilubabor, Welega, Gojam, Gonder, most of Tigray and Eritrea. Normally, in the southern parts of this region, the rain starts around the beginning of March and gradually moves northward. By the beginning of July, the rain belt approaches the northern tip of the country, then starts to withdraw around the end of August and gradually moves south until the end of November.

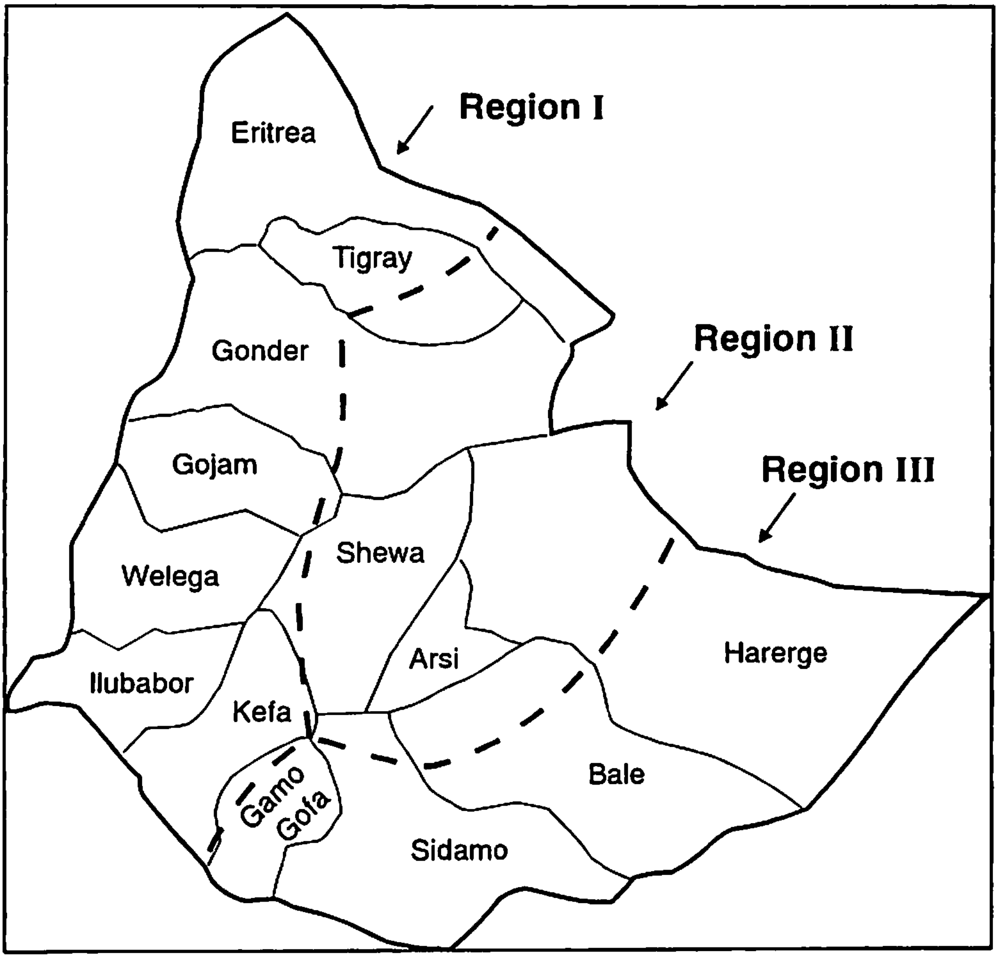

Fig. 1. Rainfall regions of Ethiopia.

The areas bounded by Region II are the administrative regions of Shewa, Welo, southern Tigray, Arsi, northern Bale, northern Sidamo and northern Harerge. The region has two rainy seasons. The first one, March to April, is a short rainy season known as *belg* (spring rainfall about 20%). *Belg* rain starts in late February or at the latest in the beginning of March and continues until mid-May. Normally there is a dry period from mid-May to mid-June, which is a transition period from *belg* to *kiremt* season. The second rainy season in this region is the *kiremt* season (mid-June to end of September). *Kiremt* rain starts in the southwestern parts of the region around the middle of June. Gradually the rain proceeds north and east until by mid-July it reaches the Eastern Lowlands of the region. Around the end of September, clear weather conditions set in.

Region III includes the central and southern parts of Harerge, Bale, Sidamo and the whole of Gamo Gofa. These areas have a tropical climate that receives rainfall twice a year. The first and major rainy season is March to May. The duration and amount of rainfall decrease from the northwest to the southeast until the semi-desert areas of the Ogaden are reached, where there is little or no rain.

Zones of suitable production of CSFL follow the pattern of rainfall distribution in the country (Fig. 2). Production zones are divided into highly, moderately and marginally suitable regions. Most of the highly suitable zones are parts of Welo, Tigray, Gojam, Gonder and Shewa provinces. Most of the moderately suitable regions are the remaining parts of those provinces already mentioned, and include small portions of Sidamo, Arsi and Bale provinces. Most of the marginally suitable regions are in Eritrea, Tigray, western Harerge, Sidamo, Gamo Gofa and the northern portion of Bale. The prevalence of marginally suitable conditions in Eritrea, parts of Tigray and Harerge is entirely due to rainfall pattern and intensity in only 3-6 months in which the precipitation exceeds evapotranspiration (Wolde-Mariam 1972).

Field pea, lentil, faba bean, chickpea and lathyrus are of temperate or subtropical origin. If they are grown near the equator, the cold requirement for these crops is only met at high elevation. Thus, optimum day/night mean temperature fluctuations during the growing season (June to late December) for dry pea and faba bean are 20/10°C. For lentil, grasspea and chickpea a temperature regime of 30/10°C during the growing season (September to late February) is optimum.

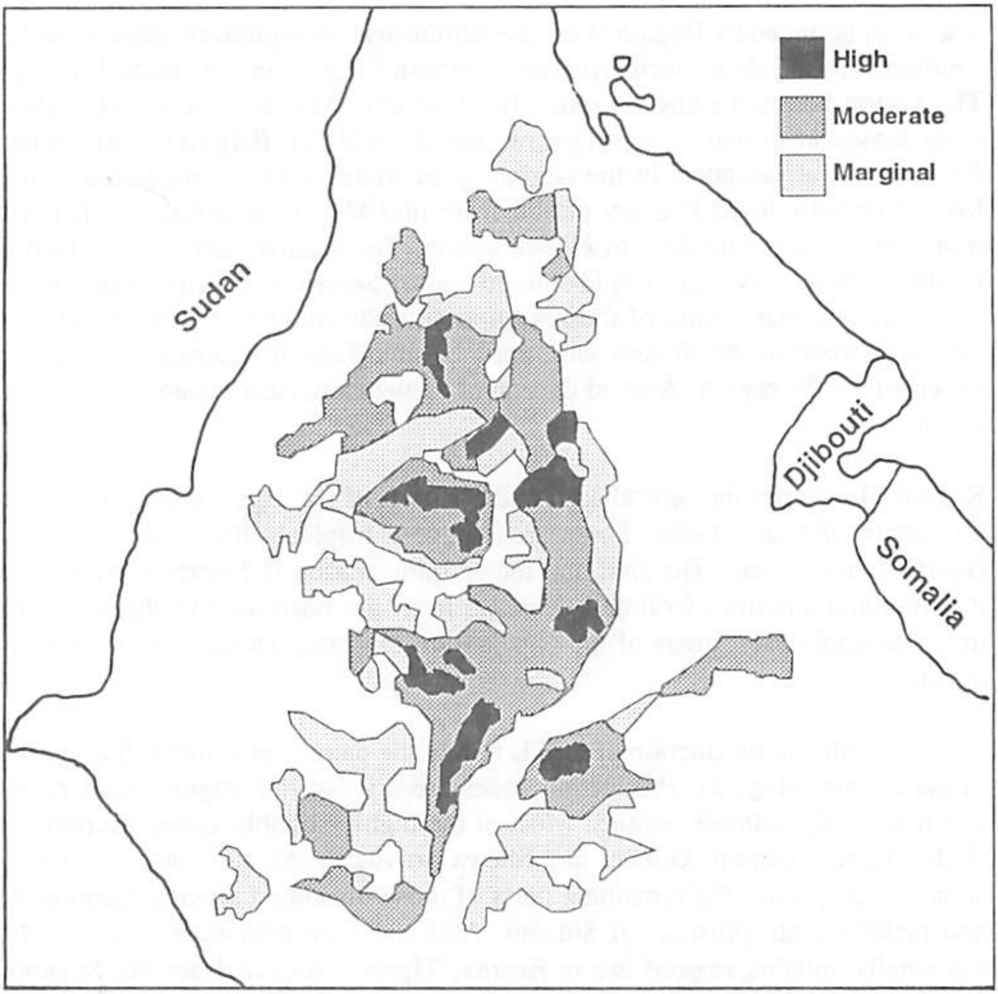

Fig. 2. Major production zones of cool-season food legumes in Ethiopia.

This region of the tropics is mainly classified as semi-arid with warm winters, hot dry summers and occasional rains (Wolde-Mariam 1972). The mean annual precipitation is 600-1200 mm while the length of the growing seasons is 4-5 months with some isolated local pockets extending to 5-6 months (Last 1963; Wolde-Mariam 1972). However, under Ethiopian conditions chickpea and lentil are grown mostly under a few rainshowers during the first part of the vegetative development stage with the rest of the crop growth depending completely on residual moisture. So, the success of these crops in this situation depends upon the rains received from mid-June to mid-October. However, there are only 3-6 months in which the precipitation exceeds evapotranspiration (Wolde-Mariam 1972).

Since rainfall in the Ethiopian climate is variable, plants have evolved diverse adaptations for survival of the stresses imposed by the high potential evapotranspiration conditions of hot and dry environments. However, the requirement of agriculture is not adaptation for survival but, rather, increased productivity. Productivity in Ethiopia requires the efficient use of the limited water available. A second means to increase productivity is to increase, through cropping and soil management practices, the amount of water available for crop use.

Soil variability constraints and degradation

Since soil varies from farms to valleys and hillsides, crop output also varies and crop breeding objectives and agronomic recommendations shift from appropriate to inappropriate. Often, the relevance of experiment station trials to farm reality is minimal because of differences in soil type, soil depth, and the soil/crop/input histories of the farmers' fields and the research station.

In the tropical highlands of Ethiopia major soils suitable for pea, lentil, faba bean, chickpea and lathyrus are predominantly brown and chestnut Vertisols (Last 1963; Wolde-Mariam 1972) and inceptisols. Major soil-related constraints to cropping are soil erosion on the slopes, lack of drainage on lowlands, acidity and low phosphate availability (Last 1963).

Biotic Factors

Pests

The African bollworm (*Helicoverpa armigera* L.) is the major cause of yield reduction in chickpea and sporadically incurs losses in faba bean and field pea. Aphids (*Aphis fabae* L.) and thrips (*Taenothrips* spp.) are other damaging insects.

Diseases

In both faba bean and lentil, rust (*Uromyces fabae* L.) is a limiting factor in areas of high rainfall (above 900 mm) and high temperature (above 20°C). Powdery mildew (*Erysiphe* spp.) is another problem in faba bean grown below 1800 m with temperatures of 20-25°C, and is the major disease problem in field pea and grasspea even at altitudes above 1950-2400 m if the weather is warm and cloudy with 22°C temperature. If these crops are planted during the off-season in the highlands, they may suffer severe attack from this organism.

Ascochyta blight is another problem in chickpea, lentil and field pea. Wilt and root rots are major problems in black Vertisols for all five food legumes. So far, the reported virus problems in food legumes are minimal, probably because aphids (the vectors) are kept at a minimum level by high rainfall (700-1000 mm during June to October) which washes them off the plants. Chocolate spot (*Botrytis fabae* L.) is the major disease problem on faba bean, particularly in areas with 2000 m and higher altitudes.

Weeds

Both grass and broadleaf weeds seriously compete with faba bean and field peas, causing grain yield losses between 20 and 95%. However, weed control technologies are available (both mechanical and chemical) for minimizing such losses.

Institutional Constraints affecting Food Legume Production

The challenge facing legume researchers is to develop new high-yielding cultivars with a plant structure that improves performance and narrows the gap between total biological and grain yields. Two plant traits that should be jointly tailored by legume breeding programs are plant height and the number of pod distributions along the stems of a plant. Success in this endeavor will be a major breakthrough in legume research that will benefit the world.

Agricultural research is only a first stage in this process. Many of the factors that determine successful adoption of new cultivars, cultural practices and farming systems, as well as consumer acceptance of the products of those systems, are beyond the influence of research organizations. Those factors are largely the prerogatives of National Governments, their policies, and the effectiveness of the institutions which they create to advance agricultural progress and to meet the demands of domestic consumers and international markets.

Any serious weakness in key national institutions serving agriculture may limit the success of research centers. The research organizations may help the government improve institutional effectiveness and accelerate the adoption of improved agricultural technology through policy research, material and other assistance to national institutions, and through training, but their ability to surmount serious institutional bottlenecks is limited.

Research Funding

Agricultural research in Ethiopia is one of the best funded by the Ethiopian Government compared to other countries particularly in eastern Africa. The support obtained especially with regard to operating funds is excellent.

However, funds required for laboratory and field facilities that may have to be obtained from outside of the country and for overseas training are not available because of the lack of sufficient supply of foreign currency in the overall economy of Ethiopia.

It is true that research scientists in the country are also at financial disadvantage compared with their counterparts in the private sector and at universities, but efforts are being made to rectify this situation at least in the Institute of Agricultural Research (IAR).

Shortage of Highly Qualified Staff

The quality of national research staff in Ethiopia in terms of experience and level of training also leaves much to be desired. The proportion of Ph.D. staff in most national programs is low. Conversely, staff trained only to B.Sc. are numerous. Overall, the number of expatriate researchers in national systems is low compared with the rest of Africa and Asia.

Research Efforts in the Ethiopian Context

General

Prior to the mid-1950s there was no agricultural research in Ethiopia, except by a few plant explorers, chiefly from Europe, who mainly reported the wealth of genetic resources in most of the economic plants. After Ethiopia started seeking the aid of the western world to modernize its agriculture, one of the top priority programs focused on the opening of agricultural schools and colleges. Although different research programs started in the early 1960s, coordinated food legume research did not materialize prior to 1972.

Agronomy

With the inception of Nazret Research Center, which shouldered the responsibilities of both tropical and subtropical food legume research coordination, the field pea, lentil, chickpea and faba bean improvement programs gained impetus in 1972. At this stage because of the lack of improved cultivars, various agronomy trials were conducted only with the Ethiopian landraces purchased from markets or collected from nearby farmers' fields. Thus the early research concentrated on agronomic practices related to dates, rates, methods of sowing and plant population levels.

Breeding

Assembly of the working population

Because of the wide genetic diversity existing in Ethiopia, it is considered one of the centers of diversity in field pea, lentil, chickpea, faba bean and lathyrus. However, the diversity in genetic resources of these crops has not been fully utilized in the improvement of the crops. Nevertheless, some modest attention has been given to collection and characterization of these food legumes since the late 1970s.

The native germplasm accessions collected so far are: lentil, 248; field pea, 1200; chickpea 539; faba bean, 1430 and lathyrus, 200 accessions. Efforts have been made to introduce materials from international communities. The main sources of introductions are ICRISAT for chickpea; ICARDA for lentil, faba bean, field pea, kabuli chickpea and lathyrus; some European countries and North America (mainly Pullman, WA and USDA) for field pea and faba bean. These materials are the sources of screening and selection for various desirable agronomic characters for Ethiopian conditions.

Cultivar improvement

Improvement programs of field pea, lentil, chickpea and faba bean are rather young, but moreso for lathyrus. The first National Variety Trials (NVTs) were initiated in 1972 with limited entries which for field pea and faba bean had to be discontinued in 1974, owing to a lack of adequate working populations.

The NVTs are conducted at various research stations and cooperating agricultural development agencies, notably the Ministry of Agriculture and the University. The cultivars are screened for 3-5 years at the center concerned prior to their inclusion in the NVTs. In NVTs any cultivar that outyields the standard check cultivar for three consecutive years is identified at the National Crop Improvement Conference (NCIC) for multiplication and the verification trial. However, before release, the performance of the cultivar is further studied for one more year by the National Seed Release Committee, and if approved, goes to on-farm trials by the Socioeconomics Department of the concerned center. Currently all possible efforts are being made to conduct trials, particularly NVTs and adoption trials, across different agroecological zones using genotypes with better yield potential than in the past.

Since 1985 new inputs in improvement of faba bean in the country have been provided by the ICARDA/IFAD Nile Valley Project on faba bean in different production zones. This work has helped in speeding up improvement of cultivars and production technology which should be available for the Ethiopian farmers in the immediate future. ICARDA/SAREC-supported programs (1989-93) on faba bean, field pea, chickpea and lentil have accelerated the speed of the improvement program.

Progress made

In the last 15 years screening and selection have been undertaken with native germplasm and introduced materials. The main objective of this work is to generate genetic material to be tested at many locations representing a range of agroecological zones. Genotypic performance is evaluated for both seed yield and reaction to locally occurring pests and diseases. Through such testing it has been possible to identify superior genotypes which are adapted to both specific and wide environments. Cultivars of all these food legumes, except grasspea, have been released for production, and many more are in the advanced stages of testing and in verification trials.

Looking Ahead

The advances in crop technology made so far in legumes are still far behind those made in cereals and horticultural crops. Consequently, legume grain yields are generally low and erratic, varying in different years on the same farm under similar management. Therefore, the Pulses Improvement Programs of Ethiopia should strive to achieve the following objectives for high and stable yields:

- Develop cultivars that are able to provide high and stable yields across several agroecological zones
- Develop an integrated system of pest and disease management for controlling diseases, insect pests and weeds
- Develop an effective package of production for the new high-yielding cultivars

- Develop a system for testing production packages
- Emphasize evaluation of nutritional quality and improved post-harvest technology for the benefit of the users
- Continue collection, introduction and maintenance of genetic materials of wide geographical origins
- Develop trained manpower through promotion of systematic training programs
- Develop a mechanism for effective disposal of the legume produce
- Develop private seed suppliers
- Create conducive environment(s) for incentive production by farmers
- Develop a system whereby natural rhizobia could be used as fertilizer.

The Highland Pulses Improvement Program of the Institute of Agricultural Research and the Debre Zeit Research Center of Alemaya University of Agriculture in Ethiopia are making steady progress in achieving the above objectives.

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Discussion

Dr Eylachew
Lupin (locally called *gibto*) has been shown to have a potential for fixing high nitrogen in northern Ethiopia. Why is it not a research priority?

Dr Asfaw
Lupin is produced in Gojam, Gonder, Welo and Tigray regions. It has also been tried in Chencha, Gamo Gofa region and found to be acid tolerant. A socioeconomic survey is being conducted on this crop in Adet. However, it has the problem of antinutritional factors and may require processing before it can be used for human consumption.

Dr Solh
You have cited bureaucracy in releasing cultivars as one major constraint. What should be done to improve the situation?

Dr Getinet
The problem of bureaucracy is not important any more. A National Seed Industry Council has been set up to facilitate the release of cultivars. Any cultivar of a crop is released according to the rules and regulations of the council.

Dr Goshu
Should we follow the specific or wider adaptability approach in developing cultivars?

Dr Asfaw
The approach to be followed should depend on research objective and ecology. There should never be a limit on which one is followed.

Dr Asnakew

I think that most of the areas presented as being moderately and highly suitable on the map may not really be so. Your map also contradicts the FAO suitability map regarding these areas. On what basis did you consider these areas as being moderately and highly suitable?

Dr Asfaw

I presented a mimeograph map prepared by the Land Use Department of the Ministry of Agriculture to be used as a working map. I, therefore, admit that the suitability of the areas for each commodity in this map can be debated.

Dr Getinet

In fact, there is no realistic land resource map on Ethiopia. Therefore, preparing a realistic land resource map based on thorough surveys should be given due consideration for facilitating future research on cool-season food legumes.

Smallholder Production Practices and Constraints in Ethiopia

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Abstract

In the highlands of Ethiopia, cool-season food legumes (CSFL) are the main relish and cash crops, providing protein for humans and by-products for use as animal feed. Production practices vary from one area to another. In most areas CSFL are grown in the main rainy season. However, in a few areas faba bean and field pea are mainly grown in the short rainy season. CSFL are intercropped with other CSFL and other crops to maximize total output. In a few areas farmers also double-crop chickpea after an early maturing tef cultivar. Land preparation usually commences immediately after the onset of the rains. Frequency of plowing ranges from 0-5 times before planting. CSFL generally are planted on a flat seedbed, although in some areas they are grown on ridges and on hand-made broad bed and furrows. Most farmers grow unimproved local cultivars. All CSFL can be broadcast, but in Angacha, most farmers row-plant faba bean by dibbling seeds after the plow. Although weeds are one of the major constraints, CSFL receive less priority in weeding than tef and wheat because of the shortage of labor caused by an overlapping of operations for these crops. The proportion of farmers applying fertilizer is very low. The most common fertilizer used is diammonium phosphate. The major production constraints of CSFL are low soil fertility, weeds, diseases and pests, frost, waterlogging, shortage of arable land, seasonal labor shortage, unavailability of inputs and shortage of draft power.

Introduction

Pulses are grown mostly by subsistence farmers under rain-fed conditions. The most important growing areas of pulses are the highlands of the central, northwestern and southeastern regions of Ethiopia. Pulses rank second in area, production and yield next to cereals (Table 1). Pulses occupy 13% of the total cultivated land and 12% of the total production of major crops in the country

Table 1. Production of major crops in Ethiopia, 1979/80 - 1991/92.

Crop	Area (1000 ha)	Production (1000 t)	Yield (t/ha)
Cereals	4682.23	5497.95	0.97
Pulses†	732.94 (85.6)‡	740.24 (87.8)	0.69
Others	239.94	115.89	0.35

Source: CSA 1987, 1992a, 1992b.
† Includes haricot bean, grasspea and soybean.
‡ Figures in parenthesis are percentage of CSFL's share.

(CSA 1987, 1992a). Cool-season food legumes (CSFL) have the largest share of area (86%) and total production (88%) among pulses. Faba bean ranks first in area, production and yield followed by field pea (Table 2). Faba bean is grown by 20-88% of farmers covering 3-18% of the total cultivated land per household. Field pea is also grown by 10-50% of farmers covering 2-18% of the total cultivated land (Table 3). About 99% of the total CSFL production is obtained from the smallholder sector. Total area covered by the same group of farmers is about 98% during the main season (CSA 1987). The smallholder sector also obtained the highest yield among the three sectors (Table 4). CSFL are mainly produced for consumption and sold for cash in small quantities in local markets and large quantities in foreign markets. They are the main relish food in the major growing areas and also are used as cash crops. By-products of CSFL are also useful to farmers as animal feed. Surveys of the production practices and production constraints of smallholders were conducted to serve as a benchmark for further research in improving the productivity of CSFL at farm level. Results of these surveys are presented here.

Table 2. Production of cool-season food legumes in Ethiopia, 1979/80 - 1991/92.

Legume	Area (1000 ha)	Production (1000 t)	Yield (t/ha)
Faba bean	301.21	376.86	1.2
Field pea	140.06	127.06	0.8
Chickpea	139.94	109.11	0.7
Lentil	46.30	36.65	0.7

Source: CSA 1987, 1992a, 1992b.

Table 3. Percentage of farmers growing cool-season food legumes, average area per farm and percentage of total cultivated land in different growing areas of Ethiopia.

Area	Legume†	% of growers	Area/farm (ha)	% of total area
Adet	FB	31	0.25	8
	FP	27	0.30	10
	CP	57	0.30	10
Debre Tabor	FB	76	0.20	11
	CP	67	0.50	14
Menagesha	FB	58	0.30	12
Selale	FB	88	0.40	18
Yerer-Keryu	FB	72	0.10	7
Genale	FB	20	0.60	4
	FP	10	0.60	2
Limu, Shewa	FB	27	0.20	3
	FP	23	0.30	5
Angacha, Shewa	FB	80	0.20	15
Ticho, Arsi	FB	82	0.30	13
	FP	50	0.40	18

† FB = faba bean, FP = field pea, CP = chickpea.
Source: Hailu and Mohammed 1987; Aleligne 1988; Chilot *et al.* 1989; Hailu 1990, 1991; Aleligne *et al.* 1992; Mohammed 1993.

Table 4. Production of cool-season food legumes by sector in Ethiopia, main season, 1979/80 - 1985/86.

Sector	Area (1000 ha)	Production (1000 t)	Yield (t/ha)
Smallholder	666.76	688.85	0.9
Producer coops.	16.85	6.70	0.5
State farm	1.11	0.56	0.2

Source: CSA 1987.

Production Practices

Production practices for CSFL vary across the main growing areas. In most of the survey areas CSFL are grown in the main rainy season. However, in an area like Sinana faba bean and field pea are mainly grown in the short rainy season because of frost problems, unreliable rainfall in the main season which results in more pests and diseases, lower yield and less time for main season land preparation (Alemayehu and Franzel 1987). In the Debre Tabor and Holetta areas farmers grow faba bean and field pea as mixed crops. The two crops are usually planted together and harvested at the same time. Mixed cropping of chickpea and sunflower is sometimes practised in the Debre Tabor areas (Aleligne *et al.* 1992). Chickpea and lentil are also mix-cropped with sorghum and noug in Gonder and Gojam, and with maize and sorghum in Harerge regions (Million and Beniwal 1988). Farmers reported that these practices improve soil fertility and give higher yield than sole cropping of either these legumes or the other crops.

Land Preparation

Land preparation for faba bean and field pea usually commences immediately after the onset of the rains during March and April. Preparation of land for chickpea and lentil starts from May to July. Land preparation is normally done with ox and plow. However, in Limu and Angacha if the field is fallowed for a long time the first plowing is done manually with a pair of hoes followed by oxen cultivation (Hailu 1990, 1991). Plowing frequency varies from area to area and even from farmer to farmer depending on availability of oxen, soil type, type of preceding crop and type of legume. Farmers who plant legumes on fallow land do more plowing than others. Frequency of plowing before planting ranges from 0-4 times for faba bean and field pea, and 1-4 times for chickpea and lentil (Table 5).

Planting Time

Planting time of CSFL is influenced by altitude, soil type and the type of legume used. It also varies from season to season depending on the time of rainfall onset and distribution. Planting in the main season is usually done from June to July for faba bean, field pea and lentil, and September to October for chickpea. In most major growing areas CSFL are planted on flat seedbeds. However, in Selale, Aleltu-Sendafa faba bean is grown on ridges (Hailu and

Chilot 1989). Faba bean, chickpea and lentil are also grown on hand-made broad bed and furrows (BBF) in Inewari (Hailu and Chilot 1989). BBFs and ridges are designed to minimize waterlogging problems, but ridges have an advantage over BBF in that they are easy to construct and thus less labor intensive.

Table 5. Plowing frequency and seedbed type in different cool-season food legume growing areas of Ethiopia.

Area†	No. of plowings	Seedbed
Faba bean		
1, 9, 11, 12	0 - 1	Flat
3, 5	1 - 3	Flat
7	1 - 2	Ridges and furrow
8	1 - 2	BBF‡
2, 13, 14	2 - 3	Flat
6, 10, 15	3 - 4	Flat
Field pea		
9, 11, 12, 14	0 - 1	Flat
15	1 - 2	Flat
10	3 - 4	Flat
Chickpea		
7, 9, 11, 15	1 - 4	Flat, BBF
4	3 - 4	Flat
Lentil		
4, 8	2 - 3	Flat, BFF

† 1 = Menagesha, 2 = Selale, 3 = Yerer-Keryu, 4 = Akaki, 5 = Limu, 6 = Angacha, 7 = Aleltu-Sendafa, 8 = Inewari, 9 = Adet, 10 = Agew-Midir, 11 = Bahir Dar, 12 = Debre Tabor, 13 = Ticho, 14 = Sinana, 15 = Genale.
‡ BBF = Broad bed and furrows.
Source: Hailu and Mohammed 1987; Alemayehu and Franzel 1987; Aleligne 1988; Chilot *et al.* 1989; Hailu and Chilot 1989; Hailu 1990, 1991; Workneh and Teklu 1991; Aleligne and Regassa 1992; Aleligne *et al.* 1992; Regassa and Asmare 1993; Mohammed 1993.

Farmers can plant all CSFL by broadcasting. However, 90% of farmers in Angacha row plant faba bean by dibbling seeds after the plow (Hailu 1991). As a result, a low seed rate (85-140 kg/ha with a mean of 114 kg/ha) is used. The reasons for row planting are to economize seed and fertilizer, facilitate weeding and get more yields. Both BBF and ridges are constructed after broadcasting the seeds. The seed rates range from 40-200 kg/ha for faba bean, 50-132 kg/ha for field pea, 28-97 kg/ha for chickpea and a mean of 58 kg/ha for lentil (Table 6). Most farmers use seeds from the last harvest while a few buy from the local market when the previous season's legume fails.

Table 6. Seed rates (kg/ha) of cool-season food legumes in major growing areas of Ethiopia.

Area	Range	Mean
Faba bean		
Adet	60 - 90	
Bahir Dar	80 - 90	
Debre Tabor	50 - 100	
Aleltu-Sendafa	160 - 185	
Angacha	85 - 140	
Limu	100 - 200	157
Menagesha	96 - 320	185
Selale	60 - 144	106
Yerer-Keryu	40 - 200	125
Genale	50 - 200	100
Field pea		
Adet	60 - 90	
Bahir Dar	80 - 90	
Debre Tabor	50 - 100	
Genale	52 - 132	93
Chickpea		
Akaki		97
Debre Tabor	28 - 40	

Source: Hailu and Mohammed 1987; Aleligne 1988; Hailu and Chilot 1989; Hailu 1990, 1991; Workneh and Teklu 1991; Aleligne and Regassa 1992; Alelign *et al.* 1992; Mohammed 1993.

Weed Management

In most of the survey areas, although weeds are one of the major constraints in CSFL production, legumes receive less priority in weeding than tef and wheat. This is mainly due to a shortage of labor caused by an overlapping of operations over several enterprises, and to the farmers' belief that weeds are not a problem for legumes. However, yield losses due to weeds were 23.6% for faba bean, 15.3% for field pea, 30.6% for chickpea and 50.6% for lentil (Rezene 1985).

Farmers manage several crops and there are overlaps of operations for these crops. In the Holetta area the critical weed competition period for faba bean and field pea coincides with land preparation and planting of tef, and weeding of wheat and barley (Hailu 1991). Similarly, in the Adet and Bahir Dar areas faba bean and field pea weeding overlap with the time of cultivating maize, preparing land for tef, planting millet and oilseeds (Aleligne 1988; Aleligne and Regassa 1992). At Debre Zeit, chickpea planting and lentil weeding overlap with tef planting (Workneh 1989). As a result farmers do not weed faba bean and field pea fields adequately. However, farmers in Limu, Angacha, Inewari, Arsi, Genale and Debre Tabor weed their faba bean fields at least once (Aleligne *et al.* 1992; Chilot *et al.* 1989; Hailu and Chilot 1989; Hailu 1990, 1991; Mohammed 1993). In Inewari and Angacha areas grass weeds from faba bean fields are used as animal feed. Because of this practice weeds are removed after they are matured in order to make the feed availability continuous for some time. Chickpea is also not weeded in most growing areas, because it is grown on residual moisture and weeds are not a problem. However, 75% of chickpea and 50% of lentil growers weed their fields once in Akaki (Workneh and Teklu 1991). The most common weeds are *Guizotia scabra*, *Snowdenia polystachya*, *Bidens* spp., *Trifolium* spp. and *Avena* spp.

Cultivars

Most of the CSFL cultivars grown in the survey areas are local. However, improved cultivars such as CS-20-DK (faba bean) are grown in Holetta and Arsi, NC-58 (faba bean) and Mariye (chickpea) in Ada. The use of improved cultivars of CSFL is limited because of unavailability and high cost of seeds. Most farmers use small, local faba bean seeds which are popular for the taste. Large seeds are mainly produced for sale as they have a good market price.

Fertilizer Use

Low soil fertility is reported as one of the major problems constraining CSFL production. Most farmers do not apply fertilizer on legumes because they believe that legumes do not need fertilizer and they give priority to its application on other crops such as tef and wheat. However, most farmers in Arsi, Limu and Angacha apply fertilizer on faba bean (Chilot *et al.* 1989; Hailu 1990, 1991). The most common fertilizer used is diammonium phosphate (DAP). Farmers apply fertilizer by broadcasting, except farmers in Angacha who apply it in the furrows with the seeds. Farmers apply 20-120 kg of DAP on faba bean per hectare (Table 7). Often, the rate is below the recommended rate (100 kg/ha DAP) and varies depending on fertilizer availability, the type of preceding crop and fertility status of the field. On average it varies from 38 kg/ha at Limu to 60 kg/ha at Ticho in Arsi. About 40% of farmers in Akaki also apply fertilizer on chickpea and lentil. On average they apply 22 kg DAP/ha for chickpea and 25 kg/ha for lentil (Workneh and Teklu 1991).

Table 7. Use of fertilizer (diammonium phosphate) on cool-season food legumes in major growing areas of Ethiopia.

Area	% farmers using fertilizer	Rate (kg/ha)	
		Range	Average
Faba bean			
Angacha	60	25 - 45	
Limu	50	50 - 120	38
Ticho	100	20 - 100	60
Chickpea			
Akaki	40		22
Lentil			
Akaki	40		25

Source: Chilot *et al.* 1989; Hailu and Chilot 1989; Hailu 1990, 1991; Workneh and Teklu 1991.

Diseases and Pests

The most economically important insect pests and diseases causing damage on CSFL are African bollworm (ABW) and aphids on faba bean and field pea; and ABW and cutworms on chickpea. Among the diseases chocolate spot and rust on faba bean, rust on field pea and lentil, root rot and ascochyta blight on chickpea and lentil are the major ones (DZARC 1990, 1991, 1993).

Farmers plant field pea early in the main season to avoid aphid damage whenever there is moisture stress and to escape frost damage. Sometimes complete crop failures due to these pests and diseases were reported by farmers. Bruchids and rats on faba bean, bruchids on chickpea and lentil are also important storage problems (Aleligne *et al.* 1992; Million and Beniwal 1988; Workneh and Teklu 1991).

Production Constraints

Production constraints reported by farmers in major growing areas are of two kinds: technical and socioeconomic. The technical constraints include low soil fertility, weeds, diseases and pests, frost and waterlogging. The socioeconomic constraints include shortage of arable land, seasonal labor shortage, unavailability of inputs and shortage of draft power.

Technical Constraints

Low soil fertility

Poor soil fertility is a major problem in northwestern Ethiopia in areas such as Adet, Bahir Dar and Debre Tabor. The soil fertility problem is aggravated by high soil erosion, low fertilization and continuous cultivation of crops. Fallowing is not practised any more because of the land shortage. As a result farmers allocate relatively fertile soil to faba bean and chickpea, the medium fertile soil to the mixed cropping of faba bean and field pea, and the infertile soil for field pea and lentil (Aleligne *et al.* 1992; Workneh and Teklu 1991).

Weeds

Weeds are one of the major problems in CSFL production causing yield loss from 15 to 50%. Weed infestation is aggravated by poor land preparation and lack of timely weeding because of an overlapping of activities and giving priority for land preparation and planting to cash crops.

Diseases and pests
Yield loss due to aphid on lentil and field pea ranges from 11-14% and 22-29% respectively (IAR 1987; Workneh and Teklu 1991). African bollworm and cutworm are important pests of chickpea. Complete crop failure due to ABW and root rot during flowering and pod setting was reported by farmers. As a result, the production pattern is changing, i.e., a decline in faba bean, field pea and chickpea and an increase in grasspea.

Waterlogging
This is an important problem which affects the planting and growth of legumes in Selale, Aleltu-Sendafa, Inewari and Debre Zeit.

Socioeconomic Constraints

Shortage of arable land
As population pressure and competition of different enterprises increase, the grazing land is reduced, and farmers practise no fallowing. High soil erosion and low fertility of the existing land aggravate the problem. Moreover, unavailability of inputs decreases the output from limited land. Thus, a shortage of arable land limits CSFL production.

Unavailability of improved inputs
Most farmers use local cultivars of CSFL. Insufficient supply of the available seeds (CS 20DK, NC58 and Mariye) is constantly reported; it does not meet the farmers' demands. Improved cultivars that are disease resistant and high yielding are not available to farmers (Awoke 1988). Late arrival of fertilizer and pesticides, and high prices of these inputs and improved seeds, discourage farmers from using them. Thus, farmers use much lower inputs than recommended and continue planting landraces with inherently low yield potential.

Seasonal labor shortage
Most crops are planted at the same time in the highlands. This results in a labor shortage because of the overlap of activities. CSFL have a lower priority than tef and wheat, and so are not weeded in time, which results in higher yield losses.

Draft power shortage
Feed shortage in the dry season makes the oxen weak during land preparation. This affects the frequency of plowing and timeliness of land preparation which

finally results in lower yield. This problem is serious in one of the study areas (Inewari) where farmers use a pair of horses or a combination of a horse and an ox. This practice requires additional manpower to guide the pair during plowing (Hailu and Chilot 1989).

Other factors

Theft of green pods of chickpea has become a major problem in chickpea production. The grain yield loss ranged from 30 to 60% (DZARC 1990, 1991, 1993).

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Discussion

Dr Goshu

You mentioned shortages of draft power and of land due to pressure of livestock as constraints. Isn't your statement self-contradictory?

Ato Hailu

No, it isn't. Farmers use both horses and oxen as draft animals in some places. On the other hand, in areas with available land, as is the case in Inewari, there is a shortage of draft power.

Dr Goshu

While conducting socioeconomic surveys, have you come across farming communities that use improved cultivars?

Ato Hailu

Definitely. We observed farmers that adopt agronomic recommendations. Farmers of the Holetta area can be cited as an example.

Marketing of Cool-season Food Legumes

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Abstract

Pulses are the second most important crops next to cereals and are mainly grown by smallholders in the highlands of Ethiopia. Cool-season food legumes (CSFL) have the largest share of area and total production of all pulses. They are produced for domestic consumption and export. Marketing of CSFL occurs in three forms: by private traders, the Agricultural Marketing Corporation (AMC) and the Ethiopian Oilseeds and Pulses Export Corporation (EOPEC). The AMC is a government organization granted the right to purchase pulses such as faba bean, field pea, chickpea and lentil from producers' cooperatives, service cooperatives, state farms and private merchants at a fixed price for sale in the domestic market. The EOPEC is another organization established by the government for the sole purpose of exporting oilseeds and pulses. Developing countries depend to a large extent on the export of primary products, mainly agricultural products such as CSFL, but the slowdown of Ethiopia's economic growth has reduced the supply of its agricultural products to the world market in general and CSFL in particular. This downward trend of supply coupled with declining international prices of agricultural exports has worsened the foreign exchange earning ability and consequently Ethiopia's capacity to import other important commodities.

Introduction

Pulses are the second major crop in Ethiopia, grown mostly by subsistence farmers under rain-fed conditions. Pulses cover 13% of the total cultivated land and provide 12% of the total production of major crops in the country (CSA 1987, 1992). Cool-season food legumes (CSFL) cover 86% of the pulse crop area and provide 88% of total pulse production. Faba bean ranks first in area, production and yield followed by field pea. More than 95% of the total CSFL area is in the smallholder sector for domestic consumption and export. They are nutritionally important because they are rich in protein, which varies from 18 to 32%. Carbohydrate content is high (>50%) and energy per unit weight provided by them is equal to that of cereals (Guler 1990).

Marketing

The marketing of CSFL has two aspects, domestic and export. Production is mostly for subsistence, but marketing is also extensive. What is sold is the amount in excess of the amount required to sustain the family. CSFL marketing has traditionally evolved in a village as well as urban market economy for many years, like any cereal (Pankhurst 1961). Marketing of CSFL is done by private traders, the Agricultural Marketing Corporation (AMC) and the Ethiopian Oilseeds and Pulses Export Corporation (EOPEC). AMC is a government organization granted the right to purchase pulses such as faba bean, field pea, chickpea and lentil from producers' cooperatives, service cooperatives, state farms and private merchants at a fixed price for sale in the domestic market (Table 1). The EOPEC is an organization established by the government for the sole purpose of exporting oilseeds and pulses. EOPEC used to receive substantial export subsidies even though it purchased at low fixed prices (Befecadu and Tesfaye 1990). The two institutions were established after the onset of the Ethiopian revolution of 1974 with socialization of the country. Often a conflict of tasks and functions has arisen between the two government organizations owing to a lack of a clear-cut policy (Befecadu and Tesfaye 1990). The policy directives vested upon EOPEC do not permit the flexibility necessary to develop the financial and organizational capacity required to compete against private traders.

Table 1. Cool-season food legumes transactions by the Agricultural Marketing Corporation of Ethiopia, 1987-92.

Legume	Purchased (t)	Sold (t)
Faba bean	16164.8	17344.5
Field pea	3180.6	3241.7
Chickpea	15186.2	14772.2
Lentil	10260.3	10069.4
Total	44791.9	45427.8

Source: AMC, Addis Abeba, Pers. comm.

Market Structures

Thoday (1969) identifies three market structures in Ethiopia: primary (village), secondary and terminal markets. They are structurally classified as small, medium and large markets, respectively. CSFL marketing in Ethiopia is predominantly a characteristic of village markets where the quantities involved in transactions are relatively small. The primary marketing is relatively small and meets the seasonal cash requirement of the farmers. In the secondary and terminal markets the quantity is also small for faba bean, field pea, chickpea and lentil. In central regions of Ethiopia, for instance, there is no significant difference between secondary and terminal markets (Abebe 1990).

Domestic market

The domestic market is less organized for CSFL than for cereals, mainly because of the mode of production. Marketing takes place in both private trade (open market) and the government-controlled AMC market. The private traders are active and influence the price and the behavior of consumers. The traders assemble from small markets and then move some distance in search of higher prices. Wholesalers often store CSFL for some times until prices are increased. Lentil is sold in many places in processed form (split) by wholesalers. Farmers must deliver quotas to the AMC at fixed prices immediately after harvest. They are exempted only in years of poor production, such as in 1985 and 1986 in Debre Tabor (Aleligne *et al.* 1992). The prices fixed by AMC were based on the feudal system and thus were fixed at relatively low levels for a long period of time. AMC pays relatively higher prices to service and producers' cooperatives than to individual farmers (Table 2).

Table 2. Cool-season food legume prices (Birr/100 kg)† paid by the Agricultural Marketing Corporation to farmers and service cooperatives (SC) in Ethiopia.

Legume	1981 - Jan 1987		Jan 1988 onwards	
	Farmers	SC	Farmers	SC
Faba bean	25	30	27	32
White pea	36	40	39	43
Chickpea	28	32	30	34
Lentil	42	47	45	50

Source: Determination of grain quota purchases implementation and grain prices for 1980 (Eth. cal.) directives, Council of Ministers, Addis Abeba 1982 (Eth. cal.).
† 1 US$= 2.1 Birr.

Farmers sell their surplus produce in the open market after meeting their quota obligation. Most of the CSFL are sold from December to January for clothing, tax and debt payments. Men are responsible for loading large amounts on donkeys, whereas women sell in small quantities whenever there is a need for cash. CSFL movement is also restricted in the production areas until AMC quotas are fulfilled. Farmers and traders are allowed to sell their produce outside their production areas only after AMC purchasing operations are completed. Until 1986 farmers used to sell directly to EOPEC. After 1987 AMC took over purchasing of CSFL from farmers and EOPEC now buys from AMC (Table 3).

The open market price is not competitive as markets are not well integrated in Ethiopia. Prices of CSFL fluctuate widely across regions in Ethiopia (Thoday 1969). Predictable price cycles occur infrequently. In general, prices are low at harvesting and higher at planting. For instance, in Adet harvesting prices were lower by 34% for faba bean, 52% for field pea and 17% for chickpea in 1986. In 1987, harvest prices were 15% lower for faba bean and 6% lower for field pea (Aleligne 1988). In Bahir Dar a simple relative index showed price increases of 0.4-10% for faba bean, 3.2-9.0% for field pea, and 4.8-13.5% for chickpea at planting when compared with May prices (Aleligne and Regassa 1992). Increments of planting prices over harvesting prices were 100% for chickpea and 150% for lentil at Woreta; and 45% for chickpea, 56% for field pea, 50% for faba bean and 167% for lentil at Debre Tabor (Aleligne *et al.* 1992). Table 4 shows the planting and harvesting prices in comparison with prices paid by AMC at Adet and Debre Tabor.

Table 3. Purchases of cool-season food legumes in Yilmana Densa *wereda*, Ethiopia.

Year	Purchaser	Amount (t)
1982/83	AMC	1526.9
1983/84	AMC	763.1
1984/85	AMC	154.2
	EOPEC	71.6
1985/86	AMC	205.2
	EOPEC	171.8
1986/87	AMC	431.4

Source: Aleligne 1988.

Table 4. Comparison of cool-season food legumes prices (Birr/100 kg)† at Adet and Debre Tabor local markets paid by the Agricultural Marketing Corporation to farmers.

	Adet	Debre Tabor		AMC	
Legume	1986	1987	1988	1981-87	1988
Faba bean	33	46	65	25	27
Field pea	50	58	57	28	30
Chickpea	38	-	102	36	39
Lentil	-	-	69	42	45

Source: Aleligne 1988; Aleligne *et al.* 1992.
† 1 US$ = 2.1 Birr.

The prices of chickpea and lentil are often related to the season of sale, the distance of flow and the structure of the market (DZARC 1992). In Shewa, central Ethiopia, the prices of faba bean, field pea, and mixtures of faba bean and field pea, for instance, decline as the harvest starts in November and then rise concomitantly until the next harvest. Chickpea prices appear to fall rapidly in February to March immediately after harvest and then start to increase slowly from May to August. Lentil prices fall in October right after harvest and then increase until February, decline again from February to April and then increase. Perhaps the most common feature of such marketing behavior is the cash demand of the farmers, in that farmers sell in the post-harvest low price season and buy in the pre-harvest high price season. On the other hand, AMC buys at low prices and sells at very high prices (Table 5). AMC prices are the same throughout the year and are much lower than the average annual market prices. AMC is now renamed the Ethiopian Grain Trade Enterprise (EGTE), which buys CSFL in the open market by competing with private traders.

Export market

Developing countries depend to a large extent on the export of primary products, mainly agricultural products including CSFL. But, because of the recent slowdown of economic growth in most developing countries, the supply of agricultural products to the world market has diminished. This downward trend of supply coupled with declining international prices of agricultural exports has worsened the foreign exchange earning ability and consequently the capacity of these countries to import. Since, in the short term, it is difficult to reorganize the export structure to concentrate on manufactured export products, it is essential to make every possible effort to export agricultural products. Developing countries must diversify the export of agricultural products instead of depending on some exportable items.

Table 5. Comparison of purchasing and selling prices (Birr/100 kg)† of cool-season food legumes by the Agricultural Marketing Corporation.

Legume	1988/89		1990		1991		1992	
	P‡	S‡	P	S	P	S	P	S
Faba bean	32	46	50	98	100	150	100	150
Field pea	39	55	72	114	72	164	81	158
Chickpea	34	48	33	119	130	187	126	169
Lentil	50	68	54	120	154	204	157	209

Source: Ethiopian Grain Trade Enterprise, Addis Abeba, 1993, pers. comm.
† 1 US$= 2.1 Birr.
‡ P = Purchasing price; S = Selling price.

Ethiopia is dependent to a large extent on the export of agricultural products, mainly coffee which accounted for 61.6% of the total export in 1991. Next to coffee are hides and skins which account for 13.3% of the total export of the country. The share of pulses was 4.38% in 1982 and 0.93% in 1991 which is an indication of the fact that Ethiopia, being one of the producers of pulses in Africa, is not able to increase its export. Among pulses the major share of export is accounted for by haricot beans and the share of CSFL in the export market has followed a declining trend for a long time, becoming nil in 1991 (Table 6). In 1982, 25 360 t of CSFL, worth US$8.85 million, were exported; in 1990, 226 t worth US$0.08 million were exported. This indicates the drastic decline in exports of CSFL (Tables 6 and 7). The share of CSFL in the export of pulses was 50.8% in 1982, 36.5% in 1983, 33.4% in 1984 and this downward trend continued up to 1986 which reached 0.7%. In 1987 this share increased to 10.5% and then followed a declining trend and in 1991 the share was nil (Table 6). When we look at individual products the share of lentil was 0.23 and 84.83%, field pea 2.6 and 0%, faba bean 96.94 and 15.17%; and chickpea 0.21 and 0% in 1982 and 1990, respectively (Table 7). These figures show that among CSFL lentil and faba bean were the major exportable pulses. The main importers of Ethiopian CSFL were Germany, Djibouti, France, Mauritius, Yemen and Saudi Arabia.

Table 6. Ethiopian export of pulses and cool-season food legumes.

Year	Pulses		CSFL		CSFL share (%)	
	1000 t	US$	1000 t	US$	1000 t	US$
1982	39.70	17433.42	25.36	8853.42	63.9	50.8
1983	35.84	11667.63	12.43	4257.95	34.7	36.5
1984	20.96	7800.58	8.25	2605.03	39.4	33.4
1985	10.23	4701.35	1.61	683.71	15.7	14.5
1986	9.08	4958.10	0.25	33.64	2.7	0.7
1987	11.45	9483.57	1.65	994.95	14.4	10.5
1988	15.70	9942.69	0.92	358.69	5.8	3.6
1989	9.71	6088.64	0	0	0	0
1990	30.85	20819.56	0.23	81.34	0.7	0.4
1991	4.29	1730.62	0	0	0	0

Source: Ministry of Finance 1982-1991.

Ethiopia, being a major producer of pulses in Africa (accounting for 18% in 1979-81 and 13.9% in 1988 of the total pulse production in Africa), is not able to increase its export of pulses in general and CSFL in particular. The main reasons for the lower export performance were decline in production caused by drought and other natural calamities, the increased domestic consumption which reduced the marketing surplus (according to FAO estimates the per capitum consumption of pulses exceeds 20 kg in Ethiopia), the high domestic price of pulses which reduced competitiveness of export of pulses and the increased illegal trade in recent years in some border areas of the country. Ethiopia increased its imports of pulses when shortages were caused by drought that struck the country for many years. The share of pulses in the total imports of the country was almost nil in 1982 and 0.10% in 1991. This increased share was accounted for by import of CSFL which was only 80 kg (2.6% of the total pulse imports) in 1982 and 770 t (100% of total pulse imports) in 1991 (Table 8). Out of the total CSFL, lentil accounted for the lion's share, 100% in 1982 and 70.1% in 1991. Next to lentil is faba bean which accounted for 29.9% in 1991 (Table 8). The main sources of CSFL imports are the USA, Canada, Denmark, Italy, Germany and the UK.

Table 7. Ethiopian exports of faba bean, field pea, lentil and chickpea.

Year	Faba bean		Field pea		Lentil		Chickpea	
	1000 t	1000 US$	1000 t	1000 US$	1000 t	1000 US$	1000 t	1000 US$
1982	24.89	8582.95	0.42	231.20	0.05	20.53	0.50	18.73
1983	9.23	3046.27	0.90	92.99	2.26	897.13	0.85	221.55
1984	4.51	1185.05	0	0	3.50	1320.93	0.21	99.05
1985	0.35	120.69	0	0	1.21	559.29	0.01	3.72
1986	0.05	19.71	0	0	0.21	13.92	0	0
1987	0.02	8.64	0	0	1.63	986.31	0	0
1988	0.59	183.87	0	0	0.29	162.58	0.03	12.24
1989	0	0	0	0	0	0	0	0
1990	0.10	12.34	0	0	0.13	69.00	0	0

Source: Ministry of Finance 1982-1991.

Table 8. Ethiopian imports of faba bean, field pea, lentil and chickpea.

Year	Faba bean		Field pea		Lentil		Chickpea	
	1000 t	1000 US$	1000 t	1000 US$	1000 t	1000 US$	1000 t	1000 US$
1982	0	0	0	0	80†	0.18	355†	0
1983	0	0	0	0	0.16	128.14	0.01	0
1984	0	0	0	0	0	0	0	0
1985	10.05	3232.91	1.03	341.97	0.10	97.39	0	0.11
1986	3.66	1778.08	0.91	328.61	1.01	340.60	0	3.69
1987	0.25	77.62	0.02	12.11	1464†	1.67	0	0
1988	1.02	795.13	1.00	402.17	5.14	3453.17	0	0
1989	3106†	6.66	0.61	280.89	0.54	167.24	0	0
1990	0.13	78.11	0	0	2.88	1950.92	0	0
1991	0.30	142.94	0	0	0.47	335.11	0	0

Source: Ministry of Finance 1982-1991.
† unit in kilograms.

Future markets

The future markets for CSFL are expected to be bright because in the past the traded volume was relative to production. According to FAO estimates not more than 10% of world CSFL production was traded. The main reason for this lower performance was the increased domestic consumption of the producing countries. For example, India, which is the world's major producer of pulses (accounting for about 21% of the total pulse production in 1988), is not the major exporter of pulses because it consumes most of its output, whereas other countries such as Argentina, Turkey, the USA and Australia export about 30% of their output (FAO 1987).

Although there is a good potential for the market of CSFL, both in domestic and export markets, the prevailing major bottleneck should be eliminated to improve exporting. However, the external factors such as price stability associated with unfavorable terms of trade affect greatly the performance of the market in exporting CSFL.

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Discussion

Dr Goshu
Do your data of imported legumes include those that are imported as food aid?

Ato Hailu
No, they are not included.

Dr Saxena
Is there an available figure for processed and unprocessed import and export items?

Ato Berhanu
Almost all the import items are processed and the export unprocessed or semi-processed. However, there is not a clear figure as to how much is processed, unprocessed or semi-processed.

Dr Asnakew
How did you conclude that there is high local consumption of cool-season food legumes?

Ato Berhanu
Preliminary survey results indicate that most of the food legumes produced are consumed. The demand for consumption is, therefore, high, but it has not been quantified so far.

Dr Saxena
What standard did you use in estimating the domestic demand for consumption?

Ato Berhanu
It is based on the FAO standard.

Technology Transfer for Cool-season Food Legumes

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Abstract

Extension and research in cool-season food legumes have a relatively long history in Ethiopian agriculture. In its simplest form, extension work is believed to have started in 1908. Since then, it has operated under the jurisdiction of many organizations and institutions, including Alemaya University of Agriculture from 1953-63 and since 1964 under the Ministry of Agriculture. During this time, agricultural extension was executed under different projects, namely: the comprehensive integrated package project, the Minimum Package Projects (MPP) I and II, Training and Visit (T & V) and the Peasant Agricultural Development Program (PADEP). In the process, various technology transfer media such as demonstrations (component technology demonstrations and package demonstrations) were used to show the advantage of improved technologies. Furthermore, these media were complemented by training of farmers and development agents and some extension publications. In addition, seed multiplication activity to support the available input was begun at the Holetta Agricultural Research Center for faba bean and field pea and at Debre Zeit Agricultural Research Center for chickpea and lentil. To evaluate the impact of the work, an adoption study was made on the transferred improved faba bean technologies. Problems encountered in creating an effective technology transfer system are described.

Introduction

Faba bean, chickpea, field pea and lentil have the major share of hectarage and production in highland pulses. In addition to their usefulness as protein sources, these crops have an advantage in ameliorating the soil (CSA 1990). Furthermore, the magnitude of their importance can be observed from the price they fetch in the market. For instance, the average Debre Zeit market prices in 1991/92 for field pea (white), lentil, tef (white) and durum wheat were 15.5, 17.5, 21.1 and 18.0 Birr/t respectively (DZARC 1993). Research and extension work, though modest, has been undertaken to utilize the potential of the crops by agricultural institutions such as the Institute of Agricultural Research, Ministry of Agriculture and Alemaya University of Agriculture.

This paper discusses the transfer of technology or extension of results of research on cool-season food legumes (CSFL) in terms of its effect on improving production and profits for farmers. Technology transfer includes education in the form of demonstrations, training and preparation of extension publications, and seed multiplication activities.

Historical Background

Agricultural extension work in Ethiopia commenced when the Ministry of Agriculture (MOA) was established in 1908 (Adugna *et al.* 1991b). At that time the major responsibilities of MOA included guiding the overall agricultural development and production in the country. Until the 1950s, there was no formal national extension program in the country. However, with the revision of the country's constitution in 1951 and with the establishment of the Alemaya College of Agriculture in 1953, a formal extension service was started as one of the triangular functions — training, research and extension — of the college (Adugna *et al.* 1991b).

Extension Work under Alemaya University of Agriculture

Technology transfer under the Alemaya extension program used demonstration plots to educate farmers and school children about new technologies introduced from abroad. The technologies included new vegetable crop cultivars, exotic lines of chickpea and improved animal health practices.

In 1963, when the administration of the College was transferred from MOA to Haile Sellassie I University (now Addis Abeba University), the responsibility for coordinating the national extension service was transferred to MOA. At that time there were only 132 extension agents located all over the country (Adugna *et al.* 1991b).

The structural advantage that the Alemaya College had to create an efficient research and extension linkage was lost with the termination of its national responsibility to coordinate the extension service.

Extension under MOA

Under MOA, the transfer of technologies continued through agricultural clubs in schools. Tree nurseries were established and forestation was encouraged by the clubs. However, the lack of new technologies and the weak linkage between research and extension hampered the sustenance of the technology transfer.

The Institute of Agricultural Research (IAR) was established in 1966 and management of extension service at the regional office was subsequently decentralized to improve the situation (Adugna *et al.* 1991b). The extension system under MOA has witnessed a change of various projects and approaches. The major ones are briefly reviewed below (from Adugna *et al.* 1991b).

Comprehensive integrated package projects

With the launching of the third 5-year development plan (1968-73), peasant agriculture received more attention. Hence to achieve the development objectives, comprehensive package projects by Chilalo Agricultural Development Unit (CADU) and Wolaita Agricultural Development Unit (WADU) were launched. The programs used model farmers for extension of technologies and included infrastructural services such as roads and water. However, the projects were found to be too expensive in terms of finance and manpower and could not be duplicated in other areas of the country.

Minimum Package Project (MPP)

MPP I. This project was launched in 1971 under the Extension Project Implementing Department (EPID). The package comprised limited extension components such as inputs, credit and extension advice. Model farmers were used to demonstrate proven technologies. The existing land tenure system was, however, a bottleneck preventing farmers from benefitting from the project. The project widened the equity gap between farmers near the road and those far from it. The project was replaced by the MPP II.

MPP II. This project was launched in 1980 to serve farmers by forming an association of peasants, the local link with the extension project, and by distributing inputs and credit. Development agents and trained farmers in turn demonstrated new technologies to members of the peasant associations. The development agents were finally centralized in *wereda* capitals, which created problems of finance, transportation and a poor farmer-extension agent contact. Although the official termination date of MPP II was 1985, the Training and Visit (T & V) extension approach commenced before then.

T & V pilot extension project
The Training and Visit extension system was initiated as a pilot project in 1983 with the assistance of the World Bank. The approach emphasized regular visits to contact farmers by the Development Agent (DA), monthly training of DAs by subject matter specialists (SMSs) and contact of SMSs with researchers every 3 months for seasonal training. The aim of the project was to test the appropriateness and suitability of the extension approach for Ethiopia. The project was tested in three areas and was planned to terminate in 1991 (Adugna *et al.* 1991b). However, a modified approach in which about 1300 farmers are assigned per DA is now being applied in the Peasant Agricultural Development Program (PADEP) which is a follow-up to the MPP II.

PADEP
The Peasant Agricultural Development Program was designed on the basis of the experience gained from MPP I and II with the aim of increasing food production and improving farmers' productivity. PADEP I, designed for Sidamo and Gamo Gofa administrative region, started its activities in 1988. The time between the termination of MPP II (1985) and the start of PADEP in 1988 was emphasized in the food self-sufficiency program, financed by the Ethiopian Government. The program adopted the modified T & V extension system. However, with the present restructuring of the country's superstructure, the extension system will also follow suit.

Research and Extension Linkage

The earlier link between research and extension in Ethiopia, which functioned from 1953 to 1963 when the College of Agriculture at Alemaya had the national responsibility of research, training and extension, was transferred to the MOA. Then there was no such linkage between research and extension. In the mid-1970s the college attempted to revive the linkage under an outreach program which has remained operational to date. In 1974, the IAR/Extension and Project Implementation Department (EPID) joint research and extension program was established at the field level. The main objective of the program was to test and if necessary adjust technology recommendations for different agroecological zones. This program was discontinued in 1976/77. In 1980/81, the National Revolutionary Development Campaign (NRDC) and the Central Planning Supreme Council (CPSC) issued a directive to both IAR and the Agricultural Development Department (ADD) of MOA which required EPID of MOA to re-establish the joint research and extension program that had been discontinued.

In 1981/82, the joint research program was launched again on 16 IAR/ADD joint research sites in nine administrative regions with an objective similar to that of IAR/EPID. The program's activities were divided into testing, verification and demonstration of technologies to effectively transfer them.

In 1985, as a result of World Bank support of agricultural development and research in the country and the PADEP of MOA, a Research and Extension Liaison Committtee (RELC) was established at the national and regional level. The main aim of RELC is to create strong research-extension links. The committees were formed of members from research and development organizations.

RELC is responsible for providing overall guidelines for research priorities, approving problems to be addressed by researchers, reviewing research findings, approving research recommendations and monitoring the operation of the research extension linkage.

The linkage is also strengthened by the extension division or outreach program of research centers, which operates in collaboration with the MOA in the various agroecological regions. This includes activities such as technology verification, demonstration, popularization, training and preparation of extension publications.

Research extension linkage has become relatively stronger under RELC, although RELC needs further refinement and consolidation.

A similar forum for linkage between research and extension with regard to cool-season food legumes is Nile Valley Regional Project (NVRP) (formed in 1985) in which MOA is a member. The forum has been a useful means for researchers and extensionists to exchange information on problems encountered in technology development and transfer or to communicate achievements.

Technology Transfer

Technology transfer is broken down into the subfunctions of knowledge transfer and input transfer. The media used to fulfil both functions are outlined in the following.

Demonstrations

Production technologies of faba bean, field pea, chickpea and lentil generated and developed by the ex-CADU agricultural research centers of IAR and AUA have been demonstrated to farmers in different parts of legume-producing areas by MOA and other organizations (EPID 1973, 1976; Extension Service 1986; FAO 1979).

The comprehensive extension package projects, minimum extension package projects and the subsequent extension programs of MOA also have been involved in technology validation trials in fenced sites. These sites have been used as technology demonstration plots for farmers.

The objective of on-farm technology demonstration done by the extension department of MOA or by extension/outreach programs of research centers is to show farmers the advantage of new agricultural technologies over the existing ones. These demonstrations are accompanied by field days, extension publications and training. As a follow-up activity of demonstrations, popularization of improved cultivars along with the recommended cultural practices is carried out jointly by extension/outreach programs of research centers and the extension department of MOA in the respective *weredas*.

A coordinated national research program on highland pulses was started in 1970. Since then 18 cultivars of faba bean, field pea, chickpea and lentil have been recommended and/or released (Table 1). At present a limited number of these cultivars are under production and demonstration (Table 1). The remaining cultivars are out of production, mainly because of disease stress.

Table 1. Cool-season food legume cultivars recommended or released in Ethiopia since 1970.

Crop	Cultivars		
	Recommended (1970-81)	Released (1982-86)	Under production (1985)
Faba bean	4		3
Field pea	4		2
Chickpea	9	2	1
Lentil	1	2	1

Source: Hiruy 1986, 1989.

Component technology demonstrations

Cultivar. CADU, later named ARDU (Arsi Rural Development Unit), Ada District Development Project (ADDP) and EPID conducted demonstration trials of promising and released food legume cultivars in their respective outreach areas. The results of validation and demonstration trials conducted in 1973/74 in the country confirmed the better performance of some improved cultivars of chickpea, faba bean and field pea (Table 2) in high-altitude zones.

Table 2. Average yields (t/ha) of improved chickpea, faba bean and field pea cultivars in demonstration trials in Ethiopia, 1973/74.

Cultivar	Lowland (<1800 m)	Midaltitude (1800-2000 m)	High altitude (>2000 m)
Chickpea			
DZ-10-1	0.500	0.810	1.050 (2)†
DZ-10-2	0.900	0.930	1.120
DZ-10-4	1.400	0.870	1.130
DZ-10-11	3.600	1.230	1.430
Dubie	0.100	0.830	1.050
H-54-3	1.160	0.770	0.850
Faba bean			
Local			1.46 (4)
20D ex-Kulumsa			1.72 (3)
38B ex-Kulumsa			1.93 (4)
Field pea			
Local			1.10 (4)
Alaska Express			1.23 (4)
Alaska-14			0.91 (4)
Prussian Blue			0.89 (3)
Local Shiro			0.75 (3)
Large white ex-DZ			1.08 (3)

† Numbers in parentheses indicate number of trials.
Source: EPID 1976.

Fertilizer. Fertilizer demonstration trials consisting of four plots of N-P-K and control were conducted on different crops including cool-season food legumes throughout the country from 1967-70. The study concluded that the use of potassium has no effect on crop yield, so K fertilizer was not used in further demonstrations. A control plot and three N-P combination demonstrations on pulses were conducted on farmers' fields to demonstrate the effect of fertilizer on crop yields from 1971/72 to 1975/76 (EPID 1973, 1976, 1977). Although the use of local cultivars partly contributed to the low yield responses, the application of N-P fertilizer at rates of 46-0, 0-46 and 46-46 kg/ha N-P_2O_5 gave grain yield advantages of 5, 22 and 34% in faba bean; 16, 64 and 59% in field pea; 56, 79 and 95% in chickpea and 37, 46 and 14% in lentil, respectively.

Weed control. To demonstrate the effect of weed control on the yield of pulses, weed control demonstrations were conducted by EPID from 1971/72-1975/76 (EPID 1977). Hand-weeded plots had higher yields than the unweeded plots (Table 3).

Table 3. Mean grain yields (t/ha) of legumes in weed-control trials in Ethiopia, 1974/75.

Treatment	Faba bean		Field pea		Chickpea	
	Yield	Incr.†	Yield	Incr.	Yield	Incr.
Control	0.850		0.849		0.673	
One weeding	1.028	21	0.870	3	0.841	25
Two weeding	1.110	30	0.937	10	0.872	30

† Yield increase as percent of control.
Source: EPID 1976.

Aphid control. A pea aphid control demonstration was conducted in east and west Gojam during the 1992 cropping season (Wondimagegnehu Seyoum, IAR, 1992, pers. comm.). The demonstration compared sprayed (50% E.C. pirimiphos-methyl at about 35% level of infestation) and unsprayed (farmers' practice) treatments on a landrace field pea cultivar. The sprayed plot outyielded the unsprayed by an overall mean of 0.48 t/ha and 33% across locations.

Package demonstrations

Faba bean. Demonstration trials were conducted to observe the yield performance of an improved cultivar (CS 20DK) on farmers' fields in selected areas of the country during 1986 and 1987. Under researchers' and farmers' management levels, CS 20DK outyielded the local cultivar by 0.45 and 0.21 t/ha respectively. Similarly, the yield increase due to improved management was 0.89 t/ha for CS 20DK and 0.65 t/ha for the local cultivar. This showed that the improved cultivar responded better to improved management than the local cultivar. The yield increase due to management was higher than that due to cultivar, indicating the importance of management in faba bean production.

In a modified approach, demonstrations of improved faba bean cultivars with their production practices were conducted in high-altitude zones of the central, northwest and southeast and in the mid-altitude zone of the country from 1986 to 1992 (DZARC 1990, 1993). The demonstrations compared the improved methodology, which included improved cultivar, recommended seed and fertilizer rates, and weeding time and frequency, with the farmers' traditional faba bean production practices in a 0.25-ha plot.

In the high-altitude zones (2200-2800 m), CS 20DK gave a yield range of 1.5-1.99 t/ha at 31% of the sites, and 2.0-2.49 t/ha at 23% of the demonstration sites. In the intermediate zone (1750-2190 m), NC-58 gave a yield range of 1.5-1.99 kg t/ha at 30% of the demonstration sites, followed by a yield range of 2.00-2.45 t/ha at 28% of the demonstration sites. The yield of the local cultivar (landrace) ranged from 0.5-1.0 and 1.0-1.5 t/ha at 54 (34%) and 57 (36%) demonstration sites, respectively.

The mean increase in grain yield of CS 20DK over the farmers' cultivar in the central, southeast and northwest zones of Ethiopia varied from 1.21 t/ha at Wobe Mariom to 3.95 t/ha at Galama. CS 20DK and the local check gave a mean grain yield of 2.19 and 1.25 t/ha respectively. In general the use of CS 20DK with its production packages resulted in a yield increase range of 30-199% over the farmers' traditional faba bean production practices, with an overall mean of 78% increase across sites.

Similarly, faba bean demonstrations conducted in intermediate zones of Ada showed that the improved cultivar NC 58, with its production package, gave a mean grain yield of 1.8 t/ha, whereas in the farmers' method the local check gave a mean yield of 1.05 t/ha. The mean grain yield advantage of NC 58 was 0.83 t/ha (80%) over the farmers' production practice.

Economic evaluation of the recommended packages and the farmers' practices was done for faba bean production at high and intermediate elevation demonstration sites of the central zone. The daily cost of labor for weeding was taken at 3.00 Birr/man. Local market price was used to estimate the value of the produce. Considering the costs that varied (seed, fertilizer and labor for weeding) the farmers' practice had a lower cost than the improved method. However, with local market prices, the improved method gave higher net benefits than the farmers' practices (Table 4). The marginal rate of return to investment in CS 20DK and NC 58 with the improved package was 322 and 337%, respectively.

Chickpea and lentil. The outreach program of DZARC, launched in 1974, demonstrated two improved cultivars of chickpea (Dubie and DZ-10 11) and one of lentil (EL-142) in Yerer-Keryu area of Shewa region in the years 1976-84. These improved cultivars with the improved packages gave 50% more yield than the local cultivars with local production practices (DZARC 1990).

After 1985, the outreach program of DZARC conducted demonstration and popularization of Mariye chickpea and Chalew (NEL 358) lentil cultivars; these were released in 1984 and 1985, respectively.

Table 4. Partial budget analysis of faba bean demonstrations in high and intermediate altitudes of the central zone of Ethiopia, 1986-92.

	High altitude		Intermediate	
	Local	CS 20DK	Local	CS 20DK
Variable cost (Birr/ha)				
Cost of seed	148.00	202.00	130.00	167.00
Cost of fertilizer		90.30		76.00
Cost of weeding	55.00	103.00	46.00	103.00
Total variable cost	203.00	395.30	176.00	346.00
Benefit				
Average yield (t/ha)	1.05	1.95	1.05	1.83
Gross benefit (Birr/ha) at farm gate price	0.95	1.76	0.94	1.69
Net benefit (Birr/ha)	0.74	1.36	0.77	1.34
Marginal Rate of Return (%)	322		337	

The improved chickpea package — consisting of improved cultivar Mariye, a seed rate of 0.80 t/ha, sowing at the end of August until early September and one hand-weeding when necessary — has been demonstrated since the 1987/88 crop season in the midaltitude (1800-2200 m) zone of Shewa region. The demonstration revealed the superiority of the improved package compared with that of the local package (Table 5). In 1991/92 the improved method on average outyielded the local package by 57% in Shenkora, Ada, Akaki and Gimbichu and by 39% in Tulubolo and Ginchi (DZARC 1993).

Table 5. Partial budget analysis of improved and local chickpea packages in Ada, Gimbichu, Shenkora, Tulubolo and Ginchi areas, 1991/92.

Description	Improved package	Local package
Yield (t/ha)		
Grain	0.99	0.68
Straw	2.44	1.84
Adjusted yield (t/ha)		
Grain	0.89	0.68
Straw	2.20	1.84
Total gross benefit† (Birr/ha)	1298.40	1020.02
Total costs that vary‡ (Birr/ha)	92.20	106.53
Net benefit (Birr/ha)	1191.87	927.88

† Field prices: seed = 1.01 Birr kg/ha; straw = 0.18 Birr kg/ha.
‡ Seeding.
Source: DZARC 1993.

Economic analysis done on pooled yields indicated that the improved package had a higher net benefit (32%) than that of the local package. During the demonstration years green pods eaten by passers-by were reported to be a bottleneck for the dissemination of the Mariye package (DZARC 1990, 1991, 1993).

Similarly, an improved lentil production package — cultivar (Chalew), seed rate (0.70 t/ha), sowing date (mid-July to end of July), hand-weeding and aphid control by insecticide (Dimethoate) — has been demonstrated since its release in the midaltitude zone of Ada, Lime, Gimbichu, Shenkora, Akaki and Tulubolo. The overall evaluation of the package indicated that it was performing better than the local package in grain yield and economic return (Table 6).

Economic analysis done for the improved Chalew package demonstration in 1990/91 gave a marginal rate of return of 285% on invested cash capital using the year's input and output prices (DZARC 1991). However, the waterlogging problem at Tulubolo hampered the cultivar (Chalew) from expressing its yield potential. This might demand a closer look into sowing date and drainage management practices before wide-scale dissemination in the area (DZARC 1991).

Table 6. Partial budget (Birr/ha) analysis for improved and local lentil packages in Ada, Shenkora and Gimbichu, 1991-92.

Description	Improved package	Local package
Yield (t/ha)		
Grain	0.98	0.56
Straw	2.56	2.16
Adjusted yield (t/ha)		
Grain	0.88	0.56
Straw	2.30	2.16
Total gross benefit† (Birr/ha)	1282.71	913.47
Costs that vary‡ (Birr/ha)	153.66	64.01
Net benefit (Birr/ha)	1129.05	849.46
Marginal Rate of Return (%)		312

† Field prices: grain = 1.09 Birr kg/ha; straw = 0.14 Birr kg/ha; insecticide = 11.06 Birr kg/ha.
‡ Seeding and insecticide application.
Source: DZARC 1993.

Popularization

After demonstration of improved technologies to farmers, a sustained popularization and follow-up of the new cultivars and practices is essential to promote the dissemination of the technologies and gather feedback on acceptance from farmers and extension workers. This is done by selling improved seeds to farmers along with advice about the recommended cultural practices through the extension department of the MOA of the concerned district.

Faba bean

With the above objectives, popularization of faba bean cultivar NC 58 was executed in Ada to widely disseminate and encourage its adoption along with its production practices during the 1989 and 1990 cropping seasons (Adugna and Bisrat 1992; Adugna *et al.* 1991a). It was conducted in about 15 development centers of Ada with the number of participant farmers varying from 1 to 18 and the plot size ranging from 0.1 to 1 ha depending on the availability of farmland. Farmers were advised to apply the recommended seed and fertilizer rates. In this program, a total of 139 farmers participated and about 54.51 ha of land was covered with the improved seed.

The results of the popularization indicated that NC 58 gave a yield range of 1.47-2.40 t/ha with an overall mean grain yield of 1.75 t/ha. Conversely, the local cultivar with farmer's production practices from adjacent farmers' fields yielded 0.65-1.40 t/ha with a mean of 1.07 t/ha. The yield increase due to the improved method of production ranged from 33 to 154% with an overall mean of 64% across locations. Economic evaluation of the popularization fields indicated that participant farmers have earned high net benefit from the improved method, 1757.85 Birr/ha, compared with the neighboring farmers' practice, 1028.40 Birr/ha. The marginal rate of return to investment in the improved method was 1303% (Adugna and Bisrat 1992).

Similarly, 16 farmers around Welemera *wereda* participated in popularization of the cultivar CS 20DK in the 1992/93 crop season. Those farmers got an average grain yield of 2.37 t/ha, a yield advantage of 80.5%, over the neighboring non-participating farmers who produced 1.33 t/ha.

The results indicated the importance of promotion of popularization activity and the need to supply improved seeds, fertilizers, pesticides and other inputs in a timely and adequate manner.

Chickpea and lentil

Mariye chickpea and Chalew lentil were popularized in Ada *wereda* in 1991/92. Mariye was grown by 13 farmers on 3.25 ha of land, while Chalew was grown by 7 farmers on 1.23 ha of land (DZARC 1993). Passers-by ate many of the green pods of Mariye. As with faba bean, this popularization activity also reflected the need for aggressive and intensive extension work for dissemination of the cultivars along with their packages. Furthermore, as reported for faba bean and chickpea, in lentil the provision of improved seed was considered a bottleneck.

Training

Training is one means of developing an effective and efficient technology transfer system. Extension personnel and farmers are active elements of the system who need appropriate training. Training has been given to extension agents since the beginning of extension service in the mid-1950s (Adugna *et al.* 1991b).

Training of extension staff

In a modified T & V extension approach which is now in use by PADEP, training is a substantial component of the approach. Extension agents are trained monthly by zonal experts (SMS). Technical staff of the main department of MOA and resource people from research centers, agricultural colleges and universities are involved in the training of SMS. This training concluded with the activities of the farmers.

In addition to this routine training, extension agents are trained at various training centers for different lengths of time. Training is done pre-season, quarterly and at other intervals.

Farmer training

Farmer training has been given since the first comprehensive package program (CADU) in 1967 (Adugna *et al.* 1991b). As a principle of the T & V extension approach, development agents train contact farmers every fortnight on current agricultural practices and technologies. Contact farmers in turn pass the extension advice to other farmers in the communities.

In addition to this kind of training, farmers are trained in farmers' training centers (Table 7) for durations ranging from 3 to 6 weeks (Adugna *et al.* 1991b). The training includes topics on food legume production, protection, utilization and knowledge transfer.

Table 7. Farmers' training centers in Ethiopia.

Training center	*Awraja*	Administrative region
Holetta	Wolmera	Addis Abeba
Bako	Chelia	West Shewa
Nejo	Nejo-Jarso	Welega
Wolaita	Damota	North Omo
Bekoji	Galama	Arsi
Kombolcha	Combolcha	East Harerge
Woreta	Fogera	South Gonder
Kombolcha	North Kalu	South Welo
Agarfa	Hora	Bale
Gewane	Gewane	West Harerge

Source: EPID 1976.

Preparation of Extension Publications

A few extension publications have been written on cool-season legumes (Table 8: not a complete list). Among those published, most are of a general nature, which do not give specific and in-depth information about cool-season legume production.

Multiplication and Distribution of Improved Seeds

Seeds are the basic component of improved technology. As indicated in the earlier sections, one of the major constraints in production of food legumes is shortage of improved seeds.

Although the Ethiopian Seed Corporation (ESC) was established in 1971 (Ethiopian calendar) in cognizance of the problem, the corporation has never been in a position to solve the problem. The corporation gives more attention to seeds of cereals than to those of food legumes. The corporation cites the farmers' demands as a justification for the emphasis on cereals. To alleviate the problem, the research centers of IAR and AUA have been involved in the multiplication of improved seeds.

Table 8. Some cool-season food legume extension publications prepared by IAR, AUA and ESC.

Title	Language	Publisher	Year
Improved crop cultivars in Ethiopia	Amharic	ESC	1987
Guide for crop production	Amharic	IAR	1982
Alemaya Agricultural University (Debre Zeit Research Center)	Amharic	AUA	1987

DZARC

The seed multiplication project of DZARC, initiated in 1974, has been multiplying seeds of released improved seeds and supplying to farmers, agricultural cooperatives and agriculture-related organizations, and later to ESC. The ESC has been taking more than half of the available seeds. The multiplication project has given much attention to multiplication of seeds of wheat, tef, chickpea and lentil. Multiplication, particularly in the initial years of the project, was low (Table 9). This might have been due to a shortage of new cultivars and low demand compared with that for tef and wheat. Improved seeds that were multiplied by the project were Dubie, DZ-10-11 and Mariye chickpea, and EL-142 and Chalew lentil.

Table 9. Production (t) of improved seeds of chickpea and lentil by Debre Zeit Agricultural Research Center, 1976-91.

Year	Chickpea	Year	Chickpea	Lentil
1976	31.2	1984	1.6	
1977	22.4	1985	4.0	0.8
1978	31.6	1986	2.8	0.4
1979	20.0	1987	9.5	
1980	14.0	1988	1.0	
1981	13.4	1989	6.8	2.0
1982	13.4	1990	1.6	5.5
1983	11.4	1991	1.4	4.7

IAR

The MOA (EPID) was responsible for seed and input distribution in the early days. Later, the Agricultural Inputs and Marketing Supply (AIMS) department was responsible for seed distribution, subsequently the Agricultural Marketing Corporation (AMC) and currently the Agricultural Input Supply department.

There was modest seed multiplication work in IAR, Holetta Center. Data related to work in other centers were not available for this review. At present, it is reported that AISCO has over 600 distributing centers in the country (Adugna and Bisrat 1992). The role of the organizations in the distribution of seeds of CSFL is, however, negligible. DZARC and research centers of IAR also distribute seeds, including those of food legumes, directly to users.

Adoption Studies

A survey was made around Welemera and Adis Alem *weredas* to study the adoption of faba bean production practices. The survey showed high rates of adoption of improved cultivar, hand-weeding and fertilizer application (Table 10).

The reasons given by farmers who were not adopting the technologies were unavailability of seeds and fertilizer, and weak extension follow-up after demonstration and popularization.

Table 10. Adoption of a technology or combination of technologies in 1988 and 1989 crop seasons by farmers around Welemera, Ethiopia.

Technology	Host farmers		Non-host farmers	
	1988	1989	1988	1989
Fertilizer (F)	0	0	2	0
Hand-weeding (HW)	23	8	42	32
Improved seed (IS)	8	15	2	2
F + HW	0	8	2	2
F + IS	8	0	0	1
HW + IS	8	15	7	7
F + HW + IS	54	46	2	0

Problems were faced in creating an effective technology transfer system. The following were reported as bottlenecks for effective technology transfer by various extension personnel:

- lack of defined policy
- inadequate farmer-development worker ratio
- rapid staff turnover
- unavailabilty of agricultural inputs and credit facilities.

Concluding Remarks

The improvement of the role of cool-season food legumes in the Ethiopian agriculture system necessitates some work in research and development. However, the documents covered in this review show that this has not been provided. Hence the need to change this dismal situation seems to be justified. Therefore, a concerted effort which puts the following into consideration is needed:

- tackling the problem of lack of improved cultivars
- improving the availability of seeds, fertilizer, pesticides and other inputs with an acceptable credit facility system
- creating an efficient technology transfer system which ensures fast and reliable dissemination of agricultural technology.

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Discussion

Dr Solh
Recent adoption studies are not included in the extension service. What are the reasons for this?

Ato Elias (presenter)
The recent adoption studies are at an infant stage. They will be included after further studies.

Dr Asnakew
Menelik II first established the Ministry of Agriculture with an aim of having an extension service like that of the Europeans. However, after a period of more than seven decades, we haven't yet caught up with European agriculture. Can you explain why?

Ato Elias
Menelik II thought that adopting the best meant doing exactly what the Europeans do. The packages to be adopted were not evaluated and modified according to local conditions. Even after extension service started to use proper practices, there were many obstacles to success. For example, activities were not regularly evaluated and approaches lacked continuity.

Utilization of Cool-season Food Legumes in Ethiopia

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Abstract

Cool-season food legumes are the most widely cultivated grain legumes in the Ethiopian farming system. Food legume products prepared in one form or another are consumed every day by Ethiopians. The nutritive contribution of food legumes derives from their higher protein and lysine contents, compared with cereals. Legumes have some antinutritional factors, but some processing methods can reduce/remove the toxic contents. About 13 traditional food types are prepared from grain legumes and consumed in various ways. A study of composite flour from cereal and food legumes indicated that a 20% legume content in the mixture produced good products. Mixtures of malt barley and chickpea, with high nutritional values, are used as weaning and supplementary foods. Grain legumes are processed by dehulling and cooking. Dehulling with a mini-dehuller reduced milling loss due to broken seeds or scouring and gave uniform splits. Cooking time of improved cultivars grown in different locations ranged from 11 to 75 minutes after 16 hours of soaking. Some of the factors affecting cookability of food legumes are grain size and lignification between the cell wall and the middle lamella. The time required for cooking is affected by the mineral composition of the soil. By-products of food legumes are used for animal feed or burned for fuel.

Introduction

The most widely cultivated food legumes in the Ethiopian farming systems are chickpea, lentils, faba bean and field pea. These food legumes are consumed as a protein supplement in the cereal-based diets of Ethiopians. The consumption rate increases during the numerous fasting days (about 139 days per annum) when orthodox church followers abstain from animal protein.

Legumes provide high-quality protein compared with cereals. They have a relatively higher content of the essential amino acids lysine and threonine

(Patwardhan 1962). A cereal diet supplemented by legumes therefore raises the quality of the protein and improves the consumer's dietary intake. Several processing procedures are used in traditional food preparations of legumes: boiling, roasting, fermenting, sprouting, dehulling and milling. These methods are helpful in removing some toxic substances present in food legumes and they improve palatability.

Nutritive Value of Legumes

Legumes and their products are consumed by humans in most parts of the world. They are excellent sources of protein (20-40%), which is approximately three times that of cereals. Legumes also contain carbohydrates (59-60%) and are fairly good sources of thiamin, niacin, calcium and iron (Aykroyd and Doughty 1977). Plant proteins are important, particularly in developing countries, because of the cost and scarcity of animal protein. Legumes give higher yields of protein per unit area than cereals (Aykroyd and Doughty 1964). The nutrient composition of some legume grains compared with cereals is shown in Tables 1 and 2. Faba bean, lentils and grasspea have high protein contents and an appreciable amount of minerals and vitamins. Table 3 lists the essential amino acids present in legumes and cereals. Legumes are high in lysine and low in methionine. The reverse is true for cereals.

Protein Content of Faba Bean and Field Pea

Advanced lines of faba bean and field pea were analyzed for crude protein content at Holetta Research Center. Samples collected from five trial sites (Holetta, Bekoji, Sheno, Dembi and Kulumsa) were ground using an ultracentrifugal mill. One gram of the sample was used for N analysis using the macro-Kjeldahl method. Crude protein content was determined by multiplying N% by a factor of 6.25. The mean protein contents for faba bean and field pea are presented in Table 4 (Addise 1989, 1991a, 1991b, 1992). The highest mean (28.3%) for faba bean was recorded in the crop season 1988 at Dembi, the lowest in 1993 at Bekoji. The overall mean for faba bean ranged between 22.3 and 28.8%. In field pea the highest mean was 26.2% at Demi in 1991/92 crop season, the lowest was 20.9% at Bekoji in 1992/93. This finding indicates that differences in protein content do exist among cultivars, which allows for further improvement in protein content.

Table 1. Chemical composition of legumes and cereals commonly used in Ethiopia.

Food grain	Composition per 100-g edible portion						
	Calorie	Moisture (%)	Protein (g)	Fat (g)	CHO (g)	Fibre (g)	Ash (g)
Faba bean	344	11.0	21.5	1.4	63.2	9.6	2.9
Chickpea	363	10.5	17.4	5.2	63.9	9.4	3.2
Lentil	344	10.2	22.6	1.0	63.2	4.8	3.0
Field pea	345	10.7	20.1	1.4	64.8	4.3	3.0
Grasspea	347	10.7	22.6	1.4	63.6	8.2	4.3
Barley	334	11.3	9.8	1.9	75.4	3.7	2.0
Maize	363	10.7	8.6	4.6	74.9	2.6	1.3
Wheat	339	10.8	10.3	1.9	71.9	3.0	1.5
Sorghum	338	12.1	7.1	2.8	76.5	2.3	1.6
Mixed tef	336	10.7	8.3	2.9	75.2	3.6	3.0

Source: Agren and Gibson 1968.

Table 2. Mineral and vitamin composition of grain legumes and cereals commonly used in Ethiopia.

Food grain	Composition per 100-g edible portion					
	Minerals (mg)			Vitamins (mg)		
	Ca	P	Fe	Thiamine	Riboflavin	Niacin
Faba bean	99	420	8.4	0.44	0.30	2.1
Chickpea	251	231	14.3	0.43	0.12	1.5
Lentil	68	359	28.3	0.37	0.15	1.6
Field pea	79	309	13.6	0.30	0.16	2.4
Grasspea	336	273	108.2		0.17	
Barley	47	325	10.2	0.32	0.12	6.3
Maize		282	4.4	0.22	0.08	3.9
Wheat	49	276	7.5	0.34	0.09	2.9
Sorghum	30	282	7.8	0.54	0.12	3.3
Mixed tef	140	368	59.0	0.32	0.13	1.7

Source: Agren and Gibson 1968.

Table 3. Essential amino acid composition of different legumes and cereals (mg/100 g of food).

Food grain	Lys	Thr	Val	Leu	Iso-leu	Meth	Tryp	Phenyl	Arg	Hist
Faba bean	426	225	306	452	273	45	45	261	653	166
Chickpea	420	228	320	476	293	89	72	361	603	156
Lentil	530	270	350	495	310	57	47	342	650	174
Field pea	479	224	291	478	276	46	47	294	609	145
Grasspea	390	216	231	414	167	36	59	272	425	205
Barley	220	218	328	429	238	103	73	324	303	135
Maize	181	248	341	790	247	132	53	307	310	206
Wheat	175	193	306	435	255	104	73	217	285	152
Sorghum	150	218	336	774	267	110	64	298	261	150
Mixed tef	169	258	365	523	275	232	85	347	260	143

† Lys = lysine; Thr = threonine; Val = valine; Leu = leucine; Isoleu = isoleucine; Meth = methionine; Tryp = tryptophan; Phenyl = phenylalanin; Arg = argnine; Hist = histidine.

Source: Agren *et al.* 1975.

Table 4. Location mean values of percent protein content of faba bean and field pea cultivars from five locations in Ethiopia, 1987-93.

			Mean protein content (%) at					
Crop	N	Crop season	Holetta	Sheno	Bekoji	Dembi	Asasa	Kulumsa
Faba bean	13	87/88	25.8	26.2	23.9	31.6	23.72	6.8
	20	88/89	27.5	26.4	26.0	28.8	28.0	28.3
	13	90/91	24.6	24.1	25.0	23.6		27.4
	14	91/92	24.8		23.5	27.7	26.3	26.0
	14	92/93	24.9	25.6	22.2			
Field pea	13	90/91	24.3		23.2	25.2		25.5
	14	91/92	22.7		23.2	26.2	25.7	26.0
	15	92/93	23.0		29.9			

Source: Addise 1989, 1991a, 1991b, 1992.

Nutrient Costing

The Ethiopian Nutrition Institute (ENI) has been collecting data for 3.5 years on the prices of important and widely used food items in Addis Abeba marketplaces. The survey was conducted to collect information on price changes, proper nutrition education and dietary counseling. From the collected data an index of nutrient density was computed to compare the nutrient contribution of food items for the same unit price. When the energy and protein values per Birr were taken into account, grasspea was the highest ranking among a few legumes (Hailemariam *et al.* 1989). Of the foods that contribute high energy and protein at low cost (Table 5), grasspea, faba bean and haricot bean rank high. Cereals contribute low protein per Birr compared with legumes. The computed nutrient density is high in grain legumes.

Table 5. Comparison of contribution of energy and protein at low cost of some cool-season food legumes and other food crops.

Food grain	Kcal/Birr [1]	Protein/Birr (g) [2]	Index of nutrient density 1×2/100
Legume			
Grasspea	4936	321	15844
Broad bean	3995	257	10267
Chickpea	3373	166	5599
Haricot bean	3877	225	8723
Cowpea	2765	163	4606
Cereal			
Corn	5633	132	7435
Barley	3144	87	2735
Sorghum	3385	74	2504
Tef	2624	78	2046
Wheat	2941	91	2676
Millet	2669	59	1574
Emmer wheat	2626	97	2547
Naked barley	2838	93	2639

Source: Hailemariam *et al.* 1989.

Toxic Principles

Food legumes require proper processing before consumption. The main objective of processing is to improve palatability and remove/reduce certain undesirable constituents present in them. It has been reported that legumes contain anti-nutritional factors that affect their utilization. The most commonly known toxic substance and biologically active principles present in legumes are trypsin inhibitors, haemagglutenines, saponins, cyanogenic anticoagulants, toxic histones, factors causing lathyrism and favism, deleterious alkaloids and astringent substances (Liener 1962). Flatulence factors, oligosaccharides (stachyose, verbacose and raffinose), are known to produce gas in the stomach. Lathyrism is caused by a neurotoxin known as β-N-oxalylamino L-alanine (BOAA) present in grasspea (*Lathyrus sativus*). Lathyrism has been known for many years in Ethiopia. According to the study by Tekle-Haimanot *et al.* (1993), the northwestern and central highland areas of the country are affected by the disease. The prevalence rate ranged from 1/10,000 to 7.5/10,000. Most toxic substances are partially or completely removed by processing methods such as dehulling, soaking, cooking, roasting, germination and fermentation. Tekle-Haimanot *et al.* (1993) indicated that the BOAA content of lathyrus can be reduced by discarding excess water after soaking or boiling. If such methods are practised in traditional food preparation, the incidence of lathyrism will be minimized.

Processing Methods

Dehulling

Dehulling is a primary processing method that removes the seed coat. Traditionally, dehulling and splitting are carried out by a manual process which involves a stone grinder called *wofcho* and *mej* (quern). This process is tedious, time consuming and the loss is very high because of broken grains and powder. In the ENI, experiments have been conducted to assess a new technique for dehulling various types of grains using a mini-dehuller. This method is time and labor efficient and the losses are comparatively low. It was reported by Wuhib and Tekabe (1987) that when a mini-dehuller was used the average yield of splits from chickpea, lentils, faba bean and field peas was 77, 72, 80 and 91%, respectively. Variations in dehulling characteristics and yield of splits exist because of cultivar differences, size and shape uniformity, and moisture content of the grain. During dehulling, size grading and tempering of the grain are important steps to reduce dehulling losses.

Cooking

Cooking is probably the oldest method of utilization. Legumes are cooked primarily to improve their palatability. Optimal cooking improves the digestibility and nutritive value because it reduces/eliminates certain antinutritional factors.

A long cooking time is one of the constraints faced by the rural community. Legumes with reduced cooking time are preferred to alleviate the fuel problem. With this objective, advanced faba bean lines were evaluated for their cooking time. The data obtained from such studies will be used to complement the crop improvement effort.

An improved cultivar of faba bean (CS 20DK) was evaluated for its cooking time. It was grown at nine on-farm trial sites. The objective was to study the effect of location on cooking time. Cooking time was determined with a modified Mattson cooking device. The result indicated that the range of cooking time was 13-26 minutes with a mean of 18.5 minutes. Highest cooking time was recorded from three sites with a cooking time of 24.4, 25 and 26 minutes, respectively (Tiruset and Senayit 1991). The soil analysis data of these three sites showed low levels of K and P. This indicates that soil nutrients play a role in cooking time. Therefore, cooking time of a given cultivar should be determined across locations.

From the 1992 crop season a set of mature dry faba bean seeds grown in three locations and two screening stages (Pre-National Variety Trial, PNVT and National Variety Trial, NVT) were evaluated for cooking time and percent nonsoakers. A total of 96 samples were tested from 20 cultivars in the PNVT and 13 in the NVT for each location. Beans were soaked for 16 hours at 27°C in distilled water. Cooking time was determined with a modified Mattson bean-cooking device. The results indicated that from the PNVT the highest range of percentage non-soakers was observed at Gondi (7.9-63.2%), while the lowest values were obtained at Dembi (0-6.5%). Range of cooking time was low at Dembi (11-20 minutes), intermediate at Gondi (19-31 minutes) and highest at Holetta (34-75 minutes). In the NVT the highest percentage of non-soakers was observed at Gondi (9.4-38.2%) and the lowest at Dembi (0.5-3.2%). Cooking time was low at Dembi (8.3-13.7 minutes) and high at Gondi (20.3-39.0 minutes). Although the cultivars were not identical across locations, effect of location on cooking time and percent non-soakers was evident. As this experiment was conducted from one season's harvest only, it is difficult to make firm conclusions.

Factors Affecting Cookability

Several studies were conducted on cookability. Haytowitz and Mathews (1983) reported that cooking time is affected by the size of legumes. Smaller legumes (cowpea and lentils) have a short cooking time (15-20 minutes) while faba beans and chickpeas have a cooking time of 2-2.5 hours. A cookability study conducted by Mwandemela *et al.* (1984) showed that soybean lines that absorbed water most rapidly tended to cook in a short time and small seeds cooked faster than larger seeds. According to the report of Paredes-Lopez *et al.* (1989) common beans (*Phaseolus vulgaris*) from a high-calcium site had a longer cooking time which increased more rapidly on accelerated storage. Hence, poor storage also has been implicated in occurrence of the hard-to-cook phenomenon. Hinks and Stanley (1987) concluded that lignification of the secondary walls and middle lamella within the cell wall of legume seeds hinders cell separation and ultimately texture during cooking.

Surveys on Utilization

A survey was conducted in 1986 of faba bean on-farm trial sites in three zones (Menagesha, Selale and Yerer-Keryu) of the Shewa administrative region. The objective of the survey was to identify the traditional faba bean dish preparations, cultivar preferences and processing constraints faced by the households of the farming community. The result indicated that faba bean was used in eight types of dishes (*shiro, kik, nifro, ashuk, endushdush, gunkul, gulban* and *siljo*) (Senayit 1987). The most preferred dishes from faba bean were *shiro* and *nifro*. The preferred faba bean seed size for dehulling was large, whereas small-seeded beans were chosen for cooking.

A similar survey conducted in three different *awrajas* (Addis Abeba, Minjar, and Ada) included utilization of faba bean, lentils, field pea and chickpea. The target groups were housewives, urban snack-bar owners and households of peasant associations. Several types of dishes from pulses were identified through this survey (Maaza 1993). These dishes could be categorized into five groups. Breakfast (*full* and *sambusa*), side dishes (*shiro wot, kik wot, azifa*, soup, and *shimbra asa*), snacks (*kollo, nifro, endushdush* and *ashuk*), weaning foods (*genfo* and *atmit*) and occasional dishes (*gulban, hilbet* and *siljo*). This survey will continue to collect more information.

The ENI conducted a household survey on grasspea preparation and a general dietary study in Gonder administrative region in 1988/89. Partially processed survey data indicated that food types prepared from grasspea were *shiro, nifro, kollo* and *kitta* (Elizabeth *et al.* 1992). The preparation method involved washing and some form of heat treatment. These survey excercises revealed numerous types of food preparations from legumes in different localities. This information could be used in formulation of traditional food recipes and the foodmaking qualities of improved cultivars could be evaluated for each preparation.

Food Uses

Legumes are consumed in one form or another in the everyday meals of the Ethiopians. Several processing procedures are used in the traditional food preparation of legume grains: boiling, roasting, fermenting, sprouting, dehulling and milling. The consumption of food legumes in Ethiopia has different patterns. When served as sauce it is eaten to complement the cereal-based staple food *injera*; when fermented or made into paste it is served as a side dish; when made into bread, boiled like rice or roasted it is served as a snack. Legume grains are mixed in weaning food formulation of Faffa (a commercial weaning food brand in Ethiopia).

Table 6. Traditional Ethiopian foods prepared from cool-season legumes.

Food product	Legume†	Mode of consumption
kik (dehulled split)	FP, FB, LT	sauce/gravy
shiro (spiced powder)	FP, FB	sauce thickener
kollo (whole roasted)	CP, FB	snack
nifro (boiled)	CP, FB + cereals	snack
siljo (fermented paste)	FB	side dish
shimbra asa (unleavened bread)	CP	mix in a sauce
azifa (cooked and mashed)	LT	side dish
gunkul (sprouted legumes)	FB	snack
elbet (paste from flour)	LT	side dish
ashuk (roasted and soaked)	FB	snack
endushdush (soaked and roasted)	FB	snack
dabo (unleavened bread)	CP (10-20%) + cereals	breakfast
fafa (weaning food)	CP + cereals + SM + vit.	infant food

† FP = field pea; FB = faba bean; LT = lentils; CP = chickpea; SM = skim milk; Vit = vitamins.

Traditional food types prepared from legumes and their mode of consumption are summarized in Table 6. About 13 food types prepared from food legumes have been identified although this listing is by no means exhaustive. Industrially processed, legume-based food products are not common in the country, except Faffa and batch production of splits of lentils and field pea. The need for industrialization of these crops should be emphasized to promote the production of convenience foods.

Weaning and supplementary foods

Faffa is an infant and child food which is commercially manufactured in Ethiopia. This food formulation consists of 57% wheat, 10% chickpea, 18% defatted soy, 5% skim milk powder, 9% sugar + iodized salt, and 1% vitamins and minerals (Backlander 1987). It is a nutritionally balanced weaning food formulation. In this formula the legumes (chickpea and soy) have played a very important role in improving the nutritional values of the final product, mainly protein and the essential amino acids.

The ENI has formulated various types of weaning foods based on the information from surveys in many regions. At different times studies have been carried out to develop weaning foods from combinations of cereals and legumes which satisfy the nutritional need of the child. All the formulations can be prepared easily from locally available resources at household level by the use of simple processing methods. The recipe for formulation of malted weaning food from barley and chickpea is 60% germinated barley, 30% germinated chickpea, 5% skim milk powder and 5% sugar (Asrat 1991). The nutrient content of this formulation is depicted in Table 7. The protein content (15.6%) of this formulation is higher than the minimum ISI recommendation (14%). Legume supplementation in weaning food plays an important role in nourishing infants and children.

Composite flour

Studies have been conducted in the experimental kitchen to develop recipes based on cereals and legumes. The objective of the experiment is to upgrade the nutritional value of traditional food and thereby improve the dietary intake of the people. In these trials chickpea, field pea, faba bean and soybean are being used as a mix with cereals in various products such as *dabo* (leavened bread), *kitta* (unleavened bread), *genfo* (a stiff porridge), *besso* (roasted barley powder) and other products which are used as snack foods (Asrat and Lakech 1990). Generally, mixing up to 20% legume flour with cereal powder makes a good product and complements the cereal-based foods by increasing the protein intake in a given diet.

Table 7. Nutrient content of malted weaning and supplementary foods.

Nutrient	Content/100 g	ISI recommendation
Moisture (g)	6.3	Max. 10.0
Protein (g)	15.6	Min. 14.0
Fat (g)	3.8	Max. 7.5
Dietary fibre		
Insoluble (g)	7.8	
Soluble (g)	3.8	
Ash (g)	2.2	Max. 5.0
Carbohydrates (g)	60.5	Min. 4.5
Calcium (mg)	13.8	Max. 1000
Phosphorus (mg)	358	
Iron (mg)	10.2	Min. 10.0
Energy (kcal)	338.6	

Source: Asrat 1991.

A study conducted at the IAR food science division to develop recipes of *injera* preparation from tef (*Ergrostic tef*) and faba bean (*Vicia faba* L.) showed that 20% faba bean mix with tef gave good-quality *injera*. Increasing the faba bean proportion decreased the *injera* quality. The texture became elastic and the appearance was poor (Tiruset and Senayit 1991).

Evaluation of Cultivars for Food Uses

Two improved faba bean cultivars (NC58 and CS 20DK) and two local cultivars (Holetta local and Debre Zeit local) were evaluated for their quality in five dishes (*nifro*, *ashuk*, *endushdush*, *gunkul* and *gulban*). According to the panel's response, NC58 was best for *nifro*, while CS 20DK was very good for *ashuk*. All cultivars including the local ones were good for all the prepared dishes (Tiruset and Senayit 1991). Such experiments should be conducted with promising lines of cool-season legumes to select the best for any special food preparation.

Uses of By-products

Small farmers can not afford to grow forage crops to feed their livestock, mainly because land must be used for food crop production to feed the increasing population. The only option left to such farmers is to use crop residues, especially during the dry season. The post-harvest by-products such as straw, pod walls and other residues from threshing, and the hulls and brokens from industrial processing are used for animal feed. The straw is used as firewood.

Future Research Directions

More information is needed on the following:

- Studies on the end-use specificity of legumes in various traditionally prepared legume-based products.
- Basic studies on the role of legume constituents such as starch, protein and lipids with reference to some processing practices. This will help in designing formulations of new products which could be industrially processed.
- Research with fermented foods to further evaluate their nutritional quality and improve methods of production.
- Development of legumes with reduced cooking time, through breeding and/or new processing methods.

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Discussion

Dr Asfaw
Cookability is dependent on soil types and those grown on Vertisols take a long time to be cooked. Farmers prefer field pea to other legumes and check the cookability by blowing in their palms. What do you say in this respect? Is it not the source location that matters?

W/o Senayit
Cookability was dependent on the composition of seed and the mineral composition of the soil rather than on source locations. Therefore, we have to analyze the soil content, which has not yet been done. Seed content should also be investigated. It seems that we have to investigate what influences the cookability of seed.

Dr Tekalign
I think the soil nutrient composition must be looked at with cookability, not the soil type. Calcium content must be known.

Dr Asfaw
How are the effects of varietal and location differences on the cookability of food legumes studied?

W/o Senayit
For the effect of cultivar, grain size is examined, whereas for the effect of location, the soil nutrient is studied.

Participant
Is the mini-dehuller, a new technology, accessible to farmers?

W/o Senayit
Of course farmers are making use of the mini-dehuller. For dehulling, seed size is very important. The machine is efficient because it works by rotating but the size of seeds should be uniform. Dehulling in the traditional way was tedious and laborious.

W/o Asrat
This machine was modified from the Canadian product. It is available for the farmers and still the improvisation is ongoing.

Yohanes Degago
What qualifies chickpea as a weaning food in comparison with others?

W/o Senayit
Not only chickpea is used, but also peas and faba beans are used for this purpose. However, chickpea is more acceptable. It is also easier to germinate.

Chapter 2
Breeding and Genetics

Genetic Resources in Ethiopia

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Abstract

Ethiopia is recognized as an important center of diversity for many crop species including cool-season food legumes. The collection and conservation of activities is far from complete; gaps in collection still exist in terms of both region and species. Although related wild species exist in the country, they are not yet included in the collections. Efforts should be made to collect the wild relatives of these species and more areas have to be covered to assemble the genetic diversity of the species. The exploitation of wild relatives in the breeding program is practically nonexistent in Ethiopia. In general, it can be said that the level of diversity among regions is similar, and thus each region has something to offer to the breeding program. Widening the genetic base by collecting highly variable primitive materials from different regions will enrich the genepool and enhance the development of improved cultivars in plant breeding. Keeping genetic diversity and increasing yield per unit area should be the strategy of breeding in order to utilize the existing genetic resources effectively and to minimize the hazards of genetic vulnerability that may result from disease epidemics, outbreaks of insect pests, drought or other factors.

Introduction

The origin of cool-season food legumes (faba bean, field peas, lentil, chickpea and grasspea) dates as far back as 6000-8000 BC. They were domesticated as early as the first cereals, i.e., barley and wheat. In general they are of temperate or subtropical origin, and the cold requirement for successful production near the equator is met by high elevation (Asfaw 1988). Agriculture in the high plateau of Ethiopia is based primarily on plants of West Asian origin. According to Harlan (1968) chickpea, lentil, field pea and faba bean are West Asian introductions to Ethiopia that still possess wide genetic diversity. Vavilov (1951) also considered Ethiopia an important center of diversity for cool-season food legumes (CSFL). The exact date for the introduction of food legumes to Ethiopia is unknown; however, they were certainly introduced at an early date and have been in Ethiopia so long that according to Vavilov (1951) they have developed their own series of endemic cultivars.

According to Westphal (1974) the CSFL are of great importance in the grain/plow complex of the highlands, whereas tropical food legumes are prominent in the sorghum/plow complex of the highlands of Harerge.

Wild Genetic Resources of CSFL in Ethiopia

Wild relatives of cultivated crops are important genetic resources for crop improvement programs. The wild relatives of crops possess important variation that no longer exists in their cultivated counterparts and have adapted to cope with many natural hazards such as extreme heat and cold, drought, insect pests and diseases. Although the exploration of wild relatives in breeding programs has been limited, a few species taxonomically related to cultivated CSFL exist in Ethiopia (Table 1).

Table 1. Wild relatives of cool-season food legumes existing in Ethiopia and elsewhere.

Crop	In Ethiopia	In other regions
Cicer arietinum	*C. cuneatum*, 1000-2000 m asl, in EW, TU, SU†	*C. echinospermum* *C. reticulatum*‡ *C. judaicum* *C. pinnatifidum* *C. bijugum*
Pisum sativum	*P. sativum* var abyssinicum, in TU, WE and also known from SU, AR, BA, HA	
Vicia faba	*V. sativa*, 1500-3000 m, widespread *V. villosa*, 2100 m, in AR, SU, EW *V. pancifolia*, 1700-2700 m, in TU, GD, GJ, WG, SU, AR, KF, SD	*V. narbonensis*‡
Lens culinaris	*L. ervoides*, 2500-3000 m, in TU, GD, SU	

† GD = Gonder; GJ = Gojam; WG = Welega; AR = Arsi; SU = Shewa; HA = Harerge; BA = Bale; SD = Sidamo; EW = Eritrea; KF = Kefa; TU = Tigray; WE = Welo.

‡ Expected to be progenitors of the species.

Collection, Characterization and Utilization

Collection and utilization of cool-season food legumes was undertaken before 1976. However, systematic and organized collection to assemble genetic diversity for present and future use started after the establishment of the Plant Genetic Resources Center of Ethiopia (PGRC/E) in 1976. The genetic erosion of field peas and lentil is accelerating because of several factors, contrary to the situation with faba beans and chickpeas where no threat of genetic erosion is observed. Lentil production is largely limited by disease and it is now generally being replaced by other legumes. Known farmers' cultivars of field peas which used to be encountered frequently in the field no longer exist or occur infrequently because of pests and natural hazards.

Faba Bean

The total collection of faba bean conserved in the PGRC/E is 1435 accessions, of which 3 were obtained through donation, 509 from other institutes' collections and 923 from the PGRC/E collection. The largest collection originated from Welo, Gonder and Shewa and the smallest from Ilubabor (Table 2). Most collections of faba bean were made at altitudes ranging from 2351 to 2550 m asl and the fewest came from altitudes below 1750 m asl (Fig. 1). Ethiopia is considered a center of diversity for faba bean because of the existence of wide genetic diversity. Simple descriptive statistics performed for some agronomic characters by PGRC/E for each region are given in Table 3.

From the characters considered, number of flowers/plant and number of pods/plant seem to be highly variable compared with other characters. Accessions from Welo, unknown regions and Shewa are highly variable compared with those from other regions (Table 3). The highlands of Welo and Shewa are major production area of faba beans. Utilization of faba bean landraces in the breeding program started in 1977 and increased until 1983 in the various stages of research work (Table 4). In 1977, 140 entries of landraces were screened. These became sources of germplasm for National Variety Trials (NVT) in subsequent seasons. From 1983 onwards it was possible to identify a large number of exogenous entries that could be tested in NVT. As a result of the introduction of exotic materials from ICARDA, Germany, Sweden, the USA and England, the number of native landraces was reduced in the NVT after 1987. A high level of variation was observed for 1000-grain weight in the NVT (218-634 g), Pre-National Variety Trial (PNVT) (198-478 g) and Observational Variety Trial (192-606 g). For the same trials, the hectoliter weight was 75-85, 75-85 and 73-88 kg/hl respectively.

Table 2. Number of accessions and source of collections of *Cicer*, *Lens*, *Pisum*, *Vicia* and *Lathyrus* by administrative regions of Ethiopia up to 1992.

Region	*Cicer*	*Lens*	*Pisum*	*Vicia*	*Lathyrus*
Arsi	23	27	74	53	5
Bale	18	25	72	35	3
Eritrea	16	16	13	19	24
Gamo Gofa	12	7	28	20	
Gojam	129	36	83	110	56
Gonder	134	63	155	164	33
Harerge	27	27	58	71	1
Ilubabor	3	0	1	4	1
Kefa	0	0	15	17	
Shewa	214	57	100	138	27
Sidamo	26	1	18	14	
Tigray	31	28	31	35	21
Welega	2	5	47	42	3
Welo	38	73	140	186	35
Unknown	21	9	33	15	62
Total	693	374	868	923	282

Source: PGRC/E documentation.

Field Pea

The total number of field pea accessions available in Ethiopia was 1346, of which 23 were donations, 11 were selections, 444 were received from other institutes and 868 were from the PGRC/E collection. The largest collections were made from Welo, Gonder and Shewa and the smallest from Ilubabor (Table 2).

Table 3. Agronomic traits (mean ± SD) of faba bean collections from different regions of Ethiopia.

Region	N	Days to flower	Days to maturity	Plant height (cm)	Flowers/ plant	Pods/ plant	Seeds/ pod
Arsi	14	66.9±4.1	147.0±9.5	87.1±13.5	30.2±5.6	12.9±2.9	2.7±0.3
Eritrea	2	42.5±0.7	109.5±0.7	122.5±3.5	28.0±12.7		
Gojam	43	66.2±3.4	147.5±10.0	88.3±12.2	34.9±8.1	14.2±4.2	2.8±0.3
Gonder	69	44.9±2.6	109.2±1.8	123.9±10.2	43.4±15.0	7.0±2.1	
Ilubabor	4	48.8±6.2	105.5±9.2	130.5±10.1	62.0±2.8	13.1±1.8	1.9±1.1
Kefa	3	55.7±2.7	135.0±35.4	115.3±22.4	47.5±29.0	15.1±4.3	2.4±0.7
Shewa	153	66.4±8.4	143.0±14.4	94.7±16.4	35.4±10.4	13.6±4.9	2.7±0.5
Tigray	9	44.6±2.9	107.4±4.6	118.0±9.1		10.6±3.8	1.7±0.6
Welega	55	55.3±5.5	114.8±6.6	126.3±10.1	45.2±14.5	9.4±3.0	2.5±0.6
Welo	65	56.4±6.3	140.0±24.3	138.0±29.5	58.9±16.8	17.1±8.9	2.0±0.6
Unknown	207	57.4±9.6	137.6±25.0	100.5±21.1	45.3±11.6	13.9±5.4	2.6±0.6

Table 4. Ethiopian faba bean landraces used in National Variety Trial (NVT), Pre-National Variety Trial (PNVT), Observation of Variety Trial (OVT) and Preliminary Screening Nursery (PSN), 1977-90.

	No. of entries (landraces)			
Year	NVT	PNVT	OVT	PSN
1977		18	27	95
1978	11	6	25	26
1979	0	13		277
1980	13	10	28	87
1981	8	16	19	19
1982	8	18 A 18 B	14	60
1983	18 A† 12 B	14	11	30
1984	18 A 18 B	14	20	217
1985	17 A 18 B	16	37	106
1986	17 A 18 B	16	23	77
1987	10 A 10 B	17	23	252
1988	14 A 7 B	5 A 10 B	16 A 13 B	228
1989	6 A 6 B	12 A	18	383
1990	11 A 7 B	7 A 10 B	8 A 9 B	659
Total	246	232	291	2516

† A and B are different sets of trials for high and mid-altitudes, respectively.

Most samples were collected from altitudes ranging from 2351 to 2550 m asl; few were from < 1750 m asl (Fig. 1). Number of pods/plant and plant height were highly variable compared with the other characters. Accessions derived from Welo and Bale showed the highest variability for these characters compared with the other regions (Table 5).

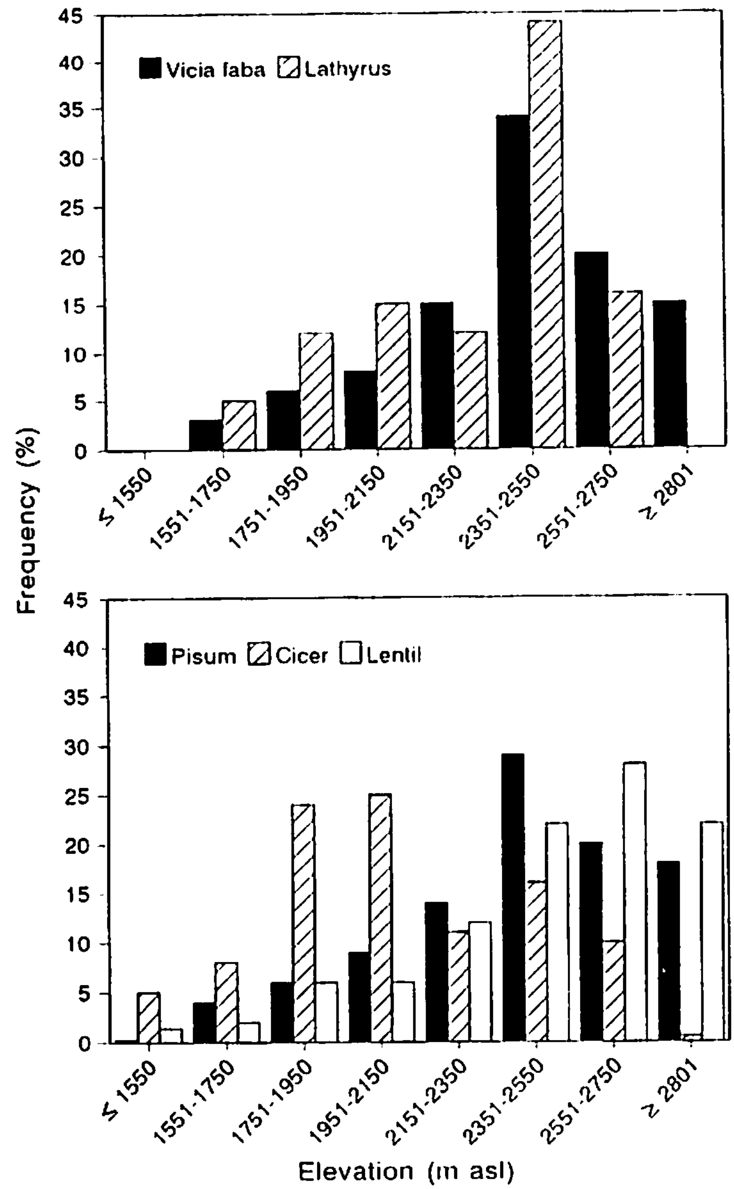

Fig. 1. Origin by altitude of PGRC/E accessions of cool-season food legumes collected in Ethiopia.

Table 5. Agronomic traits (mean ± SD) of field pea accessions collected from various regions of Ethiopia.

Region	N	Days to flower	Days to maturity	Plant height	Flowers/ plant	Pods/ plant	Seeds/ pod
Arsi	40	72±12	99±28	11.0±1.4	8.6±3.1	125±19	5.4±0.8
Bale	24	67±14	87±38	19.1±9.2	10.2±6.3	121±20	5.0±0.7
Gamo Gofa	22	74±8	108±24		9.4±3.4	136±14	5.7±0.7
Gojam	94	70±7	91±20		10.1±11.7	123±12	5.6±0.7
Gonder	119	79±7	123±35	17.8±5.7	12.6±5.9	140±13	5.8±0.8
Harerge	14	72±4	87±19		10.3±5.7	133±18	5.5±0.8
Kefa	9	83±12	104±41	38.0±8.5	12.3±9.0	145±21	4.5±0.7
Shewa	378	74±11	87±22	15.1±4.6	7.7±3.1	130±17	5.4±0.9
Sidamo	8	82±7	105±27		10.1±3.8	145±10	6.2±0.9
Tigray	9	75±8	174±145	16.6±9.3	14.6±9.0	142±8	5.2±1.3
Welega	20	75±11	96±26	13.3±3.5	9.4±5.6	133±18	5.1±0.9
Welo	182	71±21	127±42	27.2±10.9	12.8±7.8	133±23	5.4±1.1
Unknown	129	74±9	102±28	19.0±10.9	8.9±3.2	135±14	5.7±0.7

Field pea germplasm utilization was started for adaptation, high yield and desirable agronomic traits in 1977 when 120 entries were screened (Table 6). These became sources for advanced field trials and hybridization programs in subsequent years. The introduction of exotic materials from ICARDA, Germany, Sweden, the USA and England has reduced the reliance on Ethiopian landraces in the breeding program. In the last 17 years, 2095 progeny rows were screened. Indigenous cultivars released for production through the breeding program are FP ex DZ, Haik 95, CS 436-K and G 22763-2C and many more are in advanced stages of testing.

Table 6. Ethiopian field pea landrace utilization in National Variety Trial (NVT), Pre-National Variety Trial (PNVT), Preliminary Variety Trial (PVT) and Preliminary Screening Nursery (PSN), 1977-92.

Year		No. of entries (landraces)			
		NVT	PNVT	PVT	PSN
1977					20
1978		18		10	
1979		18		19	311
1980		18	25	27	136
1981		18		18	59
1982		17	18	18	168
1983		13	16	40	104
1984	A†	15	10	28	64
	B	15	13		
1985	A	15	15		49
	B	15	17		
1986	A	15	10	30	220
	B	16	10		
1987	A	15	10	21	
	B	11			
1988	A	14	7		79
	B		9		
1989	A		12	9	310
	B	10		9	
1990	A		8		171
	B	4	8	12	
1991	A	11	17	22	217
	B	11	14	17	
1992	A	9	8	25	207
	B	6	10	22	
Total		284	237	327	2115

† A and B are different sets of trials for high and mid-altitudes, respectively.

The two major diseases of field peas in Ethiopia are ascochyta leaf spot and powdery mildew. Most selected genotypes had a rating of 3 on a 1-9 scale in the PNVT program; values were 4 in the NVT. As with faba bean for ascochyta leaf spot, as long as field pea production is not extended to higher (3000 m asl) elevations a score of 9 is rarely observed. Powdery mildew of field peas is not important in the mid-altitudes.

Chickpea

A total of 859 accessions of chickpea, composed of 162 selections, 4 donated accessions and 693 PGRC/E collections, are conserved in the gene bank. Most of the collection is from Shewa, Gonder and Gojam whereas only a few accessions came from Ilubabor and Welega, and none from Kefa (Table 2).

Most accessions were from 1751-1950 and 1951-2150 m asl (Fig. 1). Number of secondary branches and number of pods/plant are highly variable characters in all regions showing above 40% coefficient of variation. Days to maturity is the least variable character (Table 7). This could be due to forced maturity by the terminal drought that usually causes cracking of the soils and exposes the roots to desiccating atmospheric air drafts.

In general, a different level of variation was observed in different regions for different characters. The highest variation was depicted in Shewa for number of pods/plant and plant height, in Eritrea for days to flowering, in Harerge for the number of secondary branches and in Sidamo for the number of primary branches.

Considering all the regions, the highest variation was observed in decreasing order in Harerge, Sidamo, Welo and Gonder while the lowest variation was shown by Welega and Gamo Gofa. Shewa, Gojam and Gonder are well represented whereas Welega, Gamo Gofa and others are not. This suggests that collection missions should be organized to these regions and to Ilubabor and Kefa where no collections were made.

The samples collected from farmers' fields and markets were evaluated at Debre Zeit Agricultural Research Center for yield and resistance to diseases and insect pests. Among these local landraces, DZ-10-1 (kabuli), DZ-10-2 (desi), DZ-10-4 (kabuli), DZ-10-11 and Dubie (desi) were selected, multiplied and distributed to the farmers in the Yerer, Keryu and Menegasha *awrajas* (subprovinces). DZ-10-2 was resistant to root rots whereas DZ-10-4 was susceptible. Cultivars DZ-10-1, DZ-10-4, DZ-10-11 and Dubie were resistant to Fusarium wilt and still do well in most farmers' fields in Ada and Akaki areas. DZ-10-2 was not recommended for release because of low demand for its black seed.

Table 7. Agronomic traits (mean ± SD) of chickpea collected from various regions in Ethiopia.

Region	N	Primary branches	Secondary branches	Days to flower	Plant height (cm)	Pods/ plant	Seeds/ pod
Arsi	29	1.8±0.4	3.7±1.6	50.4±5.1	32.1±5.3	53.8±26.3	1.4±0.5
Bale	13	1.8±0.5	4.0±2.1	50.9±5.3	30.3±5.6	49.8±32.1	1.6±0.5
Eritrea	7	1.9±0.4	3.9±2.1	47.0±10.9	31.0±4.7	37.5±11.5	1.4±0.4
Gamo Gofa	8	1.5±0.4	4.4±1.6	54.4±4.1	35.2±4.5	65.6±29.3	1.6±0.4
Gojam	241	1.9±0.4	3.4±1.1	50.7±5.2	34.7±6.2	70.9±51.2	1.5±0.4
Gonder	184	1.9±0.5	3.6±1.6	49.2±5.6	34.4±5.9	62.7±42.5	1.6±0.4
Harerge	33	1.9±0.4	4.5±2.8	51.0±6.5	33.4±6.5	48.3±29.3	1.7±0.4
Shewa	518	1.9±0.3	3.3±1.3	48.0±4.7	32.3±6.4	55.6±39.6	1.6±0.3
Sidamo	35	1.8±0.6	4.2±2.2	52.4±5.6	31.2±5.0	41.7±23.7	1.7±0.5
Tigray	36	1.7±0.6	3.8±2.0	47.3±5.0	31.0±5.0	42.1±15.5	1.6±0.5
Welega	4	1.6±0.3	3.4±0.8	49.0±3.8	31.3±2.2	65.4±23.3	1.4±0.1
Welo	49	1.6±0.2	3.7±1.4	48.7±6.1	32.8±5.7	60.5±40.9	
Unknown	134	1.6±0.5	3.9±2.3	50.6±5.6	32.4±5.1	49.4±24.4	1.6±0.4

Recently, the Ethiopian chickpea collections were systematically evaluated for resistance to the wilt/root rot complex in the sick plot developed at Debre Zeit Agricultural Research Center. Lines PGRC/E-41066, -41087, -41093, -41099, -41100, 41134, -41136 and -41161 were resistant (AUA 1990). A similar report showed that crosses that involved DZ-10-4 and DZ-10-11 had a high level of resistance against wilt/root rot diseases at Debre Zeit. These crosses included DZ-10-4 × p678-2-2, DZ-10-4 × p678-4-2, DZ-10-11 × JG79-2-2, DZ-10-11 × JG79-2-3 and DZ-10-11 × G79-3-1.

Segregants of crosses with Ethiopian landraces showed better tolerance to drought. Of these, the crosses DZ-10-4 × JG79-5-2-88 and DZ-10-4 × JG79-2-3-88 were found to be promising.

Lentil

Total collections of lentil conserved at PGRC/E are 508 accessions consisting of donations (134) and PGRC/E's own collection (374). The highest collection is from Welo, Gonder and Shewa while no collection was made from Ilubabor and Kefa and very few collections from Sidamo, Welega and Gamo Gofa (Table 2). From the characterization data it can be observed that highly variable characters are number of secondary branches and number of pods/plant while days to maturity is the least variable (Table 8). Gojam, Gonder and Harerge showed high germplasm variability among the regions while Eritrea and Arsi showed the least variable germplasm. Prior to the establishment of PGRC/E, Debre Zeit Agricultural Research Center had made several Ethiopian lentil collections which are now available at the Genetic Resources Unit (GRU) of ICARDA. The Ethiopian lentil germplasm constitutes 7.3% of ICARDA's lentil accessions (Erskine and Witcombe 1984).

Barulina (1930) described the grey aethiopiceae as having 1-2 blue or violet flowers on each peduncle and calyx teeth much shorter than the corolla. Leaves have 3-7 pairs of elongated leaflets. Fruits have a typically elongated apex, seeds are black or brown with black spots. These have been documented by Muehlbauer *et al.* (1985).

The Ethiopian lentil is early compared with the introductions and thus adapts to the lowlands of Ethiopia. Even in the world collection, Ethiopian lentil accessions are as early as Indian material and also small-seeded with a high harvest index (Erskine and Witcombe 1984). In the lowlands of Ethiopia, EL-50, EL-103, EL-142 and Lasta Lalibela performed well. Among these, EL-142 was released and is widely grown by farmers. This line is widely adapted and is more resistant to changing environments than the introduced lentils (Bejiga *et al.* 1993).

Table 8. Agronomic traits (mean ± SD) of lentil collections from various regions in Ethiopia.

Region	N	Primary branches	Secondary branches	Days to flower	Days to maturity	Plant height (cm)	Pods/ plant	Seeds/ pod
Arsi	9	2.5±0.4	5.5±1.3	52±4	95±1	28.8±6.7	38±13	1.6±0.3
Bale	11	2.8±0.9	10.4±7.6	55±12	102±3	33.5±12.9	55±27	1.7±0.3
Eritrea	4	2.6±0.4	4.7±1.6	49±5		32.2±3.6	33±6	1.7±0.3
Gamo Gofa	7	3.0±0.6	11.4±7.7	53±17		24.7±0.9	64±16	1.7±0.4
Gojam	34	2.8±0.7	9.7±7.4	54±19	96±3	28.1±6.0	49±28	1.8±0.4
Gonder	112	2.5±0.5	6.3±5.3	52±13	94±1	32.2±6.7	48±20	1.8±0.3
Harerge	19	2.8±0.6	7.7±6.2	53±14	90±15	30.0±6.5	51±32	1.9±0.2
Shewa	43	2.8±0.7	9.1±6.8	53±14	95±1	27.7±5.5	51±19	2.0±0.2
Tigray	24	2.4±0.4	4.9±2.8			36.9±9.9	49±15	1.8±0.3
Welega	11	2.6±0.3	5.8±2.1	49±6		30.1±7.9	43±17	1.6±0.4
Welo	98	26.2±0.7	9.3±6.9	55±9	94±1	28.1±5.5	50±26	1.9±0.3
Unknown	246	14.8±0.4	6.3±3.7	55±7	98±14	32.2±6.3	45±21	1.6±0.3

Except for Gonder and Welo, most of the lentil-growing regions are not well enough represented in the collection to allow the exploitation of genetic diversity existing in the country (Table 8). Further collection is needed from different regions, particularly the western parts of the country (Welega, Kefa, Ilubabor) and Sidamo.

Recently 156 germplasm accessions collected from 10 provinces of Ethiopia were evaluated for a set of quantitative traits at three contrasting locations, namely, Alem Tena (1600 m), Debre Zeit (1900 m) and Chefe Donsa (2450 m) which represent lowland, medium-altitude and highland areas, respectively. The mean, minimum, maximum and coefficient of variation were calculated. The CV was relatively high for seed yield, biomass and number of pods/plant at Alem Tena and Debre Zeit whereas it was high for the number of pods and primary branches/plant at Chefe Donsa. This indicated that locations where the germplasm materials are evaluated determined, to a certain extent, the expression of the characters under consideration.

Debre Zeit is known as one of the world's hot spots for lentil rust (*Uromyces fabae*) (Erskine 1985). Several local landraces and introductions were evaluated at Debre Zeit Agricultural Research Center to identify source of resistance to rust. PGRC/E-7 was the only line highly resistant; PGRC/E was highly susceptible. These are now standard checks in screening for resistance to rust. Among the Ethiopian landraces, EL-50, EL-59, EL-74, EL-103, EL-122 and EL-142 were tolerant to rust. Generally, most of the Ethiopian lentil accessions are susceptible to rust, but have the ability to escape the disease since they are early in maturity.

ICARDA found that drought escape through early maturity has been the most effective way to manage drought in lentil (GGLDRN 1993). Using seed yield and maturity as selection criteria, 18 Ethiopian lentil germplasm accessions were identified and are in advanced stages of yield trials whereas most of the introductions are late and failed to produce seeds. Erskine and Witcombe (1984) also found that the Ethiopian lentils were the earliest to flower, but had the lowest straw yield and protein content. This earliness not only enables them to escape the rust disease, but also helps their adaptation to the low-rainfall areas since they mature before the occurrence of terminal drought.

Lathyrus

The major collection of *Lathyrus* was made from Gojam, unknown, Welo and Gonder regions. No collection was made from Gamo Gofa and Sidamo (Table 2). *Lathyrus* was collected as part of the general collection expedition of the PGRC, which collects all crops maturing at the same time. The absence of samples from Gamo Gofa and Sidamo could be because the crop is rarely grown there or because the regions do not grow *Lathyrus* at all.

As depicted in Figure 1 the largest collection of *Lathyrus* originated from altitudes ranging from 2351 to 2550 m asl and the remainder were from altitudes. Collections were from 1550 to 2801 m asl, indicating the wide adaptation of the species.

The characterization of *Lathyrus* was made only on accessions originating from six regions (Table 9). The characters number of pods/plant and number of seeds/pod showed high variability among those considered. Among the regions, Gonder and Shewa possess the most variable accessions and Welo the least. In Gonder, where the production of *Lathyrus* is concentrated, a high incidence of lathyrism is observed.

Conclusions

Ethiopia is recognized as an important center of diversity for many species including cool-season food legumes. Despite this, collection and conservation are far from complete and gaps in collection still exist at both the regional and species level (Table 2). Although related wild species exist in the country they are not yet included in the collections. Efforts have to be made to collect the wild relatives of these species and more areas have to be covered in order to assemble and preserve the genetic diversity of the species. The exploitation of wild relatives in the breeding program is practically nonexistent in Ethiopia. In general, it can be said that the level of diversity within various regions is high and thus each region has something to offer the breeding program.

Widening the genetic base by collecting highly variable primitive germplasm from different regions will enrich the gene pool and enhance the development of improved cultivars through plant breeding. Keeping genetic diversity and increasing yield per unit area should be the strategy of breeding in order to utilize the existing genetic resources effectively and to minimize the hazards to genetic uniformity caused by disease epidemics, outbreaks of insect pests and drought.

Table 9. Agronomic traits (mean ± SD) of lathyrus from various regions of Ethiopia.

Region	N	Primary branches	Secondary branches	Days to flower	Days to maturity	Plant height (cm)	Pods/ plant	Seeds/ pod	1000-seed weight (g)
Gojam	22			65±5	152±5	69±10	72±24	2±0.3	
Gonder	9			53±6	118±30	68±15	32±19	3±0.5	253±89
Harerge		3±0.6	7±0.7						219±62
Shewa	12			53±9	153±6	67±9	41±13	2±0.2	253±163
Tigray	18			53±9	125±5	56±9	36±13	3±0.6	89±7
Welo	28			55±7	127±5	54±9	35±13	3±0.4	88±9
Unknown	65	3±0.5	7±1	48±5	100±12	54±7	28±12	3±0.4	

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Discussion

Dr Saxena
Are the different areas in the country identified by the extent of germplasm collection activities? What are future strategies?

Ato Dawit
In fact, after 1987 utilization of local landraces has been declining, but the areas where collection has not been done are already identified. There is also an ongoing collecting operation. The future strategy will be to collect the wild relatives of cool-season food legumes and cover more areas to assemble the genetic diversity of the species.

Dr Seyfu
It was indicated that the use of local cultivars (landraces) in various local and national trials has been decreasing and the use of exotic or introduced materials for the same purpose has been increasing. At the same time it was also indicated that there is a tremendous amount of variation found among cultivars

of the same species in our landraces. How do we justify the use of more exotic materials in our trials when we have enough variability among our landraces?

Ato Dawit
The problem is not in the amount of germplasm collected but in its utilization by breeders.

Dr Seyfu
As to the proportion of landraces vs. exotic materials being used, could the reason be that areas for collecting more germplasm have been neglected which probably led to less preference for them as opposed to exotic materials? What can be done to rejuvenate the use of our own landraces?

Ato Dawit
There is no confusion about areas of the country where collections have been made, but priorities in collecting germplasm are usually given to cereals. Land fragmentation in the rural areas led to genetic erosion in pulses. There is less usage of pulses in crop rotation because of small land holdings. More collection needs to be done in remote areas of the country where it hasn't been done before.

Dr Getinet
We have plenty of resources of genetic variability in the country from our germplasm collection but they are lost to international (foreign) research centers. Can we repatriate or get most of them back and strengthen our wealth of genetic diversity?

Dr Saxena and Dr Solh
There is no problem whatsoever on the part of ICARDA and ICRISAT in repatriation of any of the germplasm taken from Ethiopia. Computer printouts are available in these international research centers and in many North African countries providing information on available germplasm and seed can be requested by anyone who is interested.

Genetics and Breeding of Faba Bean

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Abstract

The faba bean (*Vicia faba* L.) breeding program in Ethiopia is based on variability available in the local collections (PGRC/E) of indigenous landraces and exotic germplasm introduced mostly from ICARDA. The overall breeding objective is to develop improved high-yielding cultivars adapted to high and midaltitude areas. The specific breeding objectives were based on the constraints facing faba bean production in Ethiopia, including biological, biotic and abiotic constraints, in addition to desirable agronomic and seed quality characters. Progress achieved in various characters is summarized here. As a result of breeding efforts four cultivars were released (CS 20DK and Kuse 2-27-33 for higher altitudes and Kala and NC58 for midaltitudes). Four new selections have been submitted for release (75TA26026-1-2-1b, CS 20DK-3-4-1-5, CS 20DK-3-4-1-3 and CS 20 DK-2-2-1) and two more will be submitted in the 1994/95 cropping season. Genetic vulnerability should be avoided by widening the genetic base of varietal releases. Future directions for the Ethiopian faba bean improvement program are indicated.

Introduction

Faba bean (*Vicia faba* L.) is cultivated in Ethiopia in the *wyndega* zone (midaltitude, 1800-2200 m asl, average annual rainfall of 740 mm and mean daily temperature of 18-22°C), and *dega* zone (high altitude, >2200 m asl, average annual rainfall of 900 mm and mean daily temperature of 10-18°C). It is grown from June to December in rotation with cereals. Faba bean is an important source of protein supplement for the majority of the population, used in various popular Ethiopian dishes such as curry and *injera* (a pancake bread).

Faba beans reached Ethiopia soon after domestication around the 5th millennium B.C. Secondary centers of diversity must have become established in Afghanistan and Ethiopia (Bond 1976), both are mountainous countries where the faba bean is well adapted. Most of the germplasm samples collected in Ethiopia are the small-seeded forms (botanically *minor*), not the primitive *paucijuga* forms (very small seeded) found in the eastern limits of faba bean's geographical distribution (Cubero 1984). After the Ethiopian 'conquest', a new and potentially important seed type was obtained: the flattened seed, that is, the *equina* type.

Of the cultivated grain legumes (pulses) in Ethiopia, faba bean ranks first in terms of hectarage and production (Table 1). However, it is a low grain yielder per unit of land. This review discusses the genetic aspects of faba bean and summarizes the breeding work completed to date. Possible future directions and strategy for the improvement of faba bean yields in Ethiopia are indicated.

Genetic Variability

Many if not most cultivars of faba bean in use today are traditional landraces resulting from several years of selection. Most of these cultivars were developed from these landraces without the use of hybridization.

In Ethiopia, mainly *minor* and *equina* types of faba bean occur although *major* (large-seeded) types were brought to the country by the Portuguese around 1900 (Westphal 1974). The *minor* types are predominant in southern Shewa, Arsi, Bale, Harerge and Sidamo highlands, whereas the *equina* types are common in northern Shewa, Gojam, Gonder, Tigray, Eritrea and Welo Administrative Regions. However, both types occur in most of these regions. It is to be emphasized that faba bean exported from Ethiopia to the world market fetches a lower price than the preferred large-seeded types.

In the Ethiopian faba bean research program there are two faba bean genetic resources: the Plant Genetic Resources Center of Ethiopia (PGRC/E) in Ethiopia and the Genetic Resources Unit (GRU) in ICARDA, Aleppo, Syria. PGRC/E is concerned mainly with conservation of Ethiopian *V. faba*. To date its collection is about 1410 samples.

ICARDA, which maintains the World Germplasm Collection of faba bean and some wild relatives, has exhaustive descriptions of genetic variation within *V. faba*, which include plant canopy, leaf, leaflet and their colors, stem and its various colors, flowers and their colors, seed sizes, shapes and their various colors, roots and rootlets, pollen colors, fertility status of ovule numbers, helium sizes and their colors (ICARDA 1986). The Ethiopian faba bean breeding program has made use of this variability for improvement of seed sizes, color, shape, stem strength, plant ideotype, independent vascular system (IVS), closed flower characters and autofertility system.

Table 1. Production of cool-season food legumes in Ethiopia in 1991 and 1992 crop seasons.

	Area (1000 ha)			Production (1000 t)			Yield (t/ha)		
Crop	1989	1990	1991	1989	1990	1991	1989	1990	1991
Faba bean	315	228	243	272	279	282	0.86	1.23	1.16
Chickpea	127	121	135	195	101	120	0.75	0.83	0.89
Field pea	135	110	130	92	97	110	0.68	0.88	0.85
Lentil	60	39	50	32	30	35	0.53	0.76	0.70
Total	637	498	558	591	507	547	2.82	3.70	3.60

Source: CSA 1987, 1988-92.

The breeding program was based on the variability in both the indigenous faba bean landraces and the exogenous germplasm collection introduced mostly from ICARDA. Through the NVRP, some germplasm was introduced from other countries and institutions, mostly from Egypt and Sudan. Germplasm introductions from ICARDA were in the form of international nurseries and yield trials in addition to specific genetic stocks from the World Germplasm Collection of faba bean. However, after the Faba Bean Improvement Program was phased out to Morocco in 1991/92, introductions of faba bean from ICARDA were restricted to genetic stocks from the World Collection.

Variability in indigenous faba bean germplasm has been discussed in the previous paper (see Genetic Resources in Ethiopia). For the last 15 years, evaluation and screening of faba bean for various agronomic characters has been underway. Results of three important characters such as days to flowering, plant height and 1000-seed weight are depicted in Figures 1 and 2 for National Variety Trials (NVT) and Pre-National Variety Trials (PNVT), respectively. Of the three characters, variations in plant height seem to follow the normal curve. Nearly 75% of the shortest plants are represented by determinate types originating from ICARDA collections and crosses; the tallest group comprises Ethiopian landraces and exotics from various sources.

The 1000-seed weight variation may be visualized as a curve with distribution gently falling from left to right (Fig. 1). In PNVT trials of 1977-92 (Fig. 2) distribution of variation in plant height is a nearly normal curve, 1000-seed weight distribution has two peaks, and days to flowering is a curve that rises and falls (number of entries flowering in less than 45 days are only 8 while those lines flowering later than 60 days are 118).

Constraints to High Yield

Faba bean in Ethiopia is affected by an array of factors which contribute to low yield and unstable productivity. These factors can be grouped into biological, biotic and abiotic constraints.

Biological Constraints

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 drop. Telaye (1990) reported that 67% of flower drop was due to the lack of fertilization, which may result from either ineffective pollination or pollen fertility. A flower drop study conducted under Ethiopian field conditions from November 1987 to November 1988 conclusively ($P \geq 0.001$) showed variations in the magnitude of fertilization from season to season.

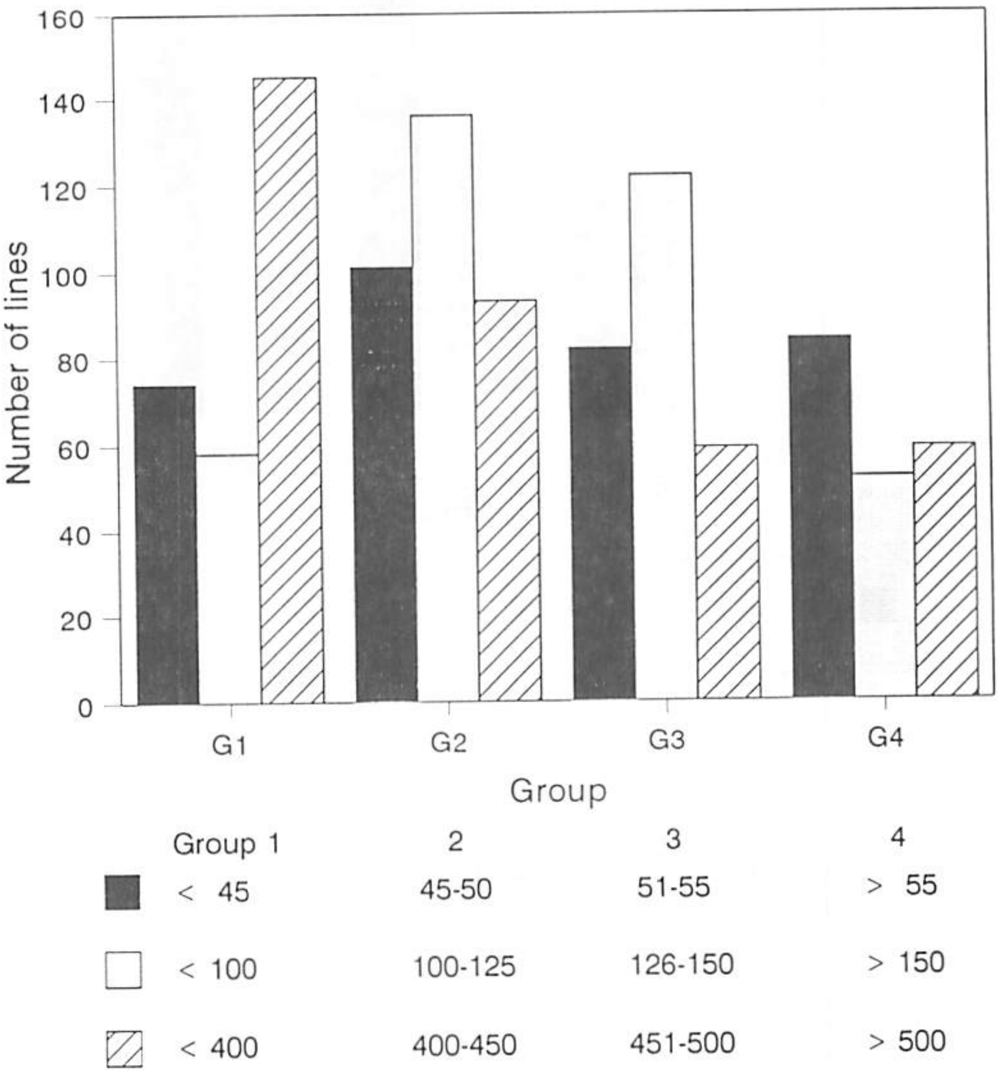

Fig. 1. Agronomic traits of faba bean selections in National Variety Trials in Ethiopia, 1977-92.

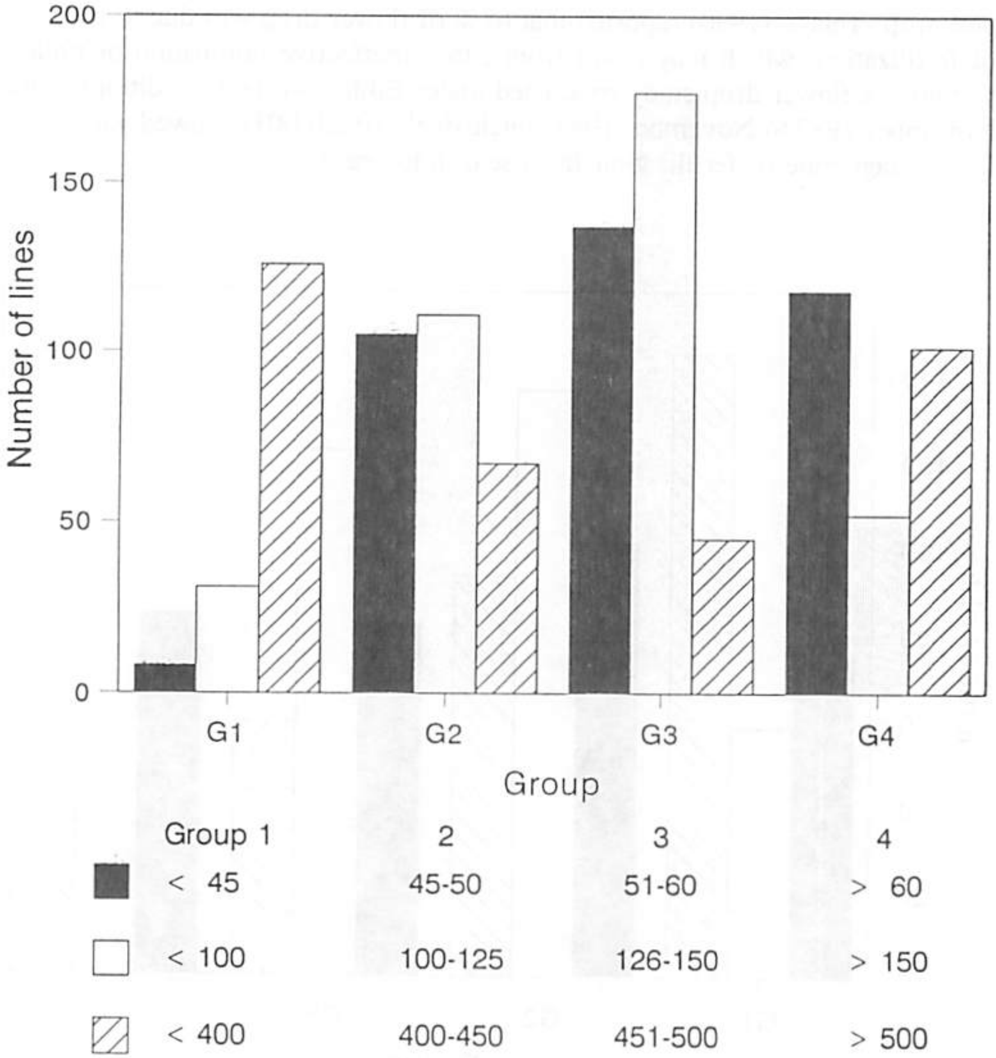

Fig. 2. Agronomic traits of advanced faba bean selections in Pre-National Variety Trials in Ethiopia, 1977-92.

Pollination/fertilization

Faba bean is a partially outcrossing species in which outcrossing is the result of insect pollinators. About 20-60% outcrossing has been reported in faba bean (Holden and Bond 1960; Bond and Pope 1974). Pollinating insects have long been recognized as important for high yield because tripping is usually necessary for maximum seed set. The activity of pollinating insects in Ethiopia varies from one location to another and in different seasons, and thus the yields of faba bean in Ethiopia are unstable. The requirement for tripping by insect pollinators is not universal and lines have been reported with high levels of autofertility (Holden and Bond 1960; Hanna and Lawes 1967; Poulsen 1977). Autofertility is one of the selection criterion of the Faba Bean Improvement Program in Ethiopia.

Infertile pollen is another reason for ineffective fertilization. In an experiment concerning *V. faba*, pollen fertility along the plant stem (Telaye 1990) showed high variability in fertility. Highly significant differences existed in fertility among the genotypes studied. A fertility gradient exists along the stem: in most genotypes the fertility declines toward the upper nodes. In all the genotypes studied, the first nodes carried more highly fertile pollen than the middle and the last flowering nodes. The middle nodes also were more highly productive than the last nodes in all the genotypes. Thus, success of fertilization depends to a degree on the source of pollen used and its fertility (Telaye 1990). In an experiment where pollen of line 248 was mixed with equal proportions of either Sudanese Triple White (STW) or line 288 pollen, and pollination was carried out on stigmas of the other lines, evidence for the above conclusion about nodes was obtained in a glasshouse and in the field in that pollen of line 248 was more fertile and seeds were formed in both STW and line 288 (Telaye 1990).

In similar studies both in the UK and Ethiopia, pollen from line 248 was mixed with each of lines STW, 288, NDP, 247 and 4/7. Line 248 was the paternal pollen parent while the rest were all recipients of the mixed pollination. The result showed that the pollen tubes from line 248 were able to produce more hybrids with crosses in mixtures involving line 288 and STW. Thus, line 248 was significantly more competitive on the stigmas of STW and line 288 only. However, on the stigmas of line 4/7, NDP and line 247, pollen grains of 248 were significantly less competitive ($P \geq 0.01$) than pollen of each of the maternal genotypes (Telaye 1990).

Intra-plant competition

Other factors that affect yield stability are climatic factors such as temperature and light (Telaye 1990), agronomic practices such as plant density, unfavorable conditions such as drought, salinity, excessive soil moisture, inadequate supply of nutrients, distribution of assimilates and hormonal balance (El-Fouly 1982). These factors affect the biology of the faba bean plant and lead to intra-plant competition for assimilates. The distribution of assimilates and the hormonal balance are major metabolic factors that affect flower and pod drop. Competition for assimilates also is partly dependent on plant type.

Plant type
In conventional indeterminate faba bean cultivars, much of the yield variability can be attributed to intra-plant competition for photosynthates. To avoid such metabolic constraints, *V. fabae*'s indeterminate plant type could be changed to a determinate growth habit to reduce intra-plant competition for photosynthates (Sjodin 1971). One benefit expected from a determinate type would be to reduce the effect of earlier fertilized flowers on drop of later developing buds.

An independent vascular supply (IVS) faba bean has been described by Gates *et al.* (1981). This plant type has flowers borne on the raceme with independent vascular tracts serving individual flowers, unlike all other genotypes where the peduncle vascular system branches. As a consequence, flower shedding is virtually eliminated and flowers are highly autofertile. Although pod set is high, pod development is restricted due to unavailability of assimilates, thus generating a source rather than a sink-limited crop. IVS is one of the selection criterion used in the Ethiopian breeding program for faba bean improvement.

Modifications to the plant have been suggested to increase yield through increased pod set (Sjodin 1971; Chapman and Peat 1978). The Ethiopian Faba Bean Improvement Program is considering plant type as one alternative to resolve the problem of instability in yield.

Biotic Stresses

Biotic stresses in faba bean contribute greatly to low and unstable yield in Ethiopia. Biotic stresses include diseases, insect pests and competitive weeds. The first two are of relevance to the breeding program in Ethiopia.

Diseases
Chocolate spot (*Botrytis fabae* L.) is the most important foliar disease problem on faba bean in Ethiopia, particularly in high-rainfall areas (>900 mm) at elevations of >2000 m asl. Rust (*Uromyces fabae* L.) is another important limiting factor in midaltitude areas with high rainfall and high temperatures (>20°C). Observations over the last 15 years indicated that complete destruction may occur from chocolate spot in faba bean areas above 3000 m asl and from rusts in areas below 1800 m asl. Powdery mildew (*Erysiphe* spp.) is another disease problem in faba bean grown at altitudes below 1800 m with temperatures of 20-25°C. The economic significance of powdery mildew is not known. Ascochyta blight (*Ascochyta fabae*) is a foliar disease of minor importance in Ethiopia. So far, the problem of viruses in faba bean is not a

limiting factor in production, probably due to the fact that aphids (the virus vectors) are kept at minimum levels by high rainfall (700-1000 mm between June and October) which washes them off the plants in the production zones.

The soil-borne diseases of wilt and root rots, particularly black root rot, are a major problem in faba bean in black Vertisol soils in the high plateau areas in Ethiopia. Considering the economic significance of these diseases, the faba bean improvement program in Ethiopia concentrates on breeding for resistance to chocolate spot, rusts and black root rots.

Insect pests
The African bollworm (*Helicoverpa armigera* L.) is the major insect pest causing damage in faba bean in Ethiopia. Aphids (*Aphis fabae* L.) and thrips (*Taenothrips* spp.) are other damaging insects. As indicated above, aphids are kept to a minimum level by high rainfall. Breeding for resistance to insect pests has not yet been initiated because they are not a serious threat.

Abiotic Stresses

Abiotic stresses in faba bean include frost, high temperature and drought/moisture stress in certain seasons. Faba bean is always vulnerable to frost damage in the highlands of Ethiopia. This usually occurs at the prime vegetative or early anthesis stage such that damages are often irreversible.

In studies of low-temperature regime effects on the viability of *V. faba* pollen, Telaye (1990) showed that if newly dehiscent pollen was desiccated at 25°C for 6 hours and stored either at -8°C or in liquid nitrogen, viability would remain at $\geq$80% for more than one year. Thus, the negative effect of low temperature on pollen is due to its moisture content rather than to temperature regime injury itself.

High temperature, particularly at altitudes of 1800 m or less, is deleterious at the reproductive stage in faba bean and thus losses due to flower and pod drop are considerable. High temperature interferes with normal pollen tube growth and fertilization. Studies indicated that high temperature causes pollen tubes to burst or causes abnormal growth that interferes with normal fertilization (Telaye 1990). Many pollen grains did not germinate, probably because of evaporation of secretion from the stigma at high temperatures and the consequent concentration of sugar ($\geq$40% instead of 5-30%) under normal temperature regimes (15-22°C). However, genetic variation exists among cultivars in their tolerance to high temperature and flower drop which could be due to zygotic abortion as well (Telaye 1990).

Moisture stress causes variation in seed yield obtained in different seasons and on different soil types (with different water-holding capacity) in Ethiopia. The inadequacy of soil moisture is one of the major limiting factors to faba bean yield in midaltitude areas. The attributes for drought or moisture stress tolerance can be improved by breeding and selecting lines that make more efficient use of soil moisture.

Objectives of the Breeding Program

The overall objective of the faba bean breeding program in Ethiopia is to develop improved, high-yielding cultivars adapted to mid- and high-altitude agroecological zones with the following desirable characters:

- High and stable yield
- Resistance to chocolate spot (*Botrytis fabae*)
- Resistance to rust (*Uromyces fabae*)
- Resistance to black root rot (*Fusarium solani*)
- Early maturity
- Tolerance to frost
- Tolerance to moisture stress
- High autofertility
- Shorter plant height (around 100 cm)
- Relatively bigger seed size and cream or greenish seed coat
- Alternative plant types: IVS and determinate types.

Breeding Methodology

The breeding program is based on the genetic variability available in Ethiopian indigenous landraces and exotic germplasm introduced mainly from ICARDA. More specifically, a total of 2039 accessions and advanced breeding lines were introduced from ICARDA, compared with 68 accessions from Europe, between 1984 and 1993.

The breeding program aims at developing improved cultivars through the evaluation of indigenous landraces and exotic introductions for adaptation and desirable characters. Most of the advanced breeding lines originated from selections within landrace populations and from segregating generations developed through hybridization.

Hybridization

Full exploitation of the available genetic resources most often requires the breeder to make hybrids of genotypes with desirable traits to allow superior gene recombination. Faba beans are relatively difficult to cross and only low success rates have been reported in terms of seeds set per cross under Ethiopian conditions. However, there are considerable variabilities within cultivars, an advantage a breeder can make use of in a crossing program.

Hybridization in Ethiopia generally is done by hand-crossing, and occasionally by using bees as pollinators. In general, the bud of the female parent is emasculated before the dehiscence of the anthers, and fresh pollen is transferred from the male parent to the stigma of the female either immediately or few hours later. The positions of the female flower on the peduncle and ovules have been found to affect the success rate and quality of seeds in crossing (Fig. 3).

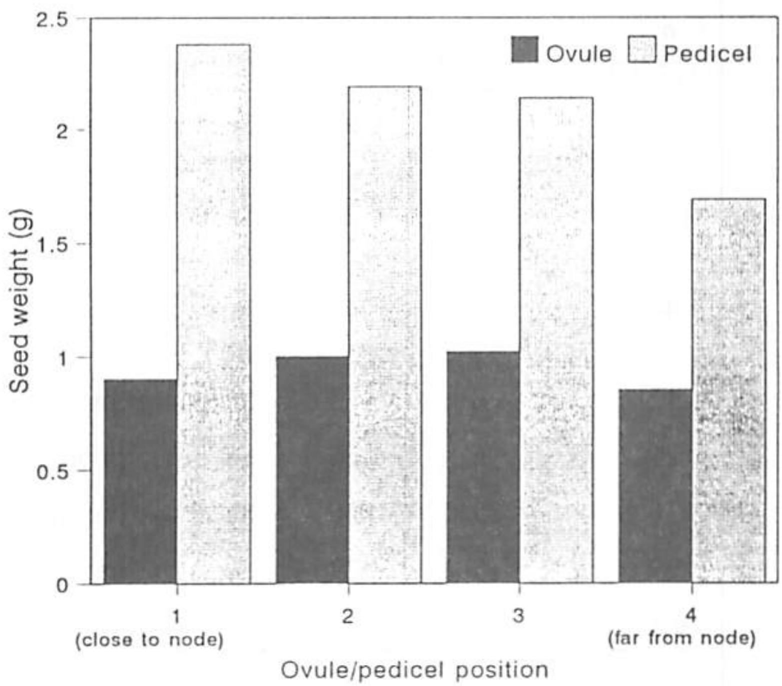

Fig. 3. Influence of ovule and pedicel positions on seed size of faba bean in Ethiopia.

The various objectives of crosses made so far (Table 2) were:

- Transfer of *U. fabae* and *B. fabae* resistance
- Transfer of seed quality character for big seed sizes and cream or greenish color
- Early maturity
- Modification of plant height to produce a short plant (< 100 cm).

A total of 385 crosses was made in faba bean between indigenous and exotic germplasm to transfer desirable characters to landraces which were used mostly as recipient female parents. Exotic lines were used as donor male parents between 1985 and 1993 (Table 2).

Table 2. Faba bean crosses made for transferring desirable genes for large seed sizes, green/cream seed color, chocolate spot and rust resistance in faba bean over years in Ethiopia.

	Parents			
Year	Female (indigenous)	Male (exotic)	No. of crosses	Objectives
1985	96	24	96	Seed size improvement; resistance to rust
1986	120	30	120	Seed size improvement; resistance to rust
1987	46	39	46	Resistance to chocolate spot and rust
1988	12	6	12	Seed size improvement
1991	25	6	26	Seed size improvement
1992	36	25	56	Seed size improvement
1993	29	15	29	Seed size improvement
Total	364	145	385	

Selection

The breeding program uses mass selection, pedigree and modified pedigree selection. The latter method is mostly used with mixed pollination from donor genotypes, both exotic and indigenous landraces, with desirable characters. Pedigree and mass selection is followed to improve landraces such as CS 20DK, NC58, Kala, Kuse 2-27-33 and Lume Nazareth.

Pollination Control

A major constraint to most breeding programs is in overcoming problems of pollination control, regardless of the selection or breeding method followed. Selfing is particularly useful when pedigree selection is used to try to develop lines with uniform characters such as seed size and, most importantly, disease and insect pest resistance. Methods used to ensure selfing have included use of selfing bags and insect-proof, mesh-covered screenhouses. Such screenhouses have allowed the maintenance of a large collection of pure lines of faba beans at Holetta Research Center.

Brassica napus L. has been used as an attractant crop for pollinators to reduce bee activity in faba bean plots. This reduces outcrossing in seed-increase plots and yield trials, since outcrossing is not possible without bee activity, and thus results in increased selfing in faba bean.

Breeding for Desirable Characters

High yield potential and stability are the main selection criteria followed in the breeding program in addition to desirable agronomic characters and tolerance to biotic and abiotic stresses that contribute to yield instability. Besides high yield potential, the breeding program focuses on the following desirable characters.

Disease Resistance

Disease resistance breeding focuses on three major diseases, namely chocolate spot, rusts and black root rot. Genetic stocks for resistance to these diseases were identified from indigenous landraces and exotic introductions from ICARDA. Through hybridization, a total of 262 crosses were made to transfer disease-resistant genes for rust and chocolate spot to local landraces. The advanced breeding lines evaluated in PNVT and NVT had a good level of resistance to both rust and chocolate spot (Figs. 4 and 5). It was apparent that the level of resistance to both diseases was higher in the more advanced NVT (Fig. 4) than in the PNVT (Fig. 5). The work on resistance to black root rot has been more difficult but sources of resistance were identified recently. These sources are being used to develop resistance in advanced breeding lines with high yield and desirable agronomic traits.

Tolerance to Abiotic Stresses

Breeding for frost tolerance was initiated fairly recently at Sinana in frost-prone areas and preliminary results showed genotypic variation for frost tolerance which is currently being confirmed through further studies.

Studies for tolerance to high temperature and moisture stress have been going on through selection for yield stability in the midaltitude areas at Dembi where high temperatures and moisture stress occur in certain seasons. As a result, several lines were selected for high yield and stability. Selections 75TA 26026-1-2-1, MKT Illubabor, NEB207 × 74TA-6D were submitted for release in 1993, and selections 75TA 26026-1-2-1b, CS 20DK-3-4-1-5, CS 20DK-3-4-1-3 and CS 20DK-2-2-1 were submitted for release in 1994. The characteristics of these selected lines are presented under **Varietal Releases**.

Early Maturity

As days to flowering is 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 as observed in the PNVT and NVT between 1977 and 1992. Days to flowering ranged from <45 to >55 days (Figs. 1 and 2).

Plant Height

Selection for shorter faba bean plants resulted in a wide range of variation for plant height in advanced breeding lines in the PNVT and NVT. The variation in plant height ranged between <100 and >150 cm in advanced breeding lines selected between 1977 and 1992 (Figs. 1 and 2).

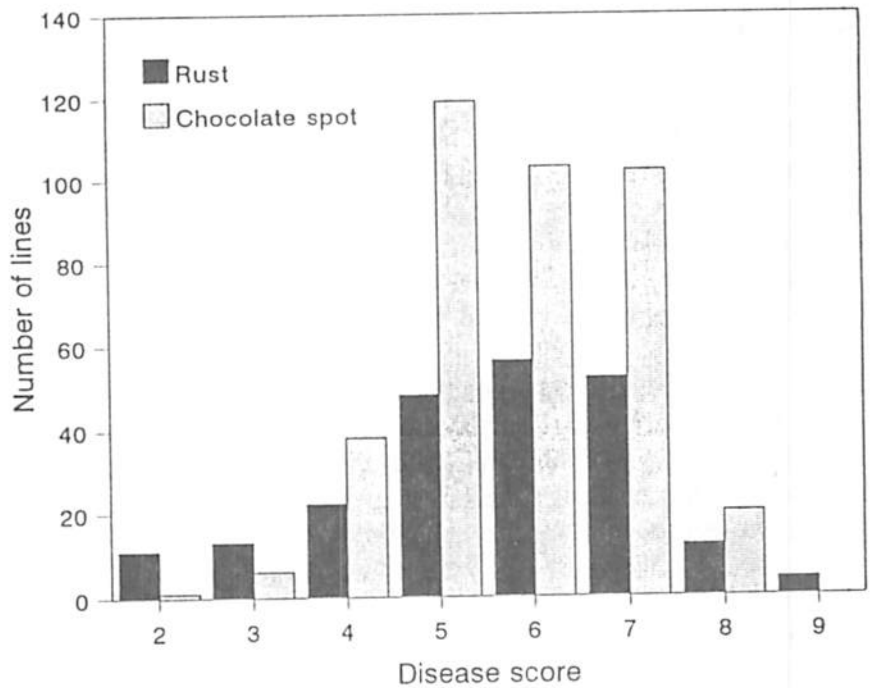

Fig. 4. Disease severity of chocolate spot and rust in faba bean National Variety Trials in Ethiopia, 1978-92.

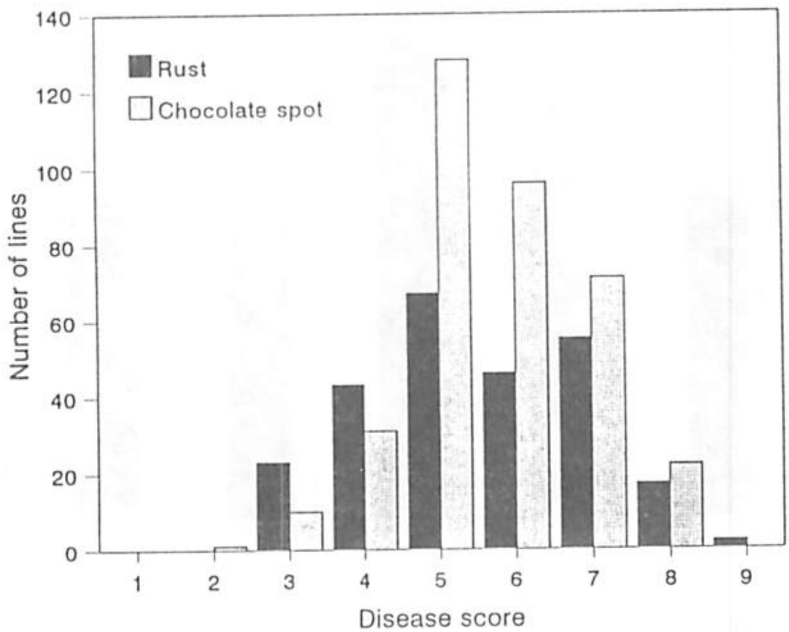

Fig. 5. Disease severity of chocolate spot and rust in faba bean Pre-National Variety Trials in Ethiopia, 1977-92.

Large Seed Size

To improve the seed size of all improved Ethiopian cultivars such as CS 20DK, Kuse 2-27-33, Kala, NC58 and Lume Nazareth, more than 300 crosses were made between ICARDA's large-seeded exotic germplasm and Ethiopian small to medium-seeded cultivars. The large-seeded U-2 and ILB 3187 were used as paternal donors of genes for large seeds. Results are shown in Figure 6 and Table 3: the paternal line U-2 gave 60% more large-seeded recombinants with five female parents compared with ILB 3167.

Seed size also was affected by the position of the ovule and the pedicel with respect to the node. There was a sharp decline in seed weight of pods far from the node (pedicel position 4) compared with that of pods nearest to the node (Fig. 3). However, the results of the effect of the distance of ovule position from the node on seed weight are inconclusive.

As a result of breeding efforts, advanced breeding lines in PNVT and NVT showed a wide range of variability for seed size: from <400 to >500 g for 1000-seed weight over the period 1977-92 (Figs. 1 and 2).

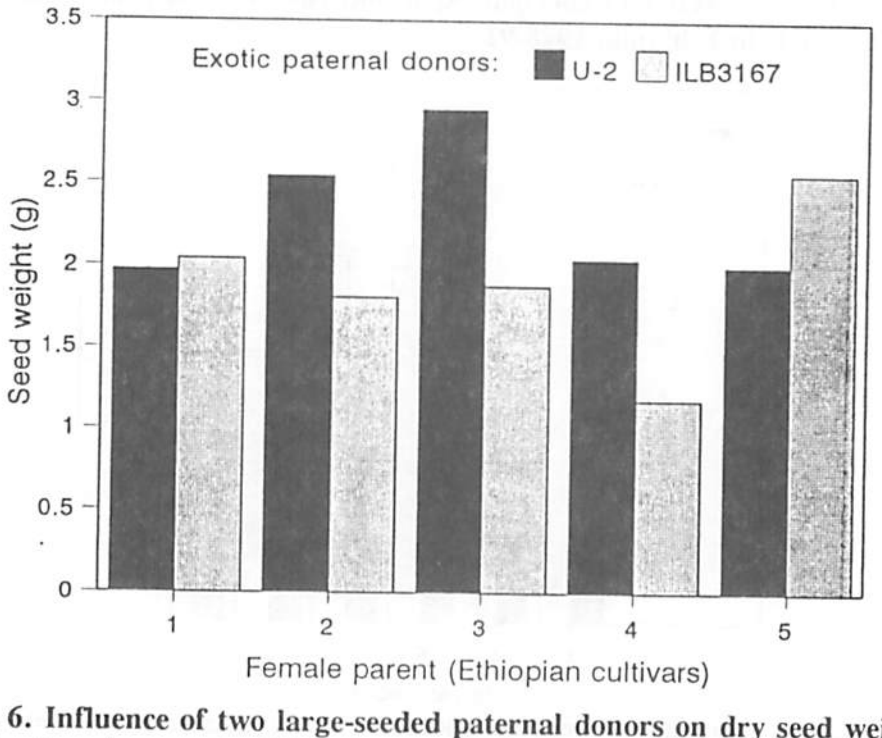

Fig. 6. Influence of two large-seeded paternal donors on dry seed weight of five female parents of faba bean crosses in Ethiopia.

Table 3. Comparative evaluation of pod size of F_2 generation compared with female parent in faba bean in Ethiopia.

Parents		No. of crosses	Number of pods and percentage of total					
			> female parent		= female parent		Intermediate	
Female	Male		No.	%	No.	%	No.	%
CS 20DK	U-2	224	353	64.4	92	16.8	103	18.8
NC58	U-2	261	302	40.4	206	27.5	240	32.1
Kasa	U-2	221	217	43.3	144	28.7	140	27.9
Kuse 2-27-33	U-2	296	251	32.6	131	17.0	389	50.4
Lume Nazareth	U-2	177	181	33.2	115	20.1	250	45.8
CS 20DK	ILB 3/87	250	117	12.5	243	26.0	573	61.4
NC88	ILB 3/87	170	90	13.3	256	37.8	332	49.0
Kasa	ILB 3/87	288	36	3.0	467	38.6	708	58.4
Kuse 2-27-33	ILB 3/87	113	185	34.1	137	25.3	220	40.6
Lume Nazareth	ILB 3/87	196	284	32.6	178	20.4	409	47.0

Autofertility

Autofertility is a desirable character which contributes to yield stability in faba bean. Currently, many entries are being screened at Holetta Agricultural Research Center to identify stable, autofertile lines. A number of these lines were identified for their high autofertility index (ratio of pod set without and with tripping) in the 1993 and 1994 seasons. The agronomic characteristics of those lines will be evaluated for directed release or for including in the crossing block.

Plant Type

The traditional faba bean is an indeterminate type which under favorable conditions can grow up to 2 m tall and is very prone to lodging and poor harvest index. The determinate type is not inherently inferior to the indeterminate type and suggested future work should concentrate on increasing the production of tillers that develop synchronously with the main shoot and preventing the production of infertile branches. In addition, resistance to rust and chocolate spot should be incorporated. Intensive work on this determinate plant type at Dembi and Holetta has been promising. From material introduced from ICARDA (456 lines) over the last 6 years, selection of 20 lines for stage III (early grain yield assessment), 38 single-plant selections, 22 lines for two-replication trials and 12 lines for preliminary grain yield trial assessments under three replications has been completed. The future prospect of this type of faba bean will be under mechanized production on large-scale farms, rather than on small farms.

Varietal Releases

Access of the Ethiopian faba bean breeding program to the wealth of germplasm collections at ICARDA (exotic germplasm and genetic stocks) and PGRC/E (indigenous landraces) has provided the variability needed to develop high-yielding cultivars adapted to the midaltitude and high-altitude agroecological zones. The cultivars are CS 20DK and Kuse 2-27-33 for higher altitudes and Kala and NC 58 for the midaltitude zones. Some of the cultivars in the pipeline for 1993 (Tables 4 to 8) and 1994 (Table 9) gave 13-18% yield increases over the standard improved cultivars. It should be mentioned that most of the standard cultivars used as checks (already released) give 100-300% more seed yield than indigenous landraces grown under farmers' conditions.

Table 4. Mean grain yield and agronomic traits of faba bean selection CS 20DK-4-4-2-6, applied for release in 1993 season, compared with standard cultivar CS 20DK in the high-altitude National Variety Trial, 1989-91 seasons.

	CS 20DK-4-4-2-6				CS 20DK			
	1989	1990	1991	Mean	1989	1990	1991	Mean
Stand (%)	87	93	88	90	86	84	88	86
Days to flowering	64	60	58	61	69	66	61	65
Days to maturity	148	149	144	147	145	149	146	147
Plant height (cm)	94	124	106	108	96	127	112	112
Chocolate spot†	5.0	5.0	5.0	5.0	6.0	5.0	5.0	5.3
Pods/plant	17	15	14	15	16	12	12	13
Seeds/pod	3	3	3	3	3	3	3	3
1000-seed weight (g)	432	454	495	460	439	489	519	482
Grain yield (t/ha)	3.30	3.89	2.91	3.37	2.99	2.70	2.78	3.16

† A 1-9 disease scoring scale where 1 = highly resistant and 9 = highly susceptible.

Table 5. Mean grain yield and agronomic traits of faba bean selection Coll 111/77, applied for release in 1993, compared with the standard cultivar CS 20DK in high-altitude National Variety Trials, 1989-91 seasons.

	Coll 111/77				CS 20DK			
	1989	1990	1991	Mean	1989	1990	1991	Mean
Stand %	82	84	90	85	86	83	86	85
Days to flowering	61	62	60	61	57	64	67	63
Days to maturity	150	143	148	147	128	150	147	141
Plant height (cm)	119	83	120	107	97	123	96	105
Chocolate spot†	6	6	5	6	5	5	6	5
Pods/plant	15	14	17	15	8	14	16	13
Seeds/pod	3	3	3	3	3	3	3	3
1000-seed weight (g)	468	368	424	426	393	522	429	448
Hectoliter wt. (kg)	80.3	80.3	82.7	81.1	79.8	78.9	79.1	79.3
Grain yield (t/ha)	3.20	3.04	3.70	3.31	1.72	3.37	2.99	2.69

† A 1-9 disease scoring scale where 1 = highly resistant and 9 = highly susceptible.

Table 6. Mean grain yield and agronomic traits of faba bean selection 75TA26026-1-2-1, applied for release in 1993, compared with standard cultivar NC58 in the midaltitude National Variety Trials, 1989-91 seasons.

	75TA26026-1-2-1				NC58			
Agronomic trait	1989	1990	1991	Mean	1989	1990	1991	Mean
Stand (%)	97	97	95	96	98	94	91	94
Days to flowering	51	58	54	54	50	54	55	53
Days to maturity	128	126	119	125	122	122	118	121
Plant height (cm)	129	129	135	131	122	122	141	128
Chocolate spot†	4.0	5.0	4.0	4.3	5.0	6.0	4.0	5.0
Rust†	5.0	6.0	4.0	5.0	6.0	6.0	5.0	5.7
Pods/plant	17	16	17	17	14	14	15	15
Seeds/pod	3	3	3	3	3	3	3	3
1000-seed weight (g)	438	430	455	441	347	383	448	393
Grain yield (t/ha)	3.32	3.75	3.90	3.66	3.06	2.91	3.72	3.16

† A 1-9 disease scoring scale where 1 = highly resistant and 9 = highly susceptible.

Table 7. Mean grain yield and agronomic traits of faba bean selection MKT Illubabor, applied for release in 1993, compared with the standard cultivar NC58 in the midaltitude National Variety Trials, 1989-91 seasons.

	MKT Illubabor				NC58			
Agronomic trait	1989	1990	1991	Mean	1989	1990	1991	Mean
Stand (%)	99	98	97	98	94	98	94	95
Days to flowering	52	49	54	52	51	50	54	52
Days to maturity	125	124	124	124	128	122	122	124
Plant height (cm)	117	123	129	123	130	122	122	125
Rust†	4	5	6	5	5	6	7	6
Pods/plant	13	18	16	15	18	14		16
Seeds/pod	3	3	3	3	3	3	3	3
1000-seed weight (g)	432	383	387	401	413	347	383	381
Hectoliter wt. (kg)	80	80.3	81.1	80.5	80	81.4	81.3	80.9
Grain yield (t/ha)	3.29	3.25	3.01	3.16	3.06	2.71	2.98	2.92

† A 1-9 disease scoring scale where 1 = highly resistant and 9 = highly susceptible.

Table 8. Mean grain yield and agronomic traits of faba bean selection NEB 207 × 74TA74-6D, applied for release in 1993, compared with the standard cultivar NC58 in the midaltitude National Variety Trial, 1989-91 seasons.

	NEB 207 × 74TA74-6D				NC58			
	1989	1990	1991	Mean	1989	1990	1991	Mean
Stand (%)	99	95	95	96	94	98	94	95
Days to flowering	49	51	55	52	51	50	54	52
Days to maturity	124	122	123	123	128	122	122	124
Plant height (cm)	119	121	129	123	130	122	122	125
Rust†	4	6	7	6	5	6	7	6
Pods/plant	14	16	15	15	15	18	16	16
Seeds/pod	3	3	3	3	3	3	3	3
1000-seed weight (g)	463	379	391	411	413	347	383	381
Hectoliter wt. (kg)	79	79.4	79.7	79.4	80.0	81.4	81.3	80.9
Grain yield (t/ha)	3.30	3.11	2.80	3.09	3.16	3.06	2.71	2.98

† A 1-9 disease scoring scale where 1 = highly resistant and 9 = highly susceptible.

Table 9. Seed yield performance of four faba bean selections, applied for release in 1994, tested for three seasons at four locations in midaltitude areas.

	Seed yield (t/ha)			
Cultivar	1990	1991	1992	Mean
75TA 26026-1-2-1b	3.25	4.44	3.63	3.77
CS 20DK-3-4-1-5	3.27	3.75	4.04	3.69
CS 20DK-3-4-1-3	3.19	3.57	4.13	3.63
CS 20DK-2-2-1	3.04	3.42	4.15	3.54
NC58	2.71	3.72	3.91	3.45

Future Directions

Ethiopia is one of the centers of diversity for faba bean where nearly 100% of Ethiopian faba bean production comes from indigenous landraces that are extensively grown in the country. The future directions of the faba bean improvement program in Ethiopia should emphasize the following:

- Continue using indigenous landraces as a basis for varietal improvement and exotic germplasm as donors of desirable genes for tolerance of biotic and abiotic stresses, specific traits contributing to high yield and stability (e.g., independent vascular system (IVS) and autofertility) and seed quality characters for the export market
- Review recommendations for varietal releases and the reasons behind lack of recent releases in faba bean
- Genetic vulnerability should be avoided by considering the genetic base of varietal releases. Recommendations for new releases having similar genetic bases will be avoided
- Modify breeding strategy to include specific adaptation in addition to wide adaptation for varietal releases
- Breeding for higher levels of resistance to *B. fabae* and rusts
- Giving more attention to breeding for resistance to wilt/root rots, particularly black root rot
- Seeking dwarfing genes to incorporate in indigenous high-yielding landraces to reduce risk of excessive lodging of the crop in fertile soils
- Strengthening the involvement in the networks of the Nile Valley Regional Program involving faba bean improvement: integrated management of chocolate spot and wilt/root rots, autogamous faba bean and virus diseases
- Seeking a continuous flow of faba bean germplasm from ICARDA, while maintaining the good working relations of IAR and that International Center.

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Discussion

Dr Getinet
Faba bean breeding and research started a long time ago but no satisfactory results have been achieved. In the stability analysis for yield, should we concentrate on wide adaptability or specific adaptability for these crops?

Dr Asfaw
Of course, lots of screening and evaluation activities have been done on faba bean with regard to many genetic and breeding aspects. As far as yield stability is concerned, no detailed analysis is done because of shortage of workforce.

Dr Solh
The research achievement is not much. Instability of yield is serious. We need to choose between breeding for specific or wide adaptability in faba bean. Is Holetta really the right place to give the best environment × genotype interaction for faba bean yield tests?

Dr Asfaw
Only the crossing work is done at Holetta and distribution is done subsequently at different places. As a matter of fact, Holetta is not used as a legume breeding center.

Dr Getinet
Location doesn't really matter when crosses are made. What matters is where selection is done. CIMMYT was cited as an example where, for corn and wheat, breeding work is being done in the highlands of Mexico but the whole world is benefiting from the result.

Dr Solh
The point to be made is that selection from early generations should be made in a center which is representative of the production area addressed. Definitely multiplication of F_1 seed of all crosses can be made in one center and F_2 segregating populations can be distributed to different agroecological zones for selection under local conditions.

Dr Seifu
In the breeding program of faba bean, attention is usually given to the export market whereby improvement in seed size and seed quality are targeted. However, given the fact that there is a critical food shortage in Ethiopia, shouldn't we give priority to local consumption and try to satisfy the needs of our own people and improve yield rather than seed color and seed size?

Dr Asfaw
The problems of seed size and seed color in the indigenous germplasm were identified in the 1970s and at one of the National Crop Improvement Committee (NCIC) meetings it was brought to our attention to target these problems. So we brought exotic materials to transfer the desirable seed color and size to our local landraces. Seed color and seed size are also important in the local market where local consumers prefer large seeds and white/creamy seed color. Such types also cook faster and conserve time and fuel.

Dr Solh
To tackle the issue of yield instability of the faba bean, should a different approach (different breeding methodology) such as the pedigree versus population improvement be evaluated under local conditions?

Dr Asfaw
We are using the modified pedigree method and mixed pollination to get aggressive donors from exotics as well as from the landraces.

Participant
Farmers in the Hosaina area manipulate the physiology of the faba bean by manipulating the stem and leaves which results in enhanced tillering, decreased lodging, and as a result higher yield is achieved. Is this local practice by farmers proved by research?

Dr Asfaw
Farmers in the Hosaina area follow traditionally better cultural practices and herbaceous plants like faba bean when manipulated at an early stage of development or even when damaged by storm and hail usually produce more tillers. However, there is neither an official report nor research to support such a practice.

Genetics and Breeding of Field Pea

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Abstract

Ethiopian field pea is one of the major cool-season food legumes in terms of diet and economics and is an integral part of Ethiopian agricultural systems. Its rich genetic diversity is reviewed here, in the context of Ethiopian research programs. The Ethiopian field pea is divided into four types: the white/cream, small-seeded, shrivelled seed with various seed colors; indented grey seed, and indented pink seed. The two latter types prevail in the midaltitude zone with moderate rainfall (600-700 mm) and well-drained soils, whereas the first two types are adapted to high-altitude areas in the high rainfall (950-1500 mm) zone. The field pea improvement program makes use of the wealth of genetic diversity for hybridization and selection. In an effort to improve the landraces, indigenous and exogenous germplasm has been screened to identify high-yielding and stable genotypes with desirable agronomic traits adapted to mid- and high-altitude agroecological zones. So far, white-seeded and grey-seeded lines have been released for high altitudes, and a large white seed line has been released for midaltitudes. Other promising lines are in the pipeline for release. Future directions of the breeding program are emphasized.

Introduction

Field pea with other food legumes covers about 11-15% of the total 6-7 million hectares of crop area in Ethiopia. Field pea is the third most important staple food legume among the highland pulses in rural Ethiopia. In 1987 the total crop area was 157 000 ha with average yields of 0.86 t/ha. Important provinces in field pea production in descending order are Shewa, Gojam, Gonder and Welo (Table 1) which cover about 70% of the total field pea area (CSA 1987). This area declined slightly in recent years.

The estimated annual consumption of field pea per person in rural Ethiopia is about 6 kg in the form of split, milled and unmilled seed. The flour mixed with various spices is popularly used as *shiro* or the pea may be split as *kik* for the preparation of curry. Field pea supplies 344 calories, 20.1 g protein and 64.8

g carbohydrate/100 g edible portion and it has no antinutritional factors. The protein content of field pea ranged from 21.3 to 24.5% in high altitudes and 22.6 to 31.8% in midaltitudes from 1988 to 1992. Thus, field pea is an important source of protein and energy in the diet of Ethiopia's population.

Table 1. Area, production and yield of field pea in different regions of Ethiopia, 1987.

Region	Area (1000 ha)	Production (1000 t)	Mean yield (t/ha)
Shewa	32.0	35.9	1.12
Gojam	25.7	20.2	0.79
Gonder	20.7	14.1	0.68
Welo	20.7	23.1	1.12
Arsi	16.3	12.0	0.74
Welega	8.5	5.5	0.65
Kefa	7.4	6.0	0.81
Bale	7.2	4.4	0.61
Eritrea	4.3	2.9	0.67
Ilubabor	3.3	2.5	0.76
Gamo Gofa	3.1	2.1	0.68
Harerge	2.9	3.0	1.03
Sidamo	2.9	1.6	0.56
Tigray	2.6	1.9	0.73
Total	157.6	135.2	

Source: CSA 1987.

The crop is mainly grown by subsistence farmers on small holdings. It is a 'break' crop in cereal rotations, especially with barley and bread wheat, which serves to restore soil nitrates and minimize weeds, insect pests and diseases of the cereals.

Because of its high demand by consumers, field pea fetches good prices for producers and retail merchants. Its selling price is only surpassed by that of lentil among the highland pulses. All of the field pea produced is consumed locally. Unlike faba bean, haricot bean, chickpea and lentil, its export market is limited owing to the rough skin of the testa and mixed color. The export market prefers cream or green plump seeds.

Production Constraints

Agricultural productivity in Ethiopia is generally low because of degraded soil fertility, recurrent droughts, inadequate traditional agronomic practices, inadequate research, inefficient extension service, and crop production policies. Field pea is mainly produced for subsistence. Its production is characterized by low-input management with insufficient supply of improved seeds, fertilizer and other inputs. The yield of field pea may be reduced by several factors among which diseases, insect pests, frost, poor cultivars and management practices are outstandingly important.

Ascochyta leaf spot (*Ascochyta pisi* Lib.) and powdery mildew (*Erysiphe pisi* Syd.) are the most important diseases. The latter is serious in the midaltitudes and may reduce yields by 20-30% under moderate severity. Pea aphid (*Acyrthosiphon pisum*) and podborer (*Helicoverpa armigera*) are serious insect pests. Pea aphid may reduce yield by 20-30%.

Broadleaf weeds compete more with field pea than grass weeds. Yields may be reduced by about 15% by weed competition. Peas are sensitive to frost and waterlogging, especially at flowering and early seed-filling stages. Yields of indigenous pea are low because of the vegetative nature of the crop which is reflected in a low harvest index, generally about 20-40%, and its small-seeded character.

Variation under Ethiopian Conditions

The magnitude of variation in days to flowering has been studied for the last 15 years under typical Ethiopian production conditions. Ethiopian field pea can be classified into types suitable for midaltitudes and high altitudes. Variations observed almost depict a normal distribution curve (Fig. 1).

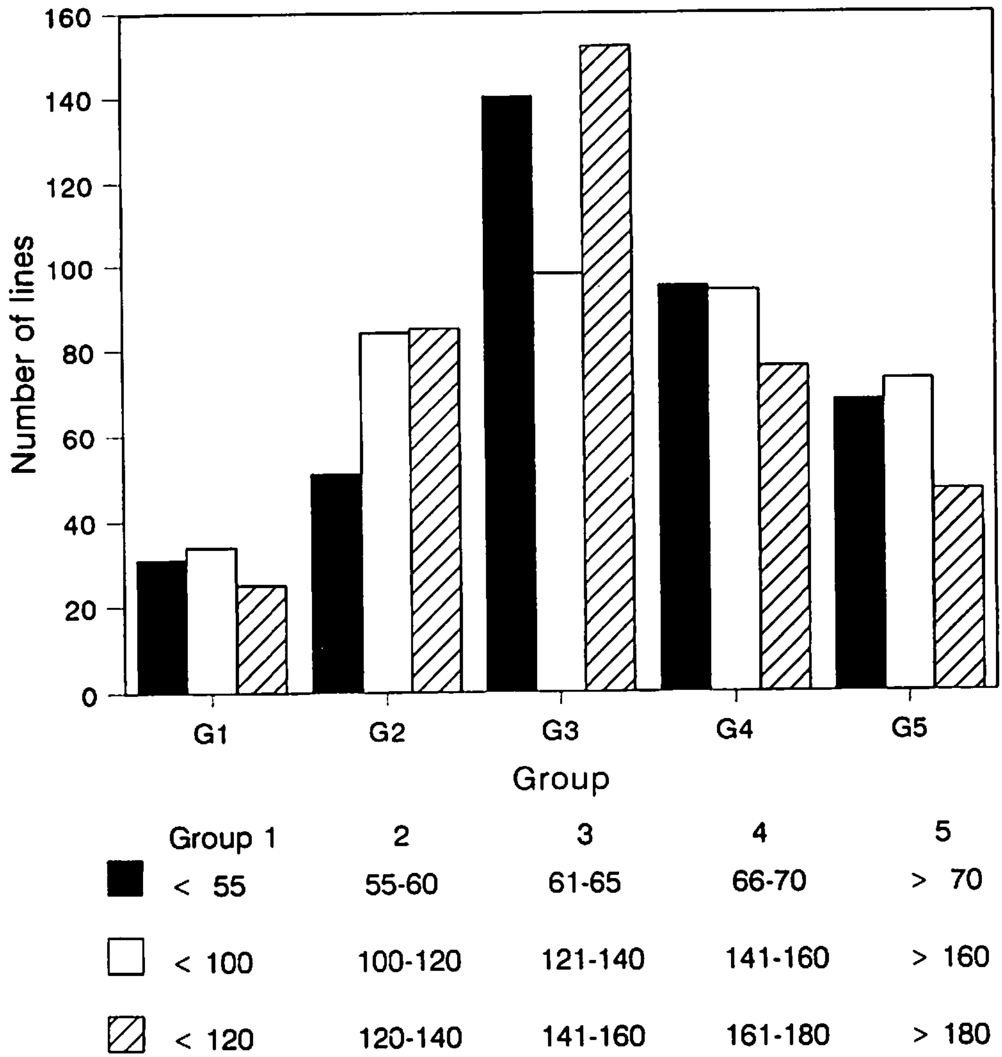

Fig. 1. Variability and improvement of agronomic traits of advanced breeding lines of field pea in National Variety Trials, 1978-92.

Screening of field pea in the Pre-National Variety Trials (PNVT) for some important agronomic traits such as days to flowering, plant height and 1000-seed weight has been going on since 1977. Data from the National Variety Trials (NVT) vary for the three important agronomic traits recorded for the last 15 years, but they almost follow a normal frequency distribution curve. For days to flowering, the early flowering (<55 days) group had about 31 lines;

the late-flowering (>70 days) had 68 lines. The late-flowering lines originated mostly from northern Europe and the USA whereas the early flowering group originated mostly from Ethiopia, India and ICARDA. For plant height, the shortest lines (<100 cm) were from ICARDA, the USA and northern Europe, and most of the tallest lines (>160 cm) were Ethiopian landraces. Likewise, lines with the heaviest 1000-seed weight (>180 g) were from Europe, ICARDA and the USA (Figs. 1 and 2). Data for 1000-seed weight depicted in Figure 2 have an almost-normal frequency distribution curve with two peaks where the lowest seed weight group (<120 g) had 60 lines. Correspondingly, the highest seed weight (>180 g) was roughly represented by half of those lines (34 entries). Days to flowering and plant height characters had similar curves. Plant height frequency distribution showed an increasing trend with taller plants (Fig. 2).

Under Ethiopian growing conditions, 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.

Most of the Ethiopian field pea germplasm, both the white, smooth seed and the grey, indented seed, are tall and leafy with long internodes. *Pisum abssynium* (agere ater) mainly has a short internode and serrated short leaves. This group is either pinkish or grey with a smooth seed. Both types are produced in midaltitudes with annual rainfall of 600-700 mm. They mature between 100 and 120 days and are suited to well-drained alluvial soils. Plant height is 70-90 cm. Short-stature lines introduced from ICARDA and the USA were used to reduce plant height and leaf characters of Ethiopian landraces.

Breeding Program

Historical Development

To improve the productivity of field pea in Ethiopia, a modest program on germplasm selection and varietal development was started in the late 1960s by the Chilalo Agricultural Development Unit (CADU) and Holetta Agricultural Research Center of the Institute of Agricultural Research (IAR). Coordination of food legume research was initiated in 1972 with the formation of a Pulse Sub-Committee by the National Crop Improvement Committee (NCIC). However, the research effort on field pea was kept at a low profile because of a shortage of trained manpower, facilities, and representative testing sites for various major production areas.

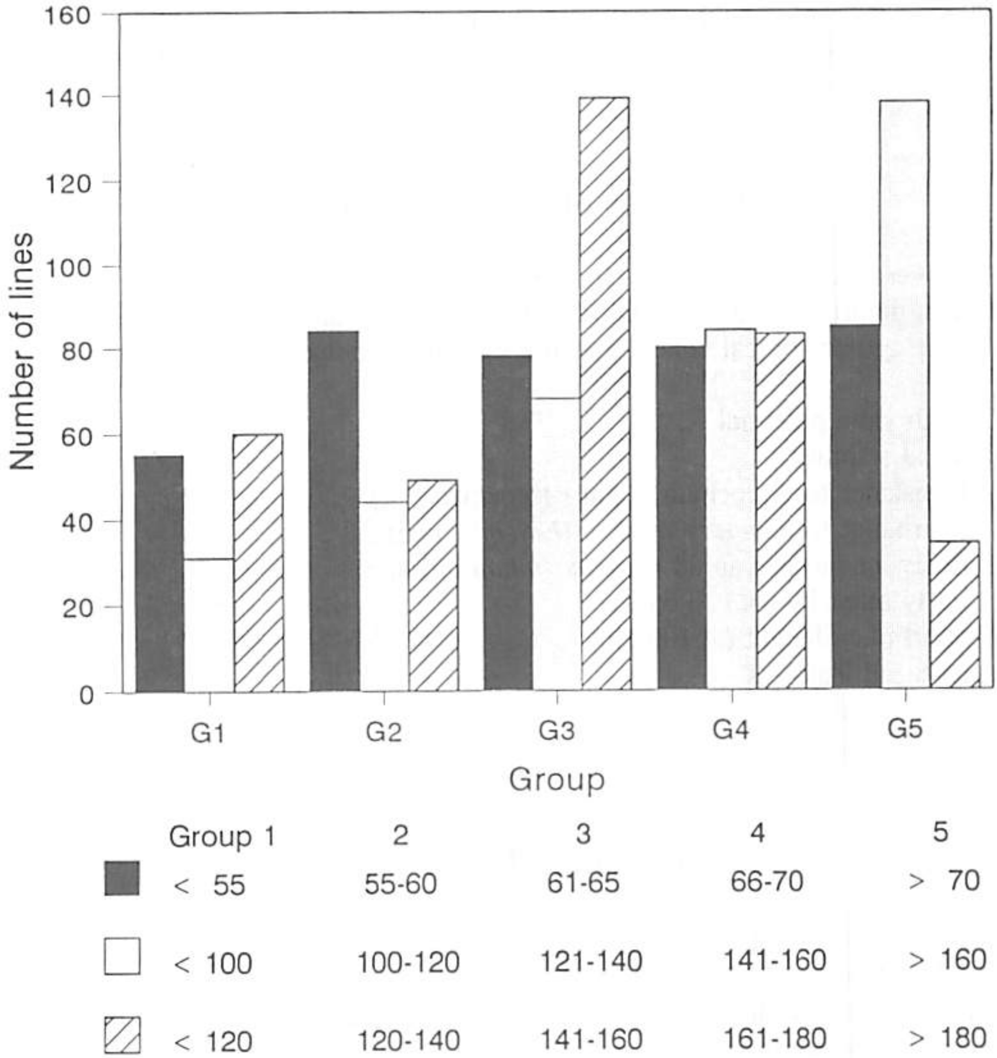

Fig. 2. Variability and improvement of agronomic traits of advanced breeding lines of field pea in Pre-National Variety Trials, 1978-92.

Since 1977 the field pea breeding program, like that of faba bean, has been fully coordinated from the Kulumsa Agricultural Research Center. However, the program was moved from Kulumsa back to Holetta in early 1979.

In 1989, field pea was included in the ICARDA/SAREC Nile Valley Regional Program. The research program, similar to that of faba bean, is being conducted by a multidisciplinary team that includes breeders, agronomists, weed science specialists, pathologists, entomologists, soil microbiologists, food scientists, agricultural economists and extension specialists.

Objectives of Breeding Program

The overall objective of the field pea breeding program in Ethiopia is to develop improved high and stable yielding cultivars adapted to mid- and high-altitude agroecological zones. Specific objectives include the following:

- High yield potential
- Yield stability
- Resistance to Ascochyta blight (*Ascochyta pisi*)
- Resistance to powdery mildew (*Erysiphe pisi*)
- Resistance to pea aphid (*Acyrthosiphon pisum*)
- Early maturity (< 120 days)
- Short plant height (< 100 cm)
- Reduced leafiness
- Large seed size
- Cream colored seed.

Breeding Methodology

The current breeding activities include evaluation of local and exotic germplasm for adaptation, resistance to diseases and pea aphid, early to medium maturity and desirable seed quality through yield testing of promising cultivars in major field pea production areas.

Germplasm Collection, Introduction and Evaluation

The Plant Genetic Resources Centre of Ethiopia (PGRC/E) currently has documented and conserved more than 1142 accessions of field pea accessions. The evaluations made so far indicate that the indigenous field pea has a poor harvest index, is tall and deficient in some desirable characters such as disease resistance, uniform seed color and large seed. Introduction of exotic field pea was envisaged as a possible solution to solve these deficiencies. A total of 1126 field pea accessions/lines was introduced from the USA, Germany, Sweden, the Netherlands, the UK, Burundi, India and ICARDA up to the early 1990s; the majority were from the first two countries. The materials introduced from India and Burundi were early maturing whereas those from the UK failed to flower. Material from the USA performed well at Bekoji (2700 m altitude) with a longer growing season.

Selection and Hybridization

After evaluating a large number of accessions of Ethiopian and exotic origin every year since 1977, one important fact emerged. In Ethiopian production environments there are two categories for adaptation of field peas: field pea for midaltitudes and field pea for high altitudes.

Since 1984 all the breeding material has been of two types. Every year a fairly large number of materials are screened out in NVT, PNVT, PVT and PSN (Table 2) to identify higher seed yield potential, Ascochyta and powdery mildew resistance, early maturity (< 120 days), short plant stature (< 100 cm) and cream-colored seeds. In the course of such screening those materials that could not be advanced directly to yield assessment studies were used for hybridization. As a result, since 1982 a large number of crosses were made for transference of genes responsible for the characters shown in Table 3. Through continuous efforts the program was able to generate high-yielding cultivars for release in the early 1980s.

Agronomic traits

Hybridization and selection for improving agronomic traits and increasing seed size have generated a wide range of variability in days to flowering, maturity, plant height and 1000-seed weight. Improvement of these characters was the result of repeated screening, hybridization and selection for wide diversity for the last 15 years. These data were based on the performance of advanced breeding lines evaluated in NVT and PNVT (Figs. 1 and 2) for three consecutive seasons across widely distributed environments in Ethiopia. More lines have been evaluated in the Preliminary Screening Nursery (PSN) and Preliminary Variety Trial (PVT) than in the NVT and PNVT (Table 2).

Disease resistance

Screening for resistance/tolerance to Ascochyta leaf spot and powdery mildew revealed a wide range of variability for disease reaction of advanced breeding lines in PNVT and NVT. Pathogen-host interactions were not necessarily severe in all production areas, taking into consideration the adaptation of the lines to zones and the prevalence of the pathogens. Therefore, the frequency distribution of the host reaction in relation to the two diseases was almost a normal curve (Figs. 3 and 4).

Table 2. Field pea lines, landraces and exotic lines evaluated in National Variety Trial (NVT), Pre-National Variety Trial (PNVT), Preliminary Variety Trial (PVT) and Preliminary Screening Nursery (PSN) in Ethiopia, 1977-92.

Year	Entry			
	NVT	PNVT	PVT	PSN
1977				20
1978	20		10	
1979	21		19	346
1980	19	25	27	331
1981	19	20	18	224
1982	18	18	18	181
1983	16	21	40	248
1984 A†	15	15	32	809
1984 B†	15	15		
1985 A	15	19	75	296
1985 B	15	18		
1986 A	24	20	30	355
1986 B	18	16	11	
1987 A	21	16	30	71
1987 B	16	15	21	
1988 A	17	10	36	265
1988 B	20	11	22	
1989 A	10	19	33	443
1989 B	16	12	33	
1990 A	8	12	20	215
1990 B	10	13	22	
1991 A	14	20	25	253
1991 B	14	19	22	
1992 A	12	14	32	254
1992 B	12	17	25	
Total	385	365	601	4351

† A: for high-altitude areas; B: for midaltitude areas.

Table 3. Field pea crosses made and characters targeted for transfer to the female parents in the field pea improvement program in Ethiopia, 1982-93.

Year	Parents: Female	Parents: Male	No. of crosses	Characters targeted for transfer to female parent
1982	61	61	61	Seed size (big); yield potential
1983	55	55	55	Seed size (big); yield potential; plant height
1984	57	57	57	Seed size (big); yield potential
1986	20	20	40	Seed size (big); yield potential; earliness
1990	13	26	26	Seed size (big); earliness
1991	26	6	26	Seed size (big); earliness
1992	12	10	12	Earliness; seed size; color
1993	86	43	78	Powdery mildew resistance; plant height modification; Ascochyta leaf spot

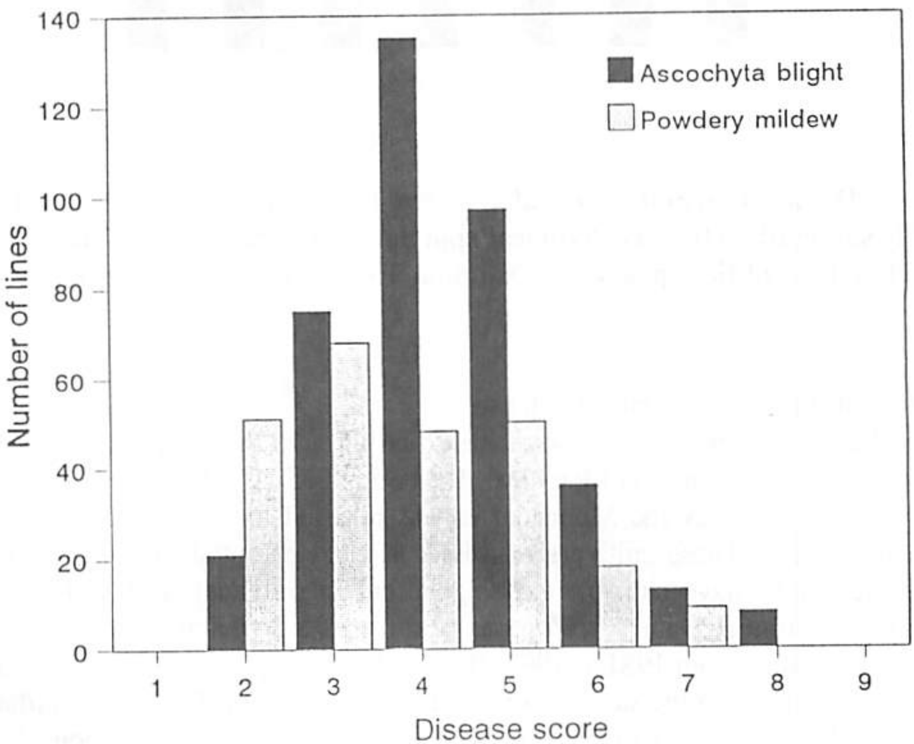

Fig. 3. Disease reaction (1-9 scale, where 1 = highly resistant and 9 = highly susceptible) to Ascochyta leaf spot and powdery mildew of advanced breeding lines of field pea in National Variety Trials in Ethiopia, 1980-92.

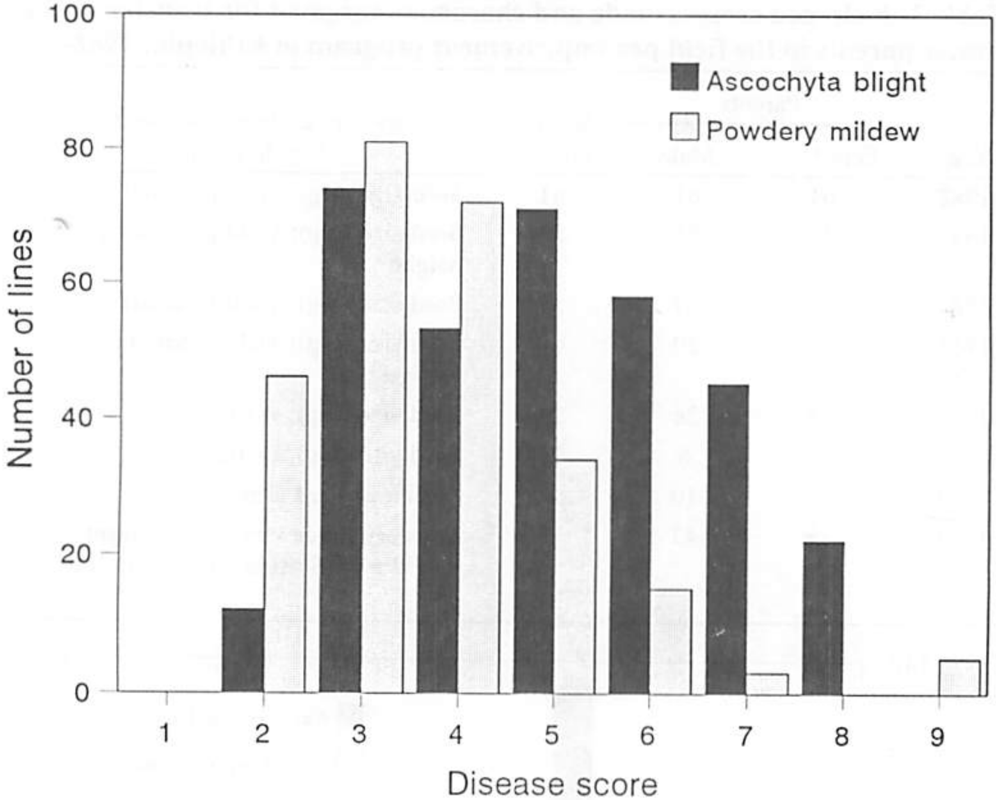

Fig. 4. Disease reaction (1-9 scale, where 1 = highly resistant and 9 = highly susceptible) to Ascochyta leaf spot and powdery mildew of advanced breeding lines of field pea in Pre-National Variety Trials in Ethiopia, 1980-92.

Yield potential and varietal release

Several high-yielding cultivars were identified through the multilocation NVT activities. Cultivars such as FP ex DZ, Haik 95 and G 22763-2C were released for high-altitude areas and Mohanderfer was released for midaltitude areas in the early 1980s. These cultivars expressed a yield potential of 1.7-3.8 t/ha. Other selections have shown much higher but inconsistent seed yields, for example 7.0 t/ha at Dabat, 6.2 t/ha at Bekoji and 5.3 t/ha at Bichena during favorable seasons from 1981 to 1992. Reasonably high-yielding location means were recorded during the same seasons at Dabat (3.98 t/ha), Bekoji (3.94 t/ha), Bichena (3.65 t/ha), Mota (3.29 t/ha,) Goha Tsion (3.11 t/ha), Shambu (2.98 t/ha) and Robe (2.93 t/ha) (IAR 1981-85).

As a result of more recent selection and repeated testing in a wide range of geographical zones, promising new lines were identified for high potential of seed yield; for instance, yield in the southeast areas of the country more than 4 t/ha. Thus cultivar 061K-2-P/92, released in 1994, had an overall seed yield performance of 4.01 t/ha between 1989 and 1991 (Table 4) while the standard check G22763-2C yielded 3.56 t/ha. Another candidate for release, Parvus × Upton, yielded 3.44 t/ha while the standard check gave 3.06 t/ha between 1987 and 1989 (Table 5). These selections are recommended for high-altitude zones.

Promising selections identified for release to farmers in the midaltitude zones are Ji No. 116 and Ji No. 335 (Table 6) with overall mean seed yields of 2.67 and 2.64 t/ha, respectively; the standard check Mohanderfer yielded 2.25 t/ha. For 1994/95 two cultivars, Light Speckled × Upton and FP Nur 74-I × 358-I with seed yields of 3.29 and 3.42 t/ha, respectively, will be applied for release for the high altitudes (Table 7). The standard check seed yield was 3.12 t/ha. These promising selections give consistently 10 and 6% yield increments over all the released cultivars. It is worth noting that the old improved cultivar released in the early 1980s, G 22763-2C, gave 100-250% higher seed yield than over the farmers' landraces under farmers' conditions.

Looking Ahead

The Ethiopian field pea genetic pool has considerable diversity which has not been fully exploited. However, there are serious problems facing farmers which need to be considered in breeding, pathology, agronomy/physiology, pathology, entomology and microbiology research. Therefore, future efforts in the improvement of field pea should be geared but not limited to:

- Systematic screening of germplasm against Ascochyta leaf spot, wilt/ root rots and powdery mildew. In this regard, introducing wilt/root rot and powdery mildew resistance from Australian and ICARDA germplasm should be exploited
- Development of cultivars resistant to these diseases
- Resistance to pea aphid should be considered as one component of integrated pest management
- Reducing leafiness of indigenous landraces should continue
- Efforts should continue to breed for large, good-quality seeds
- Upright growth habit and simultaneous early maturity should be incorporated into cultivars to facilitate mechanization
- The breeding program should also consider the importance of horticultural traits of pea for its use as a fresh vegetable.

Table 4. Mean seed yield and agronomic traits of field pea selection 016K-2P-2/92 for high-altitude zones of Ethiopia, submitted for release in 1993, compared with standard cultivar G22763-2C in National Variety Trials, 1989-91.

	Selection 016K-2P-2/92†				Standard cv. G22763-2C			
Agronomic trait	1989	1990	1991	Mean	1989	1990	1991	Mean
Stand (%)	81	87	84	84	82	87	90	86
Days to flowering	73	71	72	72	75	74	74	74
Days to maturity	136	141	136	138	138	142	137	139
Plant height (cm)	111	151	127	130	115	150	135	133
Ascochyta score‡	5.0	5.3	2.3	4.2	4.0	4.3	3.0	3.8
Pods/plant	9	11	9	10	9	11	10	10
Seeds/pod	5	5	4	5	5	5	5	5
1000-seed weight (g)	209	219	218	215	156	161	184	167
Seed yield (t/ha)	4.13	4.53	3.37	4.01	3.54	3.34	3.80	3.56

† Released officially in 1994.

‡ On a 1-9 disease rating scale where 1 = highly resistant and 9 = highly susceptible.

Table 5. Mean seed yield and agronomic traits of field pea selection Parvus × Upton for high-altitude zones of Ethiopia, submitted for release in 1993, compared with standard cultivar G22763-2C in National Variety Trials, 1987-89.

	Parvus × Upton (selection)				G22763-2C (standard check)			
	1987	1988	1989	Mean	1987	1988	1989	Mean
Stand (%)	87	81	83	82.8	90	84	81.5	85.2
Days to flowering	62	66	65	64	72	75	75	74.3
Days to maturity	126	136	136	133	129	142	138	136
Plant height (cm)	119	159	121	133	114	160	115	130
Aschochyta blight score†	5.2	6	5	5.4	4.2	5	5	4.7
Pods/plant	10	10	10	10	9	10	9	9
Seeds/pod	5	5	5	5	5	5	5	5
1000-seed weight (g)	146	171	158	158	131	156	156	148
Powdery mildew score†	5.0		4	4.5	4.5		4	4.3
Hectoliter weight (kg)	79			79	82.8			82.8
Seed yield (t/ha)	2.87	3.55	3.91	3.44	2.55	3.09	3.54	3.06

† On a 1-9 disease rating scale where 1 = highly resistant and 9 = highly susceptible.

Table 6. Mean seed yield and agronomic traits of field pea selections Ji No. 116 and Ji No. 335 for high-altitude zones of Ethiopia, submitted for release in 1993, compared with standard cultivar G22763-2C in National Variety Trials, 1987-89.

	Ji No. 116 (selection)				Ji No. 335				Mohanderfer (standard check)			
Agronomic trait	1987	1988	1989	Mean	1987	1988	1989	Mean	1987	1988	1989	Mean
Stand (%)	95	81	96	91	91	90	96	92	95	94	95	95
Days to flowering	68	63	61	64	64	56	56	59	66	69	53	63
Days to maturity	123	113	123	120	120	111	117	116	121	112	102	112
Plant height (cm)	150	148	132	143	148	142	131	140	156	141	116	138
Aschochyta blight score†	6	5	4	5	6	6	5	6	6	5	4	5
Pods/plant	14	12	8	11	15	11	9	12	14	11	9	11
Seeds/pod	4	4	5	4	5	4	5	5	5	4	5	5
1000-seed wt. (g)	120	123	153	132	141	142	159	147	137	130	200	156
Powdery mildew score†	4.5	5	4	5	5	5	4	5	4	4	4	4
Hectoliter wt. (kg)	80.5	80	80.7	80.4	80	79	81	80	81.3	81.0	81.0	81.1
Seed yield (t/ha)	2.88	2.01	3.13	2.67	3.09	1.79	3.03	2.64	2.23	1.55	2.98	2.25

† On a 1-9 disease rating scale where 1 = highly resistant and 9 = highly susceptible.

Table 7. Seed yield performance of field pea selections submitted for release in 1994, as evaluated for three seasons across three locations in the high altitudes of Ethiopia.

	Seed yield (t/ha)†			
Cultivar	1990	1991	1992	Mean
FP Nur 74-I × 358 -I	3.88	3.71	2.66	3.42
Light Speckled × Upton	3.86	3.44	2.57	3.29
G22763-2C	3.33	3.80	2.22	3.12

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Discussion

Dr Seifu
Do we need to breed for improved seed color and seed size to satisfy the export market instead of paying attention to higher yield and satisfying the local demand and food shortage?

Ato Beyene (presenter)
Our breeding program really doesn't target export. Ethiopian cultivars are usually of poor seed quality. Breeding for disease resistance, seed color and seed size is also important for the local market and local needs. Besides, most of the crosses made target high yield and disease resistance.

W/ro Senayit
Seed size is really important. Large seed size and uniformity in size are looked for by local consumers.

Dr Saxena
In your future objectives, is breeding for mechanized harvesting and threshing really an issue, taking the country's problems into consideration, or is it a fantasy?

Ato Beyene
Even though large-scale farms demand mechanizable cultivars, it is not a priority in our breeding program.

Genetics and Breeding Research in Chickpea

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Abstract

Chickpea is an important pulse crop in Ethiopia and is considered one of the priority crops for improvement. Since the inception of the National Chickpea Improvement Program several efforts have been made to identify the major constraints to chickpea production. Surveys were made in different regions and information was assembled to help the breeding program develop its priorities. The prevalence of several diseases and insect pests was documented. A genetic improvement program to develop improved cultivars was a continuous activity throughout this period. Resistance breeding with major emphasis on soil-borne diseases has been undertaken. Entomological work on *Helicoverpa armigera* received more attention although efforts were shifted towards monitoring the insect development using different traps. Studies on some quantitative genetics, breeding techniques and hybridization were made. Desi and kabuli chickpea improvement programs were separated. Work on resistance to drought, frost, waterlogging and diseases has been strengthened. The National Chickpea Improvement Program has linked its activities with ICARDA and ICRISAT Chickpea Improvement Programs. It is actively involved in the Nile Valley Regional Networks to consolidate collective efforts and resources which will enhance the alleviation of major limiting factors of chickpea production in the region.

Introduction

Chickpea belongs to the genus *Cicer* and tribe Cicereae Alef. *Cicer* has about 43 species (van der Maesen 1987). Chickpea and most of its wild relatives have 2n = 16 chromosomes. Chickpea (*Cicer arietinum* L.) is an important food legume crop in Ethiopia, is used as food in different forms and in crop rotations with cereals to improve soil fertility. The straw is used for animal feed and as firewood.

Quantitative Genetics

Most of the genetic information on chickpea has been documented in the bibliographies prepared by Singh and van der Maesen (1977) and Singh *et al.* (1984). Moreover, Muehlbauer and Singh (1987) reviewed all the genetic information in their chickpea book. Since this information is available, only a few studies were conducted in quantitative genetics.

Heritability

Thirty-six genotypes were grown by Abebe (1985) during 1982/83 and 1983/84 cropping seasons to study the heritability, phenotypic and genotypic variability and coefficient of variation. The materials were grown at Akaki and Debre Zeit and observations were recorded on plant height, number of primary and secondary branches, pods/plant, number of seeds/pod and seed yield/plant. The highest heritabilities were recorded for 100-seed weight at Akaki (98.5 and 97.7%, Table 1) and at Debre Zeit (99.0 and 95.5%, Table 2). Number of seeds/pod and plant height also had high heritability (Tables 1 and 2) whereas the number of primary and secondary branches and number of pods/plant had low heritability (Abebe 1985). This indicates that the number of primary and secondary branches and number of pods/plant are highly influenced by the environment. The genetic coefficient of variation was high for 100-seed weight at both locations in 1982 and 1983 (Tables 1 and 2). The coefficient of variation was low for the number of primary branches in both years at the two locations, indicating that selection is not effective for this character because of narrow genetic variability. The differences between phenotypic and genotypic variances confirmed that number of secondary branches and pods/plant are highly influenced by the environment (Tables 1 and 2).

Table 1. Phenotypic variability, components of genetic variance, coefficient of variation and heritability of plant characters for two years at Akaki, Ethiopia.

Character	Year	Mean	Heritability (%)	Q^2 ph	Q^2 g	CV g (%)
No. primary	1982/83	2.2	60	0.1	0.1	7.8
branches	1983/84	1.6	80	0.2	0.2	24.7
No. secondary	1982/83	6.1	23	3.5	1.2	18.3
branches	1983/84	5.8	20	1.6	0.3	9.4
Plant height (cm)	1982/83	40.8	92	46.4	42.4	16.0
	1983/84	36.2	93	48.5	45.0	18.6
Pods/plant	1982/83	73.5	52	387	201	19
	1983/84	53.4	38	175	67	15
Seeds/pod	1982/83	1.5	92	0.2	0.2	25.6
	1983/84	1.5	94	0.2	0.3	27.5
100-seed weight (g)	1982/83	14.6	99	14.6	68.0	66.9
	1983/84	14.5	98	14.5	58.2	66.6
Seed yield/	1982/83	12.3	56	14.9	8.4	23.6
plant (g)	1983/84	7.7	13	4.2	0.6	9.8

Q^2 ph = phenotypic variance; Q^2 g = genotypic variance.
Source: Abebe 1985.

Table 2. Phenotypic variability, components of genetic variance, coefficient of variation and heritability of plant characters for two years at Debre Zeit, Ethiopia.

Character	Year	Mean	Heritability (%)	Q^2 ph	Q^2 g	CV g (%)
No. primary	1982/83	2.1	38	0.2	0.1	9.7
branches	1983/84	1.8	58	0.1	0.1	13.3
No. secondary	1982/83	4.9	79	2.9	2.3	30.4
branches	1983/84	7.7	62	12.0	7.4	35.4
Plant height (cm)	1982/83	39.3	84	45.2	36.78	15.4
	1983/84	36.2	85	36.9	31.5	15.5
Pods/plant	1982/83	77.3	19	514.8	96.3	12.7
	1983/84	91.2	54	779.0	422.1	22.6
Seeds/plant	1982/83	1.4	88	0.1	<0.1	22.8
	1983/84	1.4	94	0.1	0.1	25.3
100-seed weight (g)	1982/83	16.3	99	69.9	69.2	51.2
	1983/84	16.4	96	70.0	66.9	61.2
Seed yield/	1982/83	13.4	36	21.3	7.7	20.7
plant (g)	1983/84	16.5	41	43.6	17.7	25.5

Q^2 ph = phenotypic variance; Q^2 g = genotypic variance.
Source: Abebe 1985.

In another study of 205 accessions (desi type), the coefficient of variation (phenotypic) was high for seed yield, number of pods/plant and biomass (Table 3).

Table 3. Mean, maximum, minimum, standard deviation (SD) and coefficient of variation (CV%) of desi chickpea in Ethiopia.

Variable	Mean	Max.	Min.	SD	CV%
No. branches	1.9	3.0	1.0	0.44	20.9
Days to 50% flowering	50.0	57.0	46.0	2.63	5.2
Days to maturity	88.0	96.0	80.0	3.37	
Plant height (cm)	31.7	43.0	21.6	3.91	12.3
Pods/plant	18.7	59.0	7.0	7.27	38.7
Seeds/pod	1.5	2.0	1.0	0.29	19.2
Biomass (t/ha)	21.0	50.0	6.7	9.4	37.2
100-seed wt. (g)	12.2	20.9	9.6	1.90	5.5
Grain yield (t/ha)	0.7	1.4	0.2	0.3	39.0

Source: ICARDA/IAR 1993.

Correlation

Study of the relationships between seed yield and other characters revealed that days to maturity, plant height and number of pods/plant were highly associated with seed yield (Table 4). Days to 50% flowering and maturity had significant positive association (0.411, P=0.01). Similarly, a study conducted by Abebe (1985) showed that number of pods/plant and 100-seed weight had significant positive associations with seed yield/plant in 1983/84 (Table 5). However, 100-seed weight had a negative and significant correlation with seed yield at Debre Zeit in 1982/83 but was highly significant and positive in 1983/84 (Table 6). Number of secondary branches showed a significant positive relationship with seed yield at Debre Zeit only in 1983/84. However, it also showed consistently positive associations with seed yield over locations and years (Tables 5 and 6).

The correlation coefficient among five chickpea characters studied (Abebe 1985) revealed that number of pods/plant had positive and significant associations with all characters except 100-seed weight at Akaki in both seasons (Table 5). Interestingly, 100-seed weight had a positive relationship with number of pods at Debre Zeit but negative values at Akaki (Tables 5 and 6). Generally, this report showed that selection for tall plant height, high number of primary and secondary branches and number of pods/plant are useful criteria to develop high-yielding chickpea plants.

Stability

In a country like Ethiopia which has highly variable agroecological zones, genotypic rankings usually differ from one environment to another. This significant genotype × environment (GE) interaction often complicates breeders' work because yields are not predictable on the basis of simple genotype and environment means. This poses difficulties in interpreting yield data collected for a number of genotypes in a number of environments (location and years). Therefore, stability analysis was carried out by Geletu *et al.* (1992b) using Chickpea National Yield Trials grown at 6, 5 and 4 locations over 3 years (1986/87, 1988/89 and 1989/90). Fourteen entries in the first 2 years and 15 entries in the third year were included. Mean seed yields of the cultivars grown at different locations during 1986/87 and 1988/89 are presented in Table 7. Mean yields of entries grown over 11 environments revealed that genotype 7-D-A (F_8) was the highest yielder. This was followed by PGRC-268, JG-62 × Radhy and Mariye (K850-3/27 × F378). The old cultivars such as DZ-10-11, H-54-10 and a local check ranked 8th, 12th and 13th, respectively (Table 7).

Table 4. Simple correlations coefficients between yield and yield components in chickpea germplasm in Ethiopia.

Character	Days to maturity	Plant height	Pods/plant	Seeds/pod	100-seed weight	Seed yield/plant
Days to flowering	0.411**	-0.037	-0.002	-0.300	0.087*	-0.044
Days to maturity	.	0.110	0.061	-0.036	0.023	0.112*
Plant height (cm)	.	.	0.419	0.049	-0.034	0.542**
Pods/plant	.	.	.	0.091*	-0.068	0.413**
Seeds/pod	.	.	.	.	-0.111*	0.004
100-seed weight (g)	.	.	.	.	.	0.069

*, ** = Significant at 5% and 1% levels of probability, respectively.
Source: DZARC 1991.

Table 5. Correlation coefficients among six characters and with yield in chickpeas over two years at Akaki, Ethiopia.

Character	Year	Primary branches	Secondary branches	Pods/plant	Seeds/pod	100-seed weight	Seed yield/plant
Plant height (cm)	1982/83	0.402*	0.056	0.334*	0.386*	-0.151	0.062
	1983/84	0.207	0.207	0.397*	0.104	-0.066	0.141
No. primary branches	1982/83	.	0.319	0.341*	0.205	0.130	0.222
	1983/84		0.475**	0.286	-0.247	0.170	0.227
No. secondary branches	1982/83	.	.	0.497**	0.500**	0.183	0.238
	1983/84			0.462**	0.020	-0.021	0.103
Pods/plant	1982/83	.	.	.	0.605**	-0.176	0.650**
	1983/84				0.340	-0.398	0.342*
Seeds/pod	1982/83	.	.	.	.	0.350*	0.327
	1983/84					-0.774**	-0.129
100-seed weight (g)	1982/83	.	.	.	.	.	0.185
	1983/84						0.423*

*, ** = Significant at 5% and 1% levels respectively.

Table 6. Total correlation coefficients among six characters and with yield in chickpea over two years at Debre Zeit, Ethiopia.

Character	Year	Primary branches	Secondary branches	Pods/plant	Seeds/pod	100-seed weight	Seed yield/plant
Plant height (cm)	1982/83	0.174	0.226	0.186	0.190	-0.00	-0.217
	1983/84	0.516**	0.040	0.093	-0.221	-	0.038
No. primary	1982/83	.	0.811**	0.283	0.325	-0.102	0.184
branches	1983/84		0.354**	0.138	-0.050	0.463**	0.326
No. secondary	1982/83	.	.	0.338*	0.285	-0.095	0.289
branches				0.209	-0.053	0.449**	0.503**
Pods/plant	1982/83	.	.	.	0.4676**	0.537**	0.555**
	1983/84				0.044	0.029	0.634**
Seeds/pod	1982/83	.	.	.	.	-0.749**	0.480**
	1983/84					-0.386**	-0.039
100-seed weight	1982/83	.	.	.	.	.	-0.375*
(g)	1983/84						0.505**

*, ** = Significant at 5% and 1% levels of probability, respectively.
Source: Abebe 1985.

Table 7. Mean yield of chickpea genotypes grown at different locations in Ethiopia, 1986/87 and 1988/89.

	Seed yield (t/ha)				
Genotype	1986/87	SE±	1988/89	SE±	Overall mean†
7-D-A (F_8)	1.96	0.26	1.81	0.15	1.89 (1)
ENT-46	1.74	0.28	1.53	0.18	1.63 (5)
P-127	1.61	0.24	1.48	0.17	1.54 (7)
K-850-3/27 × F378	1.71	0.26	1.63	0.18	1.67 (4)
PGRC-268	1.62	0.11	1.94	0.14	1.78 (2)
JG-62 × Radhy	1.90	0.27	1.65	0.09	1.77 (3)
Annegeri	1.57	0.09	1.61	0.06	1.59 (6)
H-54-10	1.41	0.17	1.53	0.18	1.47 (12)
DZ-10-11	1.35	0.19	1.74	0.36	1.54 (8)
ICC-6800	1.48	0.26	1.46	0.07	1.47 (11)
ICCL-80033	1.37	0.31	1.38	0.11	1.38 (14)
ICCL-82338	1.54	0.20	1.53	0.04	1.53 (9)
ICCL-82125	1.49	0.22	1.55	0.08	1.52 (10)
Local check	1.46	0.08	1.48	0.10	1.47 (13)
Mean	1.59		1.59		
LSD (P=5%)	2.18		0.40		

† Number in parenthesis shows rank of cultivars over 11 environments.

The pooled analysis of variance showed significant differences among locations during the 1986/87 and 1988/89 seasons, indicating that these locations represent different environments which can be used as testing sites of chickpea yield trials. The stability analysis also revealed that the genotype × location (nonlinear) and location (linear) components were significant in all 3 years although the magnitude of the latter was higher (Table 8). According to Geletu *et al.* (1992a), genotype 7-D-A (F_8) had high mean yield and high regression value (b=1.40) showing that it has specific adaptation and performs well only in good environments. Cultivar JG-62 × Rahdy showed high yield potential and resistance to the changing environments while PGRC-268 (of Ethiopian origin) was an average yielder, stable (b=1.00) and ranked second in the overall performance across environments. Generally, genotypes PGRC-268 and JG-62 × Rahdy were stable, whereas genotypes such as 7-D-A, ICCL-7883/82-DZ/1, ICCL-83307, IC-798/83-DZ/2-1 and ENT-1 were high yielders and had adaptation to a specific location or environment.

Table 8. Pooled analysis of variance for seed yield of chickpea genotypes in National Yield Trials in Ethiopia, 1986/87, 1988/89 and 1989/90.

	Mean square					
Source of variation	df	1986/87	df	1988/89	df	1989/90
Replication	3	85148	3	1886490	3	893500
Location (L)	5	144311000**	4	61773600*	3	37605700
Cultivar (C)	13	842639**	13	453993	14	831549
L × C	65	288414*	52	506279	42	887935
Error	249	149340	207	425278	177	1190280
C × L × L	70	324652**	56	70308**	45	833946**
L (Linear)	1	18038900**	1	3558160**	1	28204300**
C × L (Linear)	13	93371	13	9216	14	185255
Pooled deviation	56	62016	42	6174	30	224326

*, ** = Significant at 5% and 1% probability level, respectively.

Breeding

The maximum yield of crop cultivars, determined by their genetic potential, is rarely achieved because of several limiting abiotic and biotic factors such as insufficient water or nutrients, damage by plant diseases and insect pests. The first step is to detect and identify the major production constraints and priorize to set breeding strategies to improve the crop. This is followed by the evaluation and selection of desirable local landraces and introductions before starting a hybridization program to generate segregating populations.

Hybridization

Hand-crossing in chickpea is a tedious and laborious job. Hence, it requires special consideration to identify appropriate crossing techniques to produce hybrid seeds. At Debre Zeit, nine different emasculation and pollination periods were studied in the greenhouse. Genotype H-54-10 was chosen as a male parent because it has the genetic markers of brown seed coat and pink flower, which was known to be dominant over white seed coat and white flower of cultivar DZ-10-4 (female parent) as reported by Geletu and Tesfaye (1981). According to this report the highest percent of hybrid seed set was 7.7% when flowers were emasculated in the morning (0800-1000 hours) and then followed by pollination at noon (1200-1400 hours) (Table 9). Emasculation made during 1600-1800 hours followed by noon pollination the next day also produced 5.5% hybrid seed set. Abebe and van Rheenen (1989) used DZ-10-11 and ICCV-2 as female and male parents in artificial cross pollinations studied in the field at Debre Zeit Agricultural Research Center (DZARC), using two methods: emasculation at 1600 and pollination by the following day at 0830, emasculation and pollination at 0900 on the same day. These methods were used for 7 days by two trained staff. Their findings showed that crossing in the field gave better results than crossing in the greenhouse. There was no significant difference between the two people and the crossing methods (Table 10).

Gametocides

Geletu (1981) studied the effectiveness of three chemical male gametocides (Flordimex-T, Phynazol and Flordimex) at four application rates to induce male sterility in chickpea. Genotype H-54-10 (male parent) and cultivar DZ-10-4 (female) were used. The largest number of flowers were pollinated in the control plot (23.7%) followed by the plot treated with the concentrations of 417 and 833 ppm of all gametocides. The number of pollinated flowers decreased with increased concentration, indicating that higher concentrations affect the number of flowers. However, the highest percentage of hybrid seeds (42.6%)

was obtained from plots treated with Flordimex at a concentration of 3322 ppm. According to Geletu (1981) Flordimex gave better hybrid seeds than the other two chemicals (Tables 10 and 11). These results also showed that the pink (purple) color of flowers was the more reliable gene marker as was seen from the F_1 plants. Seed shape was not a good gene marker as the smooth seed can be shrivelled by adverse environmental conditions and will be difficult to differentiate from rough seed. Generally, the results of this study showed that hybrid seeds might be produced by using these chemicals (male gametocides) provided that the appropriate concentration is used.

Table 9. Average number of flowers emasculated and percent of hybrid seeds obtained following emasculation and pollination of chickpea at different times of day in Ethiopia.

Time of		Avg. no. crosses	Hybrid seeds
Emasculation	Pollination	/treatment	(%)†
0800 - 1000	0800 - 1000	31.3	4.2
0800 - 1000	1200 - 1400	17.0	7.7
0800 - 1000	1600 - 1800	17.0	4.1
1200 - 1400	1200 - 1800	19.3	5.2
1200 - 1400	1600 - 1800	15.7	1.9
1200 - 1400	0800 - 1000	14.0	2.1
1600 - 1800	1600 - 1800	25.3	2.8
1600 - 1800	0800 - 1000	17.3	1.7
1600 - 1800	1200 - 1400	12.7	5.5

† Based on flower color.

Table 10. Percent of hybrid chickpea seeds obtained as identified by using seed shape (gene marker) after application of Flordimex-T, Phynazon and Flordimex at four concentrations.

Chemical	Concentration (ppm)				
	417	833	1664	3322	Mean
Flordimex-T	12.0	15.5	14.9	31.8	18.6
Phynazol	40.0	14.5	31.0	40.3	31.5
Flordimex	14.0	34.5	28.6	42.6	29.9
Mean	22.0	21.5	24.8	38.2	

Source: Geletu 1981.

Table 11. Percent of hybrid seeds obtained in chickpea as identified by using flower color (gene marker) after application of Flordimex-T and Phynazol.

	Concentration (ppm)				
Chemical	417	833	1664	3322	Mean
Flordimex-T	20.9	36.4	17.2	23.8	24.6
Phynazol	34.2	17.1	23.0	29.9	26.1
Flordimex	25.0	40.2	14.3	42.6	30.5
Mean	26.7	31.2	18.2	32.1	

Source: Geletu 1981.

Frequency of Application

The same three chemical male gametocides were applied on chickpea plants at intervals of 5, 10 and 15 days with a concentration of 1664 ppm each (Geletu 1981). The results of this study showed that an application at 5-day intervals reduced pod set (72.9%) while 15-day application intervals produced the largest number of pods (184.8%) compared with the check, indicating that these chemicals acted as growth regulators. An application of the chemicals at 5-day intervals reduced plant height significantly.

Effect of Chemicals × Rates × Intervals

When the three chemicals were applied at the rates of 833 and 3322 ppm on chickpea cultivar DZ-10-4, all the plants were killed and failed to produce pods at 3322 ppm. There were significantly different effects on plant height for the rates and intervals of application (Table 12). Complete flower sterility was induced by Phynazol and Flordimex at 833 ppm when applied at 5-day intervals. In this study, except for a few flowers in 10-day intervals and some in 15-day intervals, most of the flowers were dried before they reached the stage of emasculation and pollination.

Table 12. Analysis of variance for the effect of chemicals, rates and frequency of application on plant height in chickpea.

Source of variation	df	Mean square
Blocks	3	17.0
Chemicals (A)	2	55.2
Rates (B)	1	2630.5**
Intervals (C)	2	602.1**
AB	2	9.2
BC	2	9.2
AC	4	15.4
ABC	4	34.4
Error	51	28.6

** = Significant at 1% probability level.
Source: Geletu 1981.

Germplasm Utilization

The wealth of inherent biodiversity has long been recognized and, increasingly, made use of in breeding for cultivars with desirable characteristics. Fewer than 1000 chickpea accessions of indigenous landraces are available in the Plant Genetic Resources Center of Ethiopia (PGRC/E). Most of these collections were made by the joint mission of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), PGRC/E and DZARC. Owing to the limited indigenous landrace collections available, the National Chickpea Improvement Program relied heavily on introductions, mainly from ICRISAT and ICARDA (International Center for Agricultural Research in the Dry Areas). To date, over 6000 chickpea lines and segregating populations have been introduced (Table 13) from which several lines were selected for yield and other desirable characters.

Varietal Improvement

All indigenous landraces and introductions are always grown at DZARC before they are included in the Preliminary Yield Trials (PYT). The materials selected at DZARC are advanced to PYT, Advanced Yield Trials (AYT) and then included in Pre-National Yield Trials (kabuli and desi) and National Yield Trials (NYT) (kabuli and desi) to be tested at several locations representing different agroecological zones of the chickpea production areas.

Table 13. Number of chickpea lines/segregating populations introduced to Ethiopia between 1978/79 and 1992/93 crop seasons.

Year	No. of entries	Type of population
1978/79	2000	Germplasm accessions
1979/80	79	Stable lines
1980/81	218	Stable lines and segregating populations
1981/82	172	Stable lines
1982/83	492	Stable lines
1983/84	264	Stable lines and segregating populations
1984/85	290	Stable lines and segregating populations
1985/86	163	Stable lines
1986/87	368	Stable lines
1987/88	273	Stable lines
1988/89	245	Stable lines
1989/90	267	Stable lines and segregating populations
1990/91	155	Stable lines and segregating populations
1991/92	200	Stable lines and segregating populations
1992/93	108	Stable lines
Total	6199	

During the early 1970s when the chickpea research progam was in its initial stages, chickpea lines DZ-10-2, DZ-10-11, CADU 54, Dubie and H-54-10 were identified for their high yields (DZAES 1972/73, 1973/74). These lines were multipled and their seeds were distributed to the farmers in Yerer-Keryu and Menagesha *awrajas* (subprovinces). The mean yields of these lines are given in Table 14. However, cultivar DZ-10-2 was not taken up by farmers because of its small and black seeds. Following these lines, DZ-10-4 and DZ-10-1, both kabuli type were released; these were popular in the region, with high demand and good prices for their seeds in the market. They were preferred for use as snacks in bars for local drinks.

Table 14. Summary of mean seed yields of five best entries in National Yield Trials, 1973-75, over locations in Ethiopia.

1973 (8 locations)		1974 (7 locations)		1975 (8 locations)	
Genotype	Yield (t/ha)	Genotype	Yield (t/ha)	Genotype	Yield (t/ha)
DZ-10-11	1.76	H-54-10	1.97	41B	1.70
DZ-10-2	1.72	CADU 54	1.92	H-54-10	1.69
CADU 54	1.68	DZ-10-11	1.82	NC-NO 9	1.67
Dubie	1.60	41B	1.83	DZ-10-2	1.56
H-54-10	1.59	DZ-10-2	1.80	CN 17	1.39

During the early 1980s, the materials introduced from ICRISAT such as JG-62 × Rhady and K850-3/27 × F 378 (Table 15) did well. These two genotypes were recommended for release during the 1984/85 season. Cultivar K850-3/27 × F378 is now known as Mariye (my honey) and is most popular, particularly for green seed. JG-62 × Rhady was rejected since it was found to be susceptible to Fusarium wilt. Since then, although many lines have performed well (Table 16), no cultivar has been released. This was a lag period due to change in the leadership of the program that affected the continuity and stability of the varietal development process.

Table 15. Mean seed yield of promising chickpea genotypes identified in Ethiopian National Yield Trials, 1980-85.

Genotype	Seed yield (t/ha)	
	Range	Mean
JG 62 × Radhy	1.47-3.06	2.10
NEL-756	1.71-3.30	2.09
NEL-979	1.49-3.28	2.08
Annigeri	1.54-2.50	1.91
850-3/27 × F378	1.02-2.69	1.98
H-54-10 (Local)	1.22-2.77	1.86

Source: Seme *et al.* 1987.

Table 16. Mean seed yield of some high-yielding chickpea genotypes in Ethiopia, 1986-89.

Genotype	Seed yield (t/ha)	
	Range	Mean
7-D-A	2.11-3.32	2.51
ICC-6800	1.44-1.80	1.66
ICCL-82326	1.79-3.33	2.53
ICCL-82307	1.56-2.46	1.93
ICCL-82303	1.64-2.53	2.09

Released Cultivars

Many chickpea lines were evaluated, multiplied and distributed to farmers by the DZARC. Most of these lines were collections from farmers' fields in Yerer-Keryu *awraja*. Those released late, continued into production and registered are given in Table 17. But, before formal registration of released cultivars, DZARC distributed seeds of DZ-10-2, DZ-10-11, H-54-10, DZ-10-1 (large-seeded kabuli) and others. Among the old cultivars, DZ-10-4, DZ-10-1, DZ-10-11 and Dubie are still tolerant to Fusarium wilt but were not tested for specific pathogens to determine their reactions to the root rot diseases. Although Mariye and others do well, with the new private farming system, the demand for kabuli-type chickpea will remain unsatisfied unless new lines are released soon. The most recent official release (DZ-10-16-2) was in early 1994.

Promising Lines

The National Chickpea Improvement Program made tremendous progress in cultivar releases during the period 1990/91 to 1993. About four desi and three kabuli-type chickpea lines have revealed good performance (Table 18). Of these, ICCL-820104/85 (DZ-10-16-2) was recommended for release in 1993 and has been planted on 10 × 10 m land along with local checks and standard cultivar Mariye at seven locations and was evaluated and approved for release early in 1994 by the National Variety Release Committee. The program also is assembling the supporting data to recommend one of the kabuli lines in the coming season. FLIP 84-112C and ICC-3141 are good candidates for release and have been advanced to NYT because of their yield stability, resistance/tolerance to wilt/root rots complex and good seed size.

Table 17. Chickpea cultivars released in Ethiopia.

Cultivar	Origin	Year released	Adaptation (m asl)	Seed rate (kg/ha)	Planting date	Plant ht. (cm)	Days to maturity	Yield (t/ha)	Distinguishing features
DZ-10-4	Ethiopia	Before 1974	1800-2300	65-70	Late Aug - early Sept	23-36	100-120	0.8-2.0	White flowered; small; kabuli; semiprostrate; 100-seed wt=10-13 g
Dubie	Ethiopia	1978	1800-2300	80-90	Late Aug - early Sept	40-57	100-130	0.8-2.4	Desi; semiprostrate; light brown; 100-seed wt=13-22 g; moderately susceptible to soil-borne diseases
JG-62 × Radhy	ICRISAT	1985	1800-2300	70-80	Late Aug - early Sept	30-36	110-140	1.9-3.0	Desi; medium, shriveled brown seed; 100-seed wt=14-20 g; semiprostrate; tolerant to soil-borne diseases
850-3/27 × F378	ICRISAT	1985	1800-2300	80-100	Late Aug	28-36	140-150	1.5-2.6	Desi; large, smooth, brown seeds; 100-seed wt=22-30 g; high, semiprostrate with relatively large leaves; tolerant to wilt diseases.
DZ-10-16-2 (ICCL-820104/85-DZ116-2)	ICRISAT	1994	1800-2300	80-100	Late Aug	28-37	91-140	1.7-2.8	Desi; large seed; 100-seed wt=18-28 g

Table 18. Mean yields of promising chickpea genotypes in National Yield Trials in Ethiopia, 1990/91-1992/93.

Cultivar	Seed yield (t/ha) Range	Seed yield (t/ha) Mean
Desi		
IC-7958/83-DZ/1-1	2.02 - 3.24	2.48
ICCL-85225	2.28 - 3.04	2.55
ICCL-84229	2.04 - 3.08	2.41
ICCL-820104/85-DZ/16-2†	2.11 - 3.10	2.50
Mariye (check)	1.86 - 3.21	2.38
Local check	1.85 - 2.58	2.18
Kabuli		
ICC-13891	1.301 - 2.830	1.752
ICC-14808	1.401 - 2.738	1.934
ICC-13886	1.567 - 2.679	1.996
DZ-10-4 (check)	1.216 - 2.095	1.708

† Proposed for release.

Breeding for Resistance to Stresses

Chickpea production is affected by several abiotic and biotic factors of which the following are the major ones.

Abiotic Stress

Drought

It is the most important abiotic factor affecting chickpea production in Ethiopia. Its effects are aggravated by late sowing of the crop which increases severity of the terminal drought that causes soil cracking and consequent root pruning. Land preparation is generally made after the cessation of rains and seeding is done on drying seedbeds with relatively high air temperatures resulting in suboptimal soil moisture conditions for seed germination. This in turn results in poor plant stands.

Geletu and Abebe (1982) provided evidence that advancing sowing time from September to late August increased seed yield by more than 50% because of partial alleviation of drought effects. However, since advancing chickpea sowing in Ethiopia coincides with high rainfall (950-1500 mm), August sowing involved risk of heavy waterlogging on Vertisols (Tamire 1987). Hence, screening for drought tolerance/resistance was started in 1991 at Alem Tena (new dry site) and some progress has been made to date.

According to Geletu *et al.* (1992b), Geletu (1993) and Geletu and Yadeta (1993, 1994), over 200 accessions were evaluated and some promising lines have been already identified. Their report on drought response index (DRI) for seed yield revealed that ICCL-89316 and ICC-14156 were resistant to drought whereas lines such as ILC-2325 and ICCL-89243 were highly susceptible (Table 19). Cultivar Mariye, released for early sowing, showed high susceptibility for biological yield. Root mass also had significant positive correlations with shoot mass (r=0.60, P=0.01) and days to flowering (r=0.64, P=0.01), suggesting that selection for heavier root weight might result in the development of a vigorous plant that flowers slowly in the dry environment (Geletu 1993). According to Geletu and Yadeta (1993, 1994) seed yield in a stressed environment showed significant positive association (r=0.54, P=0.01) with root length, indicating that the lines with fast-growing and long roots might have an advantage in dry conditions. When seed yields in stressed and nonstressed environments were correlated with other characters, there was no significant association of seed yield with these characters in stressed environments. But, in nonstressed environments, seed yield had a significant positive relationship with biological yield, and a significant negative correlation with harvest index.

Frost

Frost does not frequently occur in the chickpea-growing regions of Ethiopia, but if it occurs in October/November when the crop is at flowering/podding stage, it causes complete crop loss. Chickpea grown in the highlands at Chefe Donsa (2450 m asl) produced very high seed yield due to long growing season. Development of lines tolerant to frost will definitely ensure chickpea production in such long growing environments. Efforts will be made to introduce ICARDA's cold-tolerant materials as the program gets stronger in trained manpower and facilities.

Table 19. Drought response index (DRI) for seed and biological yields of chickpea genotypes in Ethiopia.

Entry	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-12337 × ICC-1069/ L-NO-132-1 × ICCL-85216	-0.990	0.412
ICCL-84215	0.177	-1.454*

* = Significant at 5% probability level.

Waterlogging

August planting increased seed yield significantly (Geletu and Abebe 1982). However, when rainfall is high, waterlogging causes crop failure. Several chickpea accessions were planted in 1994 during the main season and off-season (irrigated crop) to screen for tolerance to waterlogging. The results are not yet ready to include in this paper. Planting on broad bed and furrow (BBF) or ridges will avoid waterlogging, as reported in studies on planting methods.

Biotic Stresses

Soil-borne diseases

The major chickpea diseases are wilt and root rots caused by *Fusarium oxysporum*, *Sclerotium rolfsii*, *Rhizoctonia bataticola* and *Rhizoctonia solani* (Alemu 1978; Geletu 1980, 1990; Beniwal *et al.* 1992). Stunt virus caused by Pea Leaf Roll Virus also has been reported. In 1993, observations were collected on all chickpea lines planted in different trials at DZARC to assess the incidence of stunt and identify lines with less virus infection. Development of cultivars with resistance to wilt/root rot diseases and stunt virus is an important objective of the chickpea improvement program. Details of studies on screening for disease resistance are presented in the chapter on pathology in this volume.

The situation of Ascochyta blight was also reviewed by Geletu (1981). Since the disease was only important in the research centers because of early sowing, it received no further attention except ensuring that it did not spread to farmers' fields nearby. Regarding wilt and root rot diseases, the relative importance of different pathogens in descending order is: *Fusarium* spp., *R. bataticola, S. rolfsii* and *R. solani* (Beniwal *et al.* 1992). Similar reports showed that *R. bataticola* was important in the northwest Gojam region of Ethiopia with 20-25% dry root rot incidence. Many sources of resistance to diseases are now available. Rust also appears on chickpea in some years but is not important so far. Details of the disease work are reported elsewhere in this volume.

Insects

The podborer (*Helicoverpa* sp.) is the most important insect on chickpea (van Rheenen *et al.* 1991) and causes more than 80% pod damage on early sown chickpea in Ethiopia (Geletu 1993). Screening for tolerance to this insect was done during the early 1980s, but no success was achieved because of the sporadic nature of insect occurrence. Bruchids are major storage insect pests but received little attention. Detailed work on control of these insects is also presented elsewhere in this volume.

Weeds

Weeds are not a major problem in chickpea as it is planted during low soil moisture followed by the dry season, which does not favor most weed species. Hand-weeding is generally practised in Ethiopia. Weeds are important in chickpea planted in August. Weed control studies are summarized elsewhere in this volume.

Future Prospects

The demand for chickpea is high and will continue to be because animal products are becoming more expensive, beyond the reach of many Ethiopians. It is also an important crop in the farming systems as a whole and particularly in rotation with tef and wheat on the heavy clay soils. This makes it indispensable because of its potential to grow on the residual moisture as logged water recedes. It plays a major role in improving and maintaining soil fertility as fertilizers are becoming expensive and unaffordable by many subsistence farmers. This crop can be pushed up to the highlands by selecting for frost tolerance and it can be introduced to the nontraditional lowland areas by advancing sowing date from September to July, as has been already observed at Alem Tena Research Site. Of course, this may invite Ascochyta leaf blight of which the breeding program should be aware and start to look for resistance sources.

A complementary approach would be to develop cultivars with drought tolerance to avoid terminal drought. The recent emphasis on release of new cultivars with resistance/tolerance to abiotic and biotic stresses should continue to provide improved cultivars adapted to different agroecological conditions. The utilization of indigenous landraces and exotic germplasm in the breeding program as sources of genetic variability should continue.

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Discussion

Ato Kiffer
Chickpea is said to be responsive to drainage. Is there any on-farm work to support this?

Dr Geletu
Drainage is important in chickpea planting. Undrained soil is heavy for oxen when pulling the plow and ridging is being used by farmers.

Genetics and Breeding Research in Lentil

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Abstract

The National Lentil Improvement Program was started in 1972. Prior to that, the Debre Zeit Agricultural Research Center had collected lentils from farmers' fields and markets and made some evaluations. Since 1972, efforts have been made to identify high-yielding and stable genotypes through diagnostic surveys to determine production constraints for lentil in Ethiopia and a breeding program to identify adapted genotypes for different growing environments. Major diseases of lentil were known and rust, being the most severe, had first priority in research. Among insect pests of lentil, aphids were considered to be most important. Thus, screening for resistance to rust disease and aphids received more attention. Breeding for tolerance to drought and waterlogging has been initiated. Selection for frost tolerance was considered, but this required development of efficient screening techniques. Some genetic information was generated for use in the cultivar development program. This paper reviews all the achievements made and indicates the major areas of future research. The breeding program emphasizes adaptation to specific environments and the identification of stable genotypes for wider adaptation. Serious attention will be given to resistance breeding with major emphasis on rusts, wilt/root rots, drought and waterlogging. The program will be actively involved in the Nile Valley Network activities and in the WANA region via ICARDA's regional programs.

Introduction

Lentil (*Lens culinaris* Medik.) is an important cool season food legume in Ethiopia. It is almost a cash crop because it fetches very high prices compared with all other food legumes and main cereal crops such as tef, wheat and barley.

The Ethiopian lentils belong to the *macrosperma* race, known as *G. aethiopicae*, characterized by 1-2 blue or violet flowers on each peduncle, calyx teeth much shorter than corolla, leaves with 3-7 pairs of elongated leaflets and fruits with a typical elongated apex (Barulina 1930; Muehlbauer *et al.* 1985). The seeds are black or brownish with black spots.

Quantitative Genetics

As sufficient information on the genetics of lentil is available in the literature, the Ethiopian lentil program aimed at having generating information for the improvement of different desirable characters. However, some studies were made in heritability, correlations, path analysis and stability.

Heritability

This study was conducted by Seifu (1988) during 1986/87 at two locations, Akaki and Debre Zeit Agricultural Research Center (DZARC). The results showed that days to 50% flowering and 100-seed weight had high heritability in both environments (Table 1). The number of seeds/pod also had consistently high heritability. Primary branch showed moderate heritability (67% and 63%) while characters such as number of pods/plant, plant height and number of secondary branches had inconsistent heritability (Table 1). This inconsistency reveals that number of pods/plant, plant height and number of secondary branches were highly influenced by the environment they were grown in. The number of days to 50% flowering and number of pods/plant had the highest genetic advance at Akaki and Debre Zeit (Table 1).

Table 1. Heritability in broad sense (H^2b), genetic advance (GA) and genetic advance as percent of the mean of lentil characters studied at Akaki and Debre Zeit, Ethiopia during the 1986/87 crop season.

	H^2b (%)		GA		GA as % of trait mean	
Character	Akaki	Debre Zeit	Akaki	Debre Zeit	Akaki	Debre Zeit
Primary branches	67	63	0.17	0.18	7.9	8.2
Secondary branches	43	67	0.59	1.35	10.8	18.2
Days to flowering	98	99	26.3	27.2	47.2	45.5
Plant height (cm)	68	86	3.04	5.42	11.6	17.2
Pods/plant	67	85	7.69	18.08	28.2	30.2
Seeds/pod	81	80	0.27	0.26	18.5	19.7
100-seed weight (g)	92	95	1.02	1.00	41.3	45.4
Seed yield/plant (g)	76	85	0.34	0.55	37.0	56.7

Source: Seifu 1988.

Correlation

Simple correlation studies were carried out at Akaki and Debre Zeit by Seifu (1988) using 27 genotypes to determine the associations between grain yield and other yield components. His report showed that number of pods/plant had highly significant correlation (r=0.71, P=0.01) with grain yield at Akaki and at Debre Zeit (r=0.85, P=0.01), while the remaining characters had no significant association with it (Table 2). Seifu (1988) also found that number of secondary branches had significant and positive associations (r=0.46, P=0.05) with the number of pods/plant. A similar report showed that number of seeds/pod had significant and negative associations (r=-0.46 and -0.53, P=0.05) with number of days to 50% flowering at both locations. This suggests that the early flowering lines will have more seeds/pod than the late-flowering lines of lentil. Number of seeds/pod showed significant and negative association (r=-0.51, P=0.05) with 100-seed weight at Akaki (Table 2).

Path Analysis

A study was carried out at Akaki and Debre Zeit by Seifu (1988) to determine the direct and indirect effects of some characters on seed yield. The major direct contributors to seed yield were number of pods/plant (71 and 92%) and 100-seed weight (32 and 42%) at Akaki and Debre Zeit, respectively (Table 3). Characters such as days to 50% flowering, number of primary and secondary branches had negative direct effects at both locations. The major indirect contributor was the number of secondary branches via number of pods/plant (Table 3). Plant height and number of seeds/plant also had relatively high indirect contributions to seed yield via number of pods/plant (Table 3) while number of primary branches and 100-seed weight had negative indirect contributions to seed yield via number of pods/plant.

Stability

Ten late-set genotypes of lentil were tested in the highlands of Ethiopia during the 1981-84 main seasons. Stability of these lines was studied over 44 environments. The results indicated that cultivar NEL-358 (Chalew) responded to the good environments where rainfall is not a limiting factor (Table 4). Line NEL-357 was a stable and high yielder since it had a regression value near unity (b=1.04) and the lowest deviation mean square. Ethiopian lentil EL-142 was found to be resistant to changing environment (Table 4). Most of the lines such as NEL-358, NEL-355, NEL-357 and NEL-256, which originated from Mexico, performed well in the Ethiopian highlands, whereas EL-142 was one of the best lines that did well in environments with low moisture stress.

Table 2. Phenotypic correlation coefficients (r) among various characters of 27 lentil genotypes studied at Akaki and Debre Zeit, Ethipia during the 1986/87 crop season.

Character	Plant height	Primary branches	Secondary branches	Pods/ plant	Seeds/ pod	100-seed weight	Grain yield/ plant
Akaki							
Days to flowering	-0.25	0.17	-0.16	-0.46	0.46*	-0.39	0.36
Plant height (cm)	.	-0.02	0.06	0.21	0.26	-0.06	0.15
Primary branches	.	.	0.17	0.10	-0.12	0.09	-0.10
Secondary branches	.	.	.	0.46*	0.26	-0.23	0.26
Pods/plant	.	.	.	.	0.21	-0.13	0.71**
Seeds/pod	.	.	.	.	.	-0.31*	0.13
100-seed weight (g)	.	.	.	.	.	.	0.14
Debre Zeit							
Days to flowering	-0.25	0.23	-0.48*	-0.43	-0.53*	0.40	-0.31
Plant height (cm)	.	-0.30	0.16	0.20	0.21	-0.33	0.11
Primary branches	.	.	0.31	-0.23	-0.27	0.90	0.26
Secondary branches	.	.	.	0.48*	0.17	-0.18	0.28
Pods/plant	.	.	.	.	0.24	-0.18	0.85**
Seeds/pod	.	.	.	.	.	-0.45	0.27
100-seed weight (g)	.	.	.	.	.	.	0.15

*, ** Significant at 5% and 1% probability level, respectively.
Source: Seifu 1988.

Table 3. Direct (bold) and indirect (light) effects† on lentil grain yield as revealed by path coefficient analysis at Akaki and Debre Zeit, 1986/87 crop season.

	Character							
Character	1	2	3	4	5	6	7	Correlation‡
Akaki								
Days to flowering	**-0.120**	0.009	-0.014	0.004	-0.325	-0.041	0.125	-0.362
Plant height (cm)	0.030	**-0.034**	0.002	-0.002	0.146	0.023	-0.018	0.144
Primary branches	-0.020	0.001	**-0.079**	-0.004	0.071	-0.011	0.029	0.014
Secondary branches	0.019	-0.002	-0.014	**-0.025**	0.327	0.023	-0.073	0.256
Pods/plant	0.055	-0.007	-0.008	0.011	**0.705**	0.019	-0.041	0.712
Seeds/pod	0.055	-0.009	0.010	-0.006	0.149	**0.089**	-0.162	0.126
100-seed weight (g)	-0.047	-0.002	0.007	0.006	0.090	-0.045	**0.320**	0.138
Debre Zeit								
Days to flowering	**-0.022**	-0.022	-0.015	0.073	-0.391	-0.119	0.167	-0.311
Plant height (cm)	0.006	**0.020**	0.019	-0.024	0.182	0.047	0.135	0.114
Primary branches	-0.005	-0.006	**-0.063**	0.048	-0.207	-0.060	0.038	0.255
Secondary branches	0.010	-0.003	0.019	**0.157**	0.443	0.037	-0.074	0.282
Pods/plant	0.009	0.004	0.014	-0.076	**0.918**	0.054	-0.077	0.848
Seeds/pod	0.012	0.004	0.017	-0.026	0.222	**0.122**	-0.188	0.265
100-seed weight (g)	-0.009	-0.007	-0.006	-0.028	-0.169	-0.101	**0.416**	0.154

† Indirect effects through other characters.

‡ Correlation with seed yield.

Table 4. Mean yields and estimates of stability parameters for 10 late-set lentil cultivars over 44 environments in Ethiopia, 1981-84.

Entry	Yield (t/ha)	Regression coeff. (b)	Deviation mean square (S2di)
NEL-358	1.25	1.26	16896**
NEL-355	1.20	1.10	61120**
NEL-357	1.15	1.04	27558*
NEL-256	1.08	1.10	33962**
R-186	1.07	1.00	61660**
R-184	0.986	1.00	36776**
NEL-944	0.92	0.86	64174**
EL-142	0.92	0.36	84384**
R-59	0.77	1.13	200209**
R-252	0.63	1.10	140622**

Mean = 0.99; *, ** = Significant at 5% and 1% probability level, respectively.
Source: DZARC 1991.

Early set lentil genotypes were grown in the lowland areas of Ethiopia during 1981-83. Stability analysis was done over nine environments. The Ethiopian lentils were more stable and high yielders than the introduced lines in low moisture stress environments (DZARC 1991). Among these entries, EL-50 and EL-142 were more stable as these lines had regression values of unity (1.00) and less deviation mean square (Table 5).

Breeding

Breeding Strategy

Geletu *et al.* (unpublished) made a preliminary study of lentil adaptation to develop breeding strategies for lowlands, midaltitudes and highlands of Ethiopia. A total of 156 indigenous landraces of lentil collected from different agroecological zones were grown at three locations — Chefe Donsa (2450 m asl), Debre Zeit (1900 m) and Alem Tena (1600 m) — representing highlands, midaltitudes and lowlands, respectively.

Table 5. Mean yield and regression coefficients for early lentil genotypes over nine environments in Ethiopia, 1981-83.

Genotype	Mean yield (t/ha)	Regression coeff. (b)	Deviation mean square (S^2 di)
EL-59	1220	1.18	21491
EL-50	1150	1.06	2598
EL-142	1146	1.00	4077
EL-103	1125	0.95	8660
Lasta Lalibela	1065	1.10	24376
EL-122	1051	1.01	11594
EL-74	985	0.97	4628
NEL-355	973	1.10	434267
NEL-1068	822	0.64	12370

Population mean = 1060.
Source: DZARC 1991.

The results for seed yield showed similar adaptation to the conditions at Alem Tena and Debre Zeit, suggesting that selection may be effectively done in either environment with the expectation of a response to selection at the other site. Selection at Alem Tena and Debre Zeit was found to be ineffective in the highlands (Chefe Donsa) and vice versa. The conclusion was that performance under highland conditions differed from that at midaltitude and lowland conditions. Hence two separate breeding programs were proposed, one aiming at the highlands and the other for midaltitudes and the lowlands.

Germplasm Utilization

The National Lentil Improvement Program evaluated all local germplasm collections for different characters in collaboration with the Ethiopian Plant Genetic Resources Center (PGRC/E). Several accessions designated as PGRC- and ACC- were identified as resistant to rust, tolerant to drought (low moisture stress) and early maturing. Among these PGRC-7 is the most resistant line to rust, and is usually observed without any trace of rust postule (immune). Another set of 160 germplasm collections was recently evaluated at Alem Tena, Debre Zeit and Chefe Donsa. Cultivars EL-142 (early) and NEL-358 (medium) were included as checks. Observations were recorded on nine characters. The mean yield of the germplasm was very high (3.52 t/ha) at Chefe Donsa and low at Debre Zeit due to heavy lodging at podding stage (ICARDA/IAR 1993.) At Chefe Donsa, the maximum seed yield recorded was 5.18 t/ha which indicated the high yield potential of lentil that can be exploited under good management. A high coefficient of variation was recorded for grain yield, biomass, number of pods/plant and number of seeds/pod at Alem Tena and Debre Zeit, and it was high for the number of pods, primary branches and secondary branches/plant at Chefe Donsa (Table 6). In addition, about 4000 accessions and segregating populations were introduced from ICARDA (Table 7) and were evaluated in different agroecological zones for adaptation and desirable traits.

Table 6. Mean values and coefficient of variation for 160 lentil germplasm accessions grown at Alem Tena (AT), Debre Zeit (DZ) and Chefe Donsa (CD), Ethiopia, 1991/92.

	Mean values/locations			CV(%)		
Variable	AT	DZ	CD	AT	DZ	CD
Days to 50% flowering	47	49	54	6.1	5.3	5.4
Days to maturity	82	93	112	3.6	3.3	8.2
Biological yield (t/ha)	2.97	2.0	1.26	45.8	18.4	20.8
Primary branches	2.1	2.06	1.7	16.6	34.3	28.6
Pods/plant	24.5	28.0	53.5	30.2	41.7	35.4
Seeds/pod	1.6	1.4	1.6	21.3	20.2	9.4
Plant height (cm)	33.8	31.8	32.0	13.0	12.8	9.6
100-seed weight (g)	2.1	2.5	3.2	16.2	11.4	8.1
Seed yield (t/ha)	0.67	0.61	3.52	47.1	42.1	22.8

Table 7. Number of exotic entries introduced from ICARDA and evaluated by the national program.

Year	No. of entries	Type of entry
1977-82	1800	Germplasm
1983	238	Stable lines
1984	188	Stable lines
1985	143	Stable lines
1986	252	Stable lines
1987	311	Stable lines/segregating populations
1988	248	Stable lines
1989	294	Stable lines/segregating populations
1990	156	Stable lines
1991	66	Stable lines/segregating populations
1993	129	Stable lines/segregating populations
Total	3825	

Source: Seifu *et al.* 1991.

Varietal Development

Many indigenous landraces and introductions of lentil were evaluated in Ethiopia for their adaptation, stable high yield, resistance to diseases and insect pests. Ethiopia used to export lentil seeds to many countries. Hence, interest was also centered on those strains with large seed size. Three hundred and twenty accessions of green seed-coat lentil were obtained from the USDA Germplasm Laboratory and evaluated at Debre Zeit during the 1972/73 season. The highest yields were obtained from the Ethiopian small brown-black and the large-seed, green seed-coat selections from DZARC. Since sowing was done on 29 June and 4 August, the large-seeded type was favored by early planting while the Ethiopian small-seeded lines did better at the August planting (Table 8).

Table 8. Yields of lentils of two seed types planted at two dates and variable seed rates, 1972/73.

Seed type†	Source	Seed rate (kg/ha)	Yield (t/ha)	
			29 June	4 Aug
Large, green	DZARC	20	1.19	0.47
		40	1.48	0.60
Large, green	Italy import	20		0.21
		20		0.61
Large, green	Jack Rabbit	20	0.83	0.36
		40	0.80	0.60
Ethiopian small brown-black	Debre Zeit	20	0.04	1.56
	Market	40	0.16	1.55
		60	0.08	1.50

† Large, green = 50-60 g/1000 seeds; Ethiopian small = 25-30 g/1000 seeds.
Source: DZARC 1972-73.

During 1973/74 about 133 green seed-coat lentils (large seed size), mostly from the USDA world collection, were evaluated at Debre Zeit. These lentil accessions, in marked contrast to the Ethiopian type, were not infected with rust, although root rot was quite severe (DZARC 1973/74). Similar results showed that lines with the desired large seeds were lower in yield than strains with smaller seeds (Table 8). A total of 330 green seed-coat lentils also were evaluated by the Institute of Agricultural Research (IAR) during the 1974 season. The report showed that the available exotic (large-seeded type) lentils were of lower yield potential than the small brown or black seed-coat type under Ethiopian conditions (IAR 1976). This report indicated that there was an inverse relationships between seed size and seed yield (Table 9). A recommendation was made to determine the most suitable planting date at different locations where the crop has potential. Since then, several lentil international screening nurseries, segregating populations and yield trials of the large-seeded types have been introduced from ICARDA and screened in Ethiopia.

Table 9. Relationship between seed size and yield in green seed-coat lentil in 1973 trial.

Seed size (g/1000 seeds)	No. of entries	Seed yield (t/ha)	
		Mean	Highest
Debre Zeit			
<40	46	4.6	1.24
41-50	15	3.0	0.60
>50	61	2.4	0.64
Nazret			
<40	13	8.0	1.08
41-50	6	5.5	0.75
>50	6	5.3	0.66

Source: DZARC 1972-73; IAR 1976.

Several selections were screened for rust resistance and high yield. Lines FLIP 84-78L and FLIP 84-74L (large-seeded) were selected as the result of the efforts made to identify large-seeded entries adaptable to the Ethiopian conditions. Selection FLIP 84-78L has been recommended for release for the highlands of Ethiopia (> 1900 m) to be grown on black soils since it has a long growing duration.

During the initial stages of the lentil improvement program, market samples and collections from farmers' fields were evaluated for yield. Variability among small-seeded, brown-black seed-coat landraces of Ethiopia was high. According to DZARC (1973-74) the Ethiopian lentil had excellent vegetative growth and development up to flowering stages; however, the plants then became infected with rust. This report revealed that among 56 market samples grown, no landrace showed resistance to rust disease, although there were some variations in severity of rust infection. Another set of Ethiopian landraces, consisting of 26 lines collected prior to 1973, were evaluated in 1973/74 at Debre Zeit and all were severely damaged by rust, suggesting that rust is the major disease problem affecting lentil production in Ethiopia. Among the Ethiopian lentils tested during the 1975/76 season, EL-122 gave the highest yield of 2.16 t/ha, followed by EL-136 (1.99 t/ha), EL-84 (1.99 t/ha), EL-97 (1.92 t/ha), EL-103 (1.85 t/ha) and EL-142 (1.75 t/ha) (DZARC 1975-76). Through continuous selection and promotion of the lines with desirable characters, stable, high-yielding and rust resistant lentil genotypes have been selected and released.

Released Cultivars

The highly variable agroclimatic conditions in Ethiopia pose difficulties in identifying genotypes with wider adaptation that perform well throughout the lentil growing areas. In the highlands where the growing season is long, the late-maturing genotypes usually have an advantage over the early maturing lines. Similarly, the early maturing lentil do well in the lowland areas where there is low moisture stress; these lines escape the terminal drought that affects the crop at flowering and grain filling stages. Based on requirements of different regions, the National Lentil Improvement Program developed two separate sets of lentil materials (early and late sets). Following this approach many late-set lentil cultivars were tested at several locations in the highland areas (Geletu 1984) while the early set cultivars were tested at the locations representing lowlands. The lines with very good performance in these regions were identified and released (Table 10). Besides this, in 1994 new cultivars were identified and recommended for release: FLIP 84-78L, large-seeded and recommended for the highland areas, and NEL-2704 (early) for the lowlands to replace or be grown along with others to diversify and avoid the risk of relying on a single cultivar. These have been evaluated by the National Seed Release Committee (NSRC) and NEL-2704 was officially released for the lowlands while FLIP-84-78L will be re-evaluated in the 1994 season. The characteristics of these cultivars are given in Table 11.

Table 10. Lentil cultivars released in Ethiopia.

Cultivar	Origin	Year of release	Area of adaptation (m asl)	Seed yield (t/ha)	Seeding rate (t/ha)	Sowing date	Days to maturity	Reaction to rust	Distinguishing features
EL-142	Ethiopia	1980	1650-2200	0.8-1.5	50-60	Early to late July	75-122	Tolerant	Small seeded with 100 seed weight of 2.0-2.5 g; light brown; dark grey semiprostrate plant type with pale white flowers and thin leaves
R-186	Mexico	1980	1800-2450	0.6-1.8	50-60	Mid-July to early Aug.	100-170	Resistant	Light greenish medium sized seeds with 100-seed weight of 2.2-3.0 g; semierect plant type with relatively broad and large leaves
NEL-358	Mexico	1984	1850-2450	1.0-2.3	60-80	Mid-July to early Aug.	97-158	Tolerant	Medium sized seed (Chalew), 100-seed weight of 2.6-3.0 g; yellow to red in color; deep green semiprostrate plant type with white flowers and relatively broad leaves
NEL-2704		1994	1600-2000	0.95-1.75	65-75	Early to late July	94-113	Resistant	Small seeded with 100-seed weight of 1.9-2.3 g; plant height of 35-49 cm; 46-59 days to flower

Source: Million and Beniwal 1988.

Table 11. Mean seed yield and some agronomic characters of two promising lentil genotypes recommended for release in 1993/94.

Character	FLIP-84-78L	NEL-2704†
Seed yield (t/ha)	0.93-2.69	0.95-1.75
Days to 50% flowering	49-65	46-59
Days to maturity	98-141	94-113
Plant height (cm)	29.0-50.3	35.3-49.4
100-seed weight (g)	4.0-5.8	1.9-2.3
Area of adaptation (m asl)	≥1900	1600-2000
Recommended seeding rate (kg/ha)	120-140	65-75

† Released in 1994.

Generally, the National Lentil Improvement Program was very active during 1977/78-1984/85 and identified many genotypes that could be used either as commercial cultivars or parents in the crossing block to improve certain characters such as resistance to rust, seed size and color (Geletu 1984). The mean seed yields of these lines are given in Table 12. Slow progress during the period 1985/86 to 1990/91 was due to the change in program leadership. Although no cultivar was released during this period (1985/86-1990/91), some entries such as Precoz, NEL-256 and 76TA 66116 did very well in the late lentil set (Table 13). Precoz also did best in the early set and was followed by the Ethiopian lentil EL-59 (Table 14). Precoz had wider adaptation and did well over the varying environments (Tables 13 and 14). Since the 1990/91 main season the National Lentil Improvement Program has gained momentum and accelerated the identification or development of cultivars which resulted in the recommendation of FLIP 84-78L and NEL-2704 (Table 11). In addition to these lines, some genotypes have shown good performance from both late and early sets (Table 15). Since 1991/92, the program has been actively involved in the development of lentil germplasm resistant/tolerant to drought, waterlogging and frost, the research areas that have not been tackled. As a whole, tremendous progress has been made in identifing sources of resistance to rust while efforts are being made to develop efficient sick-plots to screen for resistance to wilt/root rot diseases.

Table 12. Mean seed yields of outstanding lentil genotypes over four crop seasons, 1981/82-1984/85.

Genotype	Yield (t/ha)				
	1981/82	1982/83	1983/84	1984/85	Mean
R-59	0.83	1.38	0.72	-	0.98
R-184	-	1.38	1.01	0.98	1.24
R-186	0.82	1.50	1.12	0.99	1.16
EL-142	0.60	1.58	0.96	1.21	1.02
NEL-358	1.05	1.72	1.02	1.26	1.14
NEL-355	1.20	1.78	1.12	1.09	1.30
NEL-256	1.02	1.37	0.87	1.13	1.10
NEL-357	1.07	1.39	0.98	1.10	1.13
Local check	0.20	1.65	0.62	1.09	0.79
Growing locations (N=)	3	4	5	7	

Source: Million and Beniwal 1988.

Table 13. Mean yield of promising lentil genotypes in different locations, Ethiopia, 1987/88.

Genotype	Seed yield (t/ha) per location				
	Debre Zeit	Akaki	Ginchi	Robe	Mean
Precoz	1.83	1.54	0.49	3.53	1.85
NEL-256	0.98	2.51	0.60	2.94	1.76
76TA 66116	1.47	2.37	0.60	2.34	1.69
74TA 440	0.87	2.39	0.47	2.72	1.67
NEL-357	0.87	2.39	0.47	2.72	1.61
NEL-358	0.84	2.27	0.45	2.51	1.52
Local check	1.18	0.44	0.27	2.43	1.08
Mean	1.15	1.99	0.48	2.74	
SE±	0.14	0.28	0.42	0.15	

Table 14. Yield of some early maturing lentil genotypes cultivars grown at three locations in Ethiopia, 1987/88.

Entry	Seed yield (t/ha)			
	Debre Zeit	Koka	Arsi Negele	Mean
Precoz	1.52	1.00	0.99	1.17
EL-59	1.71	0.94	0.56	1.07
NEL-944	1.60	0.92	0.63	1.05
EL-142	1.57	0.78	0.59	0.98
EL-1O3	1.34	0.76	0.72	0.94
Local check	1.46	0.91	0.28	0.88
Mean (14 entries)	1.32	0.73	0.54	
SE±	0.16	0.14	0.66	
CV(%)	16	28	24	

Table 15. Mean seed yield and agronomic characters of promising late and early maturing lentil genotypes grown in four farmers' fields, 1992/93.

Genotype	Seed yield (t/ha)	Days to maturity	Plant height (cm)	100-seed weight (g)	Rust score†
Late maturing					
ELIP 87-74L	1.72	107-117	28-41	3.0-3.6	2
FLIP 84-78L	1.60	110-139	35-45	4.8-5.5	2
FLIP 84-112L	1.56	107-138	29-40	3.3-3.8	3
NEL-358	1.89	116-133	29-43	2.7-3.3	2
Local check	1.57	36-113	26-41	2.1-2.8	7
Early maturing					
NEL-3103	1.11	80-112	26-51	1.6-2.5	
NEL-944	1.11	80-105	35-56	1.9-2.9	
NEL-2704	1.32	79-113	35-56	1.6-2.4	
EL-142	1.11	80-107	32-55	1.8-2.4	
Local check	0.99	79-105	26-51	1.6-2.5	

† Score on a 1-9 scale, where 1 = highly resistant and 9 = highly susceptible.
Source: DZARC. Annual Research Report, 1992/93 (Unpublished).

Breeding for Resistance to Stresses

Abiotic Stresses

Drought

Variability of rainfall from year to year has been the major concern of Ethiopian farmers. The low moisture environments are unfavorable for the growth and development of rainfed crops and always result in low and unstable yields. Hence it is essential to screen several lines of lentil for their resistance/tolerance to drought to identify lines with better performance and adaptability to dry environments.

One hundred and fifty-six Ethiopian collections and other introductions were evaluated at Alem Tena (new dry site) during the 1991/92 cropping season. Some accessions were found to have a combination of desirable characters. Some of the lines which had large seed size and earliness are ACC-207265, ACC-211065, ACC-21887 and ACC-221719. Lines ACC-213091, ACC-215088, ACC-215384 and ACC-215708 were early and high yielders. Accessions which have a combination of earliness with large seed size and high yield potential with earliness are highly desirable. Geletu *et al.* (unpublished) reported a seed yield range of 1.25-1.90 t/ha for 10 accessions selected at Alem Tena (Table 16). All these accessions are Ethiopian landraces indicating that they have ability to escape drought. Fifty-four lentil lines which were identified as short and extra short duration during the 1991/92 season were replanted at Alem Tena in 1992/93. Only 10 accessions yielded the same or more than the standard check EL-142 (Table 17).

Table 16. The top ten high-yielding lines selected in the dry environment (Alem Tena) of Ethiopia.

Accession	Seed yield (t/ha)	Days to flowering	100-seed weight (g)
ACC-207306	1.90	49	2.0
ACC-207300	1.60	49	2.6
ACC-36136	1.50	48	2.1
ACC-216882	1.46	47	2.2
ACC-207258	1.35	49	2.9
ACC-223223	1.35	47	2.6
ACC-207902	1.35	47	2.4
ACC-36159	1.33	48	2.4
ACC-219229	1.26	48	2.0
ACC-212851	1.25	49	1.9
Mean	1.31	48	2.3

Table 17. High yielding and early lentil accessions selected under relatively dry conditions at Alem Tena, Ethiopia in 1992/93.

Entry	Seed yield (t/ha)
ACC-36112	1.14
ACC-207300	1.02
ACC-212851	0.96
ACC-207306	0.94
ACC-207305	0.91
ACC-36121	0.83
ACC-211112	0.72
ACC-215249	0.70
ACC-211091	0.70
ACC-215249	0.70
ACC-215707	0.69
ACC-207265	0.66
ACC-211096	0.66
ACC-36146	0.62
Standard check (EL-142)	0.70
Local check	0.46
Mean	0.78
SE±	0.21

Source: Geletu and Yadeta 1993.

Correlation analysis was made between seed yield and other characters to determine the traits that can be used as selection criteria in stressed environments. Seed yield had highly significant and positive associations with biological yield, plant height, 100-seed weight and harvest index (Table 18). This suggests that in a dry condition, selection for high biological yield and harvest index along with large seed size will help to identify high-yielding genotypes. However, since the program is at its initial stage, further investigation on characters responsible for drought tolerance is required.

Table 18. Simple correlation coefficients of seed yield and other characters of 54 lentil entries grown under low moisture-stressed conditions in Ethiopia.

Character	Seed yield
Days to 50% flowering	0.185
Days to maturity	0.161
Biological yield (g)	0.716**
Plant height (cm)	0.332**
100-seed weight (g)	0.398**
Harvest index (%)	0.645**

*, ** = Significant at 5% and 1%, respectively.

Waterlogging

Lentil is traditionally sown in late August-early September. However, July sowing proved to have a yield advantage over September sowing, provided that the crop is planted on well-drained heavy black soils. Geletu (1991) reported that in 1978 about 87% yield reduction was obtained in lentil planted on 27 August compared with 7 July. Similarly, over 90% yield reduction occurred when yields of August-planted lentil were compared with those of lentils sown in June-July in 1979 and 1980. These results suggest that early planting gives higher yields. But, when there is heavy rain on the black soils, 2-3 days waterlogging causes heavy damage and sometimes results in complete crop failure. Considering this as one of the major constraints to lentil production, a breeding program has been initiated and screening techniques for waterlogging are being developed. Over two hundred lentil accessions were sown during the 1993/94 main season at DZARC to screen for tolerance to waterlogging. However, since water distribution in the furrows was not uniform, results are inconclusive, and the same material was replanted under irrigation. The results were not ready for inclusion in this document.

Frost

Frost does not occur regularly every season, but when it does (usually in October-November, particularly in the highlands), all susceptible lines are completely killed. The Lentil Improvement Program has started to evaluate for tolerance to frost at Chefe Donsa (2450 masl) and Sheno (over 2500 masl). Screening techniques need to be developed to effectively evaluate and identify tolerant material. Cold-tolerant lentil accessions introduced from ICARDA will be screened at Chefe Donsa and Sheno.

Biotic Stresses

Rust

Rust is the most important disease of lentil in Ethiopia and causes heavy loss when it occurs before flowering/podding stages. When the disease is severe, susceptible lines such 87S-13549 and PGRC-1 can be killed. Realizing the importance of this disease on lentil, efforts concentrated on developing resistant lines that could be released as commercial cultivars (e.g., NEL-358) or used as parents in crossing blocks. Many exotic and indigenous landraces were evaluated during the main growing seasons. However, since it was difficult to get uniform disease severity every season, a systematic study was made to identify the appropriate techniques to screen for resistance to rust. Bernier *et al.* (1988) also suggested that exposure of plant material to the pathogen should be as uniform as possible to prevent any escape from infection.

Through repeated studies, the off-season planting (December-February) was found to be the most effective to screen for resistance to rust. Therefore, large numbers of introductions and new collections of landraces are sown in December-February every year. These are grown under irrigation to create the humidity that favors disease development. By doing so, more than 70 lines resistant (1-3 rating on a 1-9 scale) to rust were developed. Now, the National and Pre-National Yield Trials of late sets consist only of resistant lines. We tried to assess if there were differences between the rust diseases that occur during the off-season and main season but the reactions of all entries were the same in both seasons, suggesting that no race differences exist. However, for the lowlands of Ethiopia, it was not possible to identify rust resistant and early material. The characters earliness and rust resistance were found to be negatively associated. This inverse relationship requires further studies before attempting to break the linkage.

Soil-borne diseases

Fusarium wilt and root rots are the major diseases on lentil, mainly on the heavy black clay soils. These diseases cause up to 50% plant losses in some farmers' fields. Considering their importance, we started to develop the sick-plot at DZARC. The debris of dead plants is continuously incorporated into the soil. Susceptible lines are grown and underplowed to increase the uniformity of the pathogens in the soils. Isolates are also multiplied on boiled lentil seeds in the flask and are distributed over the sick-plot being developed.

Aphids

Aphids are economically important insect pests and can determine the fate of the crop. Farmers are now reluctant to grow lentil since the yield loss is extremely high due to aphids. Only those farmers near the extension agents can get aphicides to protect the crop. Even where aphicides are available, farmers may not be in a position to identify the appropriate time to spray. These aphids are partly responsible for reduction of lentil production areas in Ethiopia. A program on aphid resistance is being developed for lentil.

Future Areas of Research

The major factors that influence yields of lentil in Ethiopia have been identified and priorities have been set. Therefore, future work will focus on the following:

- Identify sources of resistance to Fusarium wilt and root rot diseases
- Identify drought tolerant/resistant cultivars so that the yield loss due to terminal drought will be alleviated
- Coordinate efforts to handle Ascochyta leaf blight disease, which is potentially dangerous to the crop
- Continue to screen for tolerance to waterlogging because waterlogging forces the farmers to plant lentil late in the season on the Vertisols
- Develop improved drainage methods to allow early sowing
- Evaluate for tolerance to frost in the frost-prone areas of the central highlands
- Direct researchers to work in specialized areas, e.g., breeding for disease resistance, drought resistance and for high and stable yield. Such a specialized approach will consolidate the efforts to produce promising results.

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Discussion

Kesrat Ali
In the breeding of chickpea and lentils, disease resistance is usually the main target. Resistance to insect damage is neglected. Why?

Dr Geletu
In the past, the absence of a senior staff in the field was the problem. Now since Dr Tibebu is back at Debre Zeit Station the research on insect damage will be started up again in full.

Genetics and Breeding of Grasspea

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Abstract

Grasspea ranked fifth in 1987/88 in total area among the food legumes of Ethiopia, with a mean production of 42 220 t of grain on 60 030 ha of land. Inappropriate agronomic practices, diseases and insect pests limit the yield of grasspea and thus its economic returns. The major restriction of grasspea production is a disorder called lathyrism in humans and domestic animals, brought about when the seeds are consumed in excess. The risk of lathyrism might be reduced if the β-N-oxalyl amino-L-alanine (BOAA) alkaloid content in grasspea seed is reduced. Research in 1992/93 identified lines from Canada and Ethiopian landraces with low BOAA content. Hybridization programs are underway with exotic lines from ICARDA and Canada. Screening for agronomic performance and transfer of the gene(s) responsible for low BOAA to the Ethiopian landraces are being done at Adet and Holetta Research Centers. The genetic improvement of grasspea has been continued since 1987 in Adet. The direction and scope of this program have to be defined in the future, but the development of cultivars with low BOAA content and with fairly good grain yields is the main objective to reduce and combat the menace of lathyrism.

Introduction

Grasspea (*Lathyrus sativus* L.) in Ethiopia is grown at altitudes ranging from 1700 to 2240 m asl, predominantly in areas having adverse agricultural conditions such as moisture stress and waterlogging. Grasspea ranked fifth in 1987/88 in total area among food legumes with a mean of 60 030 ha of land and 42 200 t of grain (Table 1). Inappropriate agronomic practices, diseases and insect pests limit the yield of grasspea and thus its economic returns.

Another restriction to grasspea production is a disorder called lathyrism in humans and domestic animals, brought about when the seeds are consumed in excess. This disorder prevails, especially when other food crops are scarce. It has been suggested that a mixture of *L. sativus* and seeds of *Vicia sativa* L., which occurs as a weed in the crop, aggravates the situation (Westphal 1974).

Table 1. Area and production of grasspea compared with small cereals and other food legumes in Ethiopia, 1987/88.

Crop	Area (1000 ha)	Production (1000 ha)	Yield (kg/ha)
Grasspea	60.03 (8.7)†	42.2 (7.6)	703 (9.8)
Pulses	686.16	557.97	714
Pulses and cereals	5,611.5 (1.07)*‡	6,444.6 (0.65)*‡	952 (7.4)*‡

† Numbers in parentheses indicate grasspea as a percentage of pulses.

‡ Numbers with parentheses and asterisk indicate grasspea as a percentage of pulses and cereals combined.

Source: CSA 1987.

This determinental effect is due to the presence of a neurotoxin identified as β-N-oxalyl amino-L-alanine (BOAA) (Roy and Rao 1978). Large white seeds are best for human food but they should be parched and boiled carefully (Purseglove 1968). Several cases of lathyrism have been recorded over a wide geographical range in the *L. sativus*-producing areas of Ethiopia. Attempts have been made to ban the cultivation of this crop but farmers still cultivate it because it is considered a reliable crop against drought, waterlogging and flooding in the Indian subcontinent and Bangladesh (Ramanuyam *et al.* 1980; Thulin 1983). However, research efforts should be made to remove the neurotoxic property and exploit the potential of this poor man's food crop in a proper manner rather than attempting to ban the crop. One way to utilize the crop properly in Ethiopia is to identify grasspea cultivars low in BOAA toxin and improve yield potential using available genetic resources.

Genetic Research

Lathyrus sativus is a native of Southern Europe and Western Asia. Its chromosome number is 2n=14 (Purseglove 1968; Westphal 1974). Ethiopia is considered a secondary center of diversity for grasspea, which is spread over almost all of the country in black clay soils at 1800-2700 m asl (Table 2). In areas of 600-1100 mm rainfall, the crop is grown during June to September on residual moisture.

Research on grasspea in Ethiopia started in the 1960s at Holetta Research Center with the evaluation of existing germplasm. A small collection of grasspea was sown in 1974/75 at Nazret (IAR 1975), a lowland location (1576 m asl), as no highland station was working on the crop at that time. Work on

Table 2. Area, production in various regions of Ethiopia, and potential yield of some grasspea lines, 1988.

Region	Area		Production		Yield
	1000 ha	%	1000 ha	%	(t/ha)
Gojam	21.2	39.2	18.0	45.2	1.74
Gonder	12.83	27.7	7.94	19.9	1.33
Shewa	11.06	20.3	6.81	16.6	2.17
Welo	7.5	13.9	6.48	16.2	1.33
Arsi	1.23	2.3	0.47	1.2	3.80
Harerge	0.29	0.5	0.13	0.33	4.60
Welega	0.08	0.1	0.01	0.03	1.20
Bale	0.02	0.04	0.01	0.03	6.00
Total	54.18	100.0	39.85	100.0	

this crop was also initiated at Kulumsa Research Center in 1978/79 (IAR 1982). Observation trials were conducted at Ginchi and Debre Zeit experiment stations in 1981-83 by IAR (1984). Research was then discontinued because facilities for BOAA analysis were lacking.

A multidisciplinary research program for the genetic improvement and production management of grasspea has been initiated in collaboration with Addis Abeba University (AAU), the Ethiopian Nutritional Institute (ENI) and the Third World Medical Research Foundation, with financial assistance from Band Aid.

The main objectives of the grasspea research program are to develop high-yielding cultivars with low BOAA content, develop production packages for the crop, and to release, demonstrate and disseminate those cultivars along with their production packages.

The following research activities have been undertaken at Adet Research Center.

- A diagnostic survey to quantify the extent of grasspea production, consumption and the occurrence of lathyrism
- Field evaluation of grasspea germplasm; varietal evaluation and testing of grasspea in screening nurseries

- A survey to identify major diseases, insect pests and weeds on grasspea
- Study on the nodulation pattern of grasspea.

This paper deals with various aspects of genetic stock utilization and the findings to date in the above research activities, in addition to the directions for future research.

In 1987/88 a multidisciplinary approach was adopted for grasspea improvement (Wolde-Amlak and Alelign 1989). The program was restarted with the support of the Third World Medical Research Foundation and financial assistance from Band Aid. This program was organized in a national network. The research on genetic improvement and crop management by the Institute of Agricultural Research is based at Adet Research Center in the northwestern part of the country where grasspea is one of the major food legumes.

Grasspea in Ethiopian Farming Systems

Grasspea is grown in Cambisols and Vertisols. The crop is sown between late August and September and harvested between January and February. Two to three plowings are common during land preparation. Farmers do not apply fertilizer. Grasspea is also planted to compensate for the loss of a preceding crop due to unpredictable environmental factors such as hail or waterlogging conditions or after harvesting the main season crops to utilize efficiently the scarce arable land. Double cropping after tef or barley and intercropping with chickpea and barley are common practices. Thus the common rotation is tef/grasspea/tef, but noug and finger millet also may be used as the preceding crop.

A quarter to one-half of the farmers' production is delivered to the local market, as most farmers consume at least 50% of their produce. According to farmers, the following forms of grasspea diet cause lathyrism: (a) pancake (*kita*) with milk, meat or butter, (b) grain seed and steam from the boiling grain, (c) unripe forms of grasspea. Several food items are prepared with the grain including hot curry (*shiro wot*), roasted grain (*kolo*), boiled grain (*nifro*) and dry bread (*kita*) (Alelign and Regassa 1989; Bekele *et al.* 1991). Excessive consumption of grasspea has severe side effects (i.e., lathyrism) (Ramanuyam *et al.* 1980; Alelign and Regassa 1989).

Evaluation of Germplasm: Screening Nursery Program

Germplasm screening has begun with a limited number of *L. sativus* accessions obtained from the Plant Genetic Resources Center of Ethiopia (PGRC/E). Preliminary observation from the screening of 127 accessions grown during 1987/88 indicated some variability among accessions (Table 3). Although these data were collected from a restricted population and represent only one season, they do indicate great variability in grain yield and yield components.

Table 3. Summary of different agronomic characters of 127 local germplasm accessions of *Lathyrus sativus* in Adet, Ethiopia, 1987/88.

Character	Range
Days to flowering	25 - 58
Days to maturity	131 - 157
Plant height (cm)	36 - 99
Pods/plant	7 - 77
Seeds/pod	1 - 5
Yield /plant (g)	12 - 12.8

Source: Wolde-Amlak 1991.

Twenty lines tested and selected in different years were evaluated in the laboratory at Adet Research Center for high BOAA content, which was as high as 0.51% but varied among the germplasm. The local landrace was 0.61% BOAA content (Table 4). Grasspea germplasm with a BOAA level ranging from 0.2 to 0.5% and with desirable agronomic traits was advanced. According to Ramanuyam *et al.* (1980) a BOAA level of 0.4% or less is low. The performance of the Canadian germplasm under Adet conditions seems promising except that it was susceptible to powdery mildew (Asgelil *et al.* 1992). In 1992/93 screening, nine Ethiopian landraces were identified with BOAA content ranging as low as 0.072-0.098%. Two Canadian lines in the same year were detected with BOAA content of 0.093-0.081 out of eight lines tested.

Breeding for Low BOAA Content

Research activities on *L. sativus* started in the early stages in the Institute of Agricultural Research. The development of cultivars with low BOAA content but with fairly high good grain yield is the main objective to reduce and combat the menace of lathyrism.

Hybridization programs are already underway with exotic lines introduced from ICARDA and Canada to evaluate them for field performance and transfer the gene(s) responsible for low BOAA to the Ethiopian landraces. The germplasm entries (127 accessions) were evaluated for various quantitative and qualitative characters at Adet Research Center.

Table 4. Mean grain yield and BOAA content of 20 genotypes of grasspea in a trial at Adet Research Center, Ethiopia, 1989.

Genotype	BOAA (%)	Grain yield (t/ha)
PGRC/E 46050	0.40	2.87
PGRC/E 46052	0.51	2.02
PGRC/E 46053	0.37	2.60
PGRC/E 46054	0.46	3.25
PGRC/E 46057	0.37	2.44
PGRC/E 46058	0.43	2.90
PGRC/E 46066	0.44	3.19
PGRC/E 46073	0.47	3.09
PGRC/E 46071	0.47	2.29
PGRC/E 46008	0.39	2.90
PGRC/E 46031	0.39	2.85
PGRC/E 46070	0.39	2.87
PGRC/E 46030	0.37	2.56
PGRC/E 201538	0.35	2.79
PGRC/E 46072	0.42	2.70
PGRC/E 46079	0.43	2.65
PGRC/E 46060	0.47	3.39
PGRC/E 201547	0.42	2.46
PGRC/E 201513	0.40	3.30
Local check	0.61	3.02
Mean	0.43	2.86

LSD 5% = NS, 1% = NS; SE± (t/ha) = 0.32; CV% = 21.8.
Source: Wolde-Amlak 1991.

Grain Yield and BOAA Content

The performance of 20 grasspea cultivars in a cultivar trial at Adet in 1989 is shown in Table 4. Lines with high grain yield had comparatively high BOAA contents (e.g., PGRC/E 46060). Line PGRC/E 46053 had a reasonable yield (2.60 t/ha) and a minimum BOAA content of 0.37%. According to Quader *et al.* (1989) lines with low neurotoxic content have low yield potential while lines with high yield potential are high in BOAA.

In a trial with 20 entries conducted in 1991/92 at Adet, no significant yield differences occurred among the genotypes. The overall mean yield was 3.30 t/ha, ranging from 2.98 to 3.66 t/ha. The local cultivar yielded 3.34 t/ha. PGRC/E 46066 gave the highest yield of 3.66 t/ha followed by PGRC/E 46054 with a yield of 3.58 t/ha. The BOAA contents of these lines have not been reported.

Correlation of Grain Yield and BOAA Content

There was no correlation between BOAA content and yield components of grasspea entries in a cultivar trial at Adet Research Center in 1987 (Table 5). Lack of correlation has been indicated by other workers (Lal *et al.* 1986). There was a correlation between BOAA content and maturity (Table 5), suggesting the possibility of developing strains low in neurotoxin by selecting for early maturity. There is a need to determine BOAA content in the seed at physiological maturity and for a breeding program to increase seed size and pods/plant for increasing grain yield.

Genetic Responses to Biotic Factors

Survey work conducted in the northwestern region of Ethiopia in 1988 and 1990 revealed that powdery mildew (*Erysiphe polygoni*) and rust (*Uromyces fabae*) were low in incidence (<5% of the plants infected) and light in severity (<5 on a 1-9 scale) except that a heavy powdery mildew infection with ratings of 8 and 9 was recorded on cultivars with low toxicity (Canadian materials NC 8a-971 and NC8a-108, respectively). In 1989 both powdery mildew and rust infection were heavy at Woreta and Meshenti of Bahir Dar Zuria (Asegelil *et al.* 1992) (Table 6).

Table 5. Correlation coefficients of BOAA content, yield and yield components of grasspea genotypes in a trial at Adet, Ethiopia, 1989.

Parameter	Seed yield	1000-seed weight	Pods/ plant	Seeds/ pod	Height	Days to maturity
BOAA	0.01	0.14	-0.14	-0.18	0.10	0.49**
Seed yield	·	0.47**	0.62**	-0.05	0.04	0.08
1000-seed weight	·	·	0.54**	-0.11	0.19	0.13
Pods/plant	·	·	·	0.06	0.07	0.05
Seeds/pod	·	·	·	·	0.16	0.17
Height (cm)	·	·	·	·	·	-0.01

** = Significant at 1% probability level.
Source: Wolde-Amlak and Alelign 1990.

The severity and incidence of root rot/wilt disease (*Fusarium* spp.) ranged between 5 and 9%. It can be concluded from the survey results that powdery mildew and rust are important diseases in the northwestern part of Ethiopia in years with high rainfall. Powdery mildew is associated with cloudy and humid conditions which occur at grain filling or physiological maturity of the crop. Currently efforts are underway to transfer some gene(s) for low BOAA content from some Canadian lines to Ethiopian landraces, keeping the same level of resistance to powdery mildew and rust.

Table 6. Powdery mildew and rust incidence and severity on grasspea in Woreta and Bahir Dar Zuria *awrajas*, 1989.

Region/location	Powdery mildew		Rust	
	Incidence	Severity	Incidence	Severity
Woreta				
Tunani Zachena	70-100 (3)†	6-9	70-100 (30)	6-9
Kuhar Michael	60-100 (4)	5-9	60-100 (4)	5-9
Gegna	100 (2)	9	100 (2)	9
Dera	100 (2)	9	100 (2)	9
Bahir Dar Zuria				
Meshenti-Gulagulam	80-100 (2)	6-8	20-100 (7)	6

† Numbers in parentheses are the number of fields sampled.
Source: Asgelil *et al.* 1992.

A survey of 20-30 farmers' fields of grasspea was made to identify and determine major insect pests. The insect pests attacking grasspea were aphids (*Acyrthosiphon pisum*), African bollworm (*Helicoverpa armigera*) and thrips (*Caliothrips impurus*); these were among the most important factors limiting production. The degree of infestation varies from season to season and location to location. Aphids are mainly problematic at lower altitudes. Coccinellid beetles were encountered as predators of the aphids; 3-20 beetles per 10 sweeps were noted in most cases. This indicates the possibility of biological control for aphid infestation (Asgelil *et al.* 1992). Most of the farmers' fields assessed were low in weed infestation. Weeds such as *Hygrophila auriculata*, *Cynodon dactylon*, *Guizotia scabra*, *Lactuca serriola*, *Pennisetum ramosum* and *Daucus carota* were found to be major (Bekele *et al.* 1991).

Conclusion

Research activities on *L. sativus* are in progress in the Institute of Agricultural Research. A multidisciplinary research program for genetic improvement and crop management is presently underway at Adet Research Center in collaboration with Holetta Research Center.

Field survey studies have provided the necessary information on grasspea such as production, consumption and lathyrism in Ethiopia in general and in the northwest region in particular.

Evaluation of grasspea germplasm, varietal evaluation and testing of grasspea in screening nurseries have shown promising lines with high yield potential but high BOAA content. The germplasm received from Canada is being tested in Adet and some of the lines seem promising except for powdery mildew infection.

Survey work conducted in the northwestern region of Ethiopia revealed that powdery mildew and rust were the major diseases on grasspea. The major insect pests attacking grasspea are aphids, African bollworm and thrips.

Hygrophila auriculate, *C. dactylon* and *G. scabra* were found to be the major weeds on this crop.

The nodule formation of grasspea was poor, which indicated that the local strains of bacteria are ineffective in fixing nitrogen. Inoculation with effective bacterial strains is necessary.

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Discussion

Ato Kiflu
Does grasspea affect animals such as horses, mules and cows as it does human beings?

Dr Asfaw
No farmer feeds his cattle pure grasspea but mixes it with other grasses. If fed pure, animals will be affected too. Dr Asgelil, who attended the International Grasspea Conference, can answer the question better than I can.

Dr Asgelil
There was a report presented at the conference on *Lathyrus sativus* by the AAU's Dr Tedda in which it was indicated that lathyrism affects chickens, horses and pigs.

Participant
Animals such as horses which are not ruminants are affected quicker than chicken and pigs by lathyrism. The part of the crop that affects animals more is the seeds, indicating the high concentration of BOAA (the undesirable alkaloid) in seeds compared with other plant parts.

Dr Getinet
How much is known about the genetics of grasspea?

Dr Asfaw
Genetic collection has already been done by PGRC/E, but crossing has not been done. The genetics of BOAA content, which varies from place to place, is already known.

Dr Getinet
Maybe more germplasm collection is needed by region since we have genetic variation. BOAA content may be different from region to region and therefore screening for low BOAA may be possible.

Dr Asfaw
Yes, there is genetic variation in grasspea and more collection needs to be done. However, the variabilities are in other plant characteristics but BOAA content is high anywhere. There is no significant difference between PGRC/E lines in BOAA content. There are Canadian (exotic) lines low in BOAA. Crossing has begun to transfer this trait to our improved cultivars. IAR needs

to build its own genetic screening facilities where we can do the work ourselves rather than relying on other institutions outside the country.

Dr Seyfu
Production of grasspea is increasing in the country while there is a serious problem of the alkaloid. At the same time the production of the more important CSFL such as chickpea and field pea is decreasing due to problems such as moisture stress and diseases. Shouldn't we concentrate on solving chickpea and field pea problems?

Dr Asfaw
Although not included in the presentation, there are results of the recent studies which indicate that the grasspea area is increasing, while the other crops are declining in area. This might be attributed to the fact that chickpea and other crops suffer waterlogging but grasspea does not. The issue calls for further socioeconomic surveys.

Ato Berhanu
Dr Asfaw's statement on grasspea's resistance to waterlogging is not true. It is, in fact, sensitive. Also aphids can reduce and are reducing its yield.

Ato Hailu
Grasspea may be mistaken as increasing in area simply because the area for other crops is declining owing mainly to disease and pest attack which sometimes result in complete crop failure.

Participant
Even though acreage and production of grasspea have increased, pests and diseases such as pea aphids and powdery mildew cause heavy damage in the northern part of the country.

Ato Dawit
The previous government mandated that farmers need to grow grasspea and sell a certain amount (quota) to the government. So farmers have to grow it whether they like it or not.

Dr Geletu
Grasspea is a low-input crop. It requires no fertilizer and can be grown with less plowing.

Dr Asgelil
The production of faba bean and lentil is declining because of waterlogging. Hence, the farmers' alternative is to grow grasspea which can resist excessive moisture. The fact that it is a low-input crop encourages farmers to plant it.

Dr Saxena
Data presented were only those that were collected before 1988. Why don't we have more recent data?

Dr Asfaw
Up-to-date data are indeed available. It is a matter of going to the central statistics office and getting and compiling them.

Dr Saxena
Ethiopia participated in the Grasspea Project that was done at Adet. Data are available for BOAA content. Data are also available for similar work done in India, Pakistan and Bangladesh. Have there been any cultivars of grasspea released so far? Are there any known landraces at farmers' level?

Dr Asfaw
No cultivars of grasspea have been released so far. There may be some next year. We have to determine the BOAA content of lines with high yields before they are released.

Chapter 3
Agronomy

Faba Bean and Field Pea Agronomy Research

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Abstract

Faba bean and field pea are important low-input 'break' crops in the highlands of Ethiopia. Although coordinated research efforts started in 1972, few agronomic studies were done prior to the mid-1980s. Experimental evidence indicated that faba bean and field pea are good preceding crops for cereals and when grown in association resulted in increased land productivity per unit area; a Land Equivalent Ratio greater than 1 was obtained for all mixed proportions of faba bean and field pea. At Holetta investigations on tillage requirements of faba bean showed that plowing several times with either tractor or oxen significantly increased faba bean yields compared with one plowing. For field pea, highly significant yield differences among plowing treatments with oxen occurred in a 1-year trial. A delay in sowing from the recommended sowing dates decreased faba bean and field pea yields. Optimum sowing date differed with location, cultivar and availability of soil moisture. Sowing dates from mid-June to early July have been recommended for most faba bean and field pea growing areas. Seed yields are increased by increasing plant population. For faba bean, depending upon the seed size, a seeding rate of 180-250 kg/ha has been recommended. Inter-row spacing of 40 cm and interplant spacing of 5 cm gave the optimum plant population of 500 000 plants/ha. For field pea, inter-row spacing of 20 cm for small-seeded and 40 cm for relatively large-seeded, and interplant spacing of 5 cm have been recommended. For broadcast seeds, a seeding rate of 100-150 kg/ha was recommended. Experimental evidence showed that row sowing and hand-weeding increase seed yields compared with broadcast sowing and no weeding. Faba bean productivity is constrained by excessive soil moisture and poor drainage on heavy clay soil receiving high rainfall (> 600 mm) in the growing season. Faba bean productivity in Vertisols markedly increased with improved surface drainage. Faba bean on-farm trials using recommended sowing date, improved cultivar, weed control and fertilizer application showed tremendous yield increases over the farmers' practices in the central and southeastern highlands of Ethiopia. In the northwest region a similar response was obtained with improved cultivars.

Introduction

Faba bean and field pea are important low-input break crops throughout the highlands of Ethiopia (1800-3000 m asl). The crops have been cultivated since antiquity under diverse production systems in a wide range of soil and environmental conditions (Westphal 1974; Amare and Beniwal 1988; Asfaw 1988).

Amare (1985) reviewed research in faba bean and field pea agronomy up to 1985. All subsequent research findings on these crops are included in this review. Prior to 1972 agronomic studies were conducted along with cereals and oil crops (IAR 1972, 1975; Amare 1985). Since coordinated research work on highland pulses started in 1972, the limited agronomic studies at four to five locations showed the importance of the improved practices for maximizing yield. Since the mid-1980s substantial agronomic studies, particularly on faba bean, have been done (Amare 1985, 1990; Amare and Beniwal 1988).

This paper reviews the recent work done by the Institute of Agricultural Research and other organizations on faba bean and field pea agronomy. Future agronomic and physiological research priorities are suggested.

Cropping System

Faba bean and field pea are cultivated in the highlands of Ethiopia (1800-3000 m asl), being most common in the temperate or *wyndega* zone (2000-2500 m asl) of the cereal-pulse zone (Asfaw 1985, 1979a, 1979b, 1988; Amare and Beniwal 1988; Amare 1990).

In Ethiopia, mainly *minor* and *equina* types of *Vicia faba* (small- and medium-seeded, respectively) are known to occur although *major* (large-seeded) types were introduced into the country by the Portuguese around 1900. The *equina* types predominate in southern Shewa, Arsi, Bale, Harerge and Sidamo highlands whereas the *minor* types are common in northern Shewa, Gojam, Tigray and Welo zones (Asfaw 1985; Amare and Beniwal 1988; Amare 1990).

The field pea grown in Ethiopia is mainly of two types, *Pisum sativum* ssp. *arvense* and *P. sativum* ssp. *abyssinicum* (EPID 1975). The *arvense* type have colored flowers, usually purplish, and angular seeds, normally brownish grey or variegated in color (EPID 1975). The *abyssinicum* type has leaves with one pair of leaflets, very small reddish-purple flowers and globose, glossy, sweet seeds with a black hilum (EPID 1975; Kay 1979). The *abyssinicum* type matures in a shorter time than the *arvense* (EPID 1975).

Surveys in different parts of Ethiopia indicated that faba bean and field pea are important rotation crops in different parts of the country (IAR 1986; Hailu and Chilot 1987, 1992; Aleligne 1988; Hailu 1992; Chilot *et al.* 1992). Rotation crops include barley (*Hordeum vulgare*), wheat (*Triticum* spp.) and tef (*Ergrostic tef*) in lighter soils under high rainfall and at attitudes lower than 2300 m. On Vertisols faba bean and field pea are replaced by chickpea and grasspea which are grown on stored soil moisture (Amare 1990).

Several studies showed the advantage of including legumes in rotation (Getinet *et al.* 1985; Hailu *et al.* 1989; Amanuel *et al.* 1990, 1993; Amanuel and Tanner 1991; Tanner *et al.* 1991). In Holetta zone faba bean and field pea are the most favorable preceding crops for wheat production (Table 1). In Kulumsa zone, wheat after faba bean resulted in the largest yield increment relative to monoculture wheat (Amanuel and Tanner 1991; Tanner *et al.* 1991).

Table 1. Average grain and straw yields (t/ha) of wheat following different preceding crops, Holetta, 1987.

Preceding crop	Grain yield	Straw yield
Faba bean	2.7a	4.1a
Potato	2.5ab	3.4ab
Field pea	2.4ab	3.3ab
Linseed	2.3ab	3.1abc
Rape	2.0bc	2.9bc
Barley	1.6c	2.3bc
Wheat	1.6c	2.2c
P	0.01	0.01
CV%	8.5	14.00

Values within a column followed by a common letter are not significantly different at the 5% level by DMRT.
Source: Hailu *et al.* 1989.

At Holetta field pea followed by faba bean were the best preceding crops for food barley production (IAR 1983). The recent work at Sheno indicated that faba bean was the second best break crop of barley (Table 2) which improved barley grain yield by 20.4% (Adamu 1991). In another experiment faba bean was reported to be the best preceding crop for malting barley at Bekoji and economic analysis of rotation crops revealed that the 3-year cycle with faba bean combined with two crops of barley gave 16.5% more net benefit over the continuous malting barley production (Amanuel *et al.* 1993).

Table 2. Effects of preceding crop on grain and straw yields (t/ha) of barley, Sheno, 1987.

Preceding crop	Grain yield	Straw yield
Vetch	1.8a	2.8a
Faba bean	1.8a	2.6a
Wheat	1.5ab	1.6b
Linseed	1.4ab	1.9b
Barley	1.4ab	1.5b
Oat	1.4b	1.9b
Potato	1.3b	1.6b
P	0.05	0.05

Values within a column followed by a common letter are not significantly different at the 5% level by DMRT.
Source: Adamu 1991.

In most cases faba bean and field peas are grown as sole crops but some farmers mix faba bean and field pea in different proportions (Amare *et al.* 1993b; IAR 1993). Recent studies showed that by growing faba bean and field pea in association the productivity of land per unit area is much higher than growing either crop species as a sole crop (Amare, unpublished). Combined data for 2 years (1991/92) indicated a Land Equivalent Ratio greater than 1 for all mixed proportions (Table 3).

Table 3. Seed yields (t/ha) of faba bean (FB) and field pea (FP) grown together at different populations and as a sole crop at Holetta, 1991/92 crop season.

Treatment mixture FB:FP	Hand-weeding	Yield (t/ha)		Yield as fraction of sole crop		Land Equivalent Ratio (A+B)
		Faba bean	Field pea	Faba bean (A)	Field pea (B)	
0:100	Yes		1.51		1.00	1.00
	No		1.17		1.00	1.00
25:75	Yes	0.26	1.35	0.16	0.89	1.05
	No	0.15	1.29	0.12	1.10	1.22
50:50	Yes	0.51	1.21	0.31	0.80	1.11
	No	0.47	1.16	0.39	0.99	1.38
75:25	Yes	1.04	1.15	0.64	0.76	1.40
	No	0.70	0.92	0.57	0.79	1.36
100:0	Yes	1.63		1.00		1.00
	No	1.22		1.00		1.00
SD (1%)	0.4	0.5				
CV (%)	25.8	21.5				

Temperature and Moisture

Temperature is one of the most important environmental factors that determines the distribution, growth, development and thereby seed yields of pulse crops (Saxena *et al.* 1988).

In Ethiopia, at higher altitudes in *dega* zone, frost is a perpetual hazard especially in the late-sown crop where it causes severe damage every 3-4 years and thus limits the cultivation of faba bean and field pea (Amare 1990). In addition, hail damage also causes problems to faba bean and field pea production in certain areas in higher altitudes (Amare 1990). The mean temperature in this zone during the faba bean and field pea growing season

(May to November) remains between 8 and 21°C (average for Holetta, Mota, Debre Tabor, Fiche, Robe, Sinana and Bekoji stations) and frequently fluctuates (NMSA 1993) which affects crop growth, flowering and pod-setting.

In midaltitudes, the mean temperature in the growing season (June to October) remains between 10.8 and 23.7°C (average for Debre Zeit, Adet and Kulumsa stations) (NMSA 1993). This again shows fluctuation depending upon the rainfall pattern in a particular season. These higher and fluctuating temperatures are known to adversely affect growth, flowering and pod-setting of faba bean (Amare 1990; Asfaw *et al.* 1992). Field pea can tolerate frost in the vegetative stage, but frost at flowering can cause heavy pod losses and at pod-set is liable to produce deformed and discolored seed. Temperatures above 27°C shorten the growing period and adversely affect pollination (Kay 1979). However, there is a range of temperature for faba bean (18-27°C) and field pea (13-18°C) within which they give optimum yield (Kay 1979).

The rainfall pattern in Ethiopia is bimodal, which differs from place to place with maximum rainfall (70-80% of the total) during June to August and the remainder from March to May (Westphal 1974). Faba bean and field pea in Ethiopia are produced under rain-fed conditions. Thus, onset of rainfall is a prerequiste for sowing and the crop productivity is adversely affected in areas with unreliable or erratic and suboptimal rainfall patterns (Amare 1990). This is because the crops require fairly moderate and evenly distributed annual rainfall of approximately of 650-1000 mm for faba bean and 800-1000 mm for field pea. In areas of low rainfall the crops grow successfully under irrigation (Kay 1979).

In Ethiopia, the midaltitudes (1800-2200 m) receive an annual average rainfall of about 741 mm (mean of Adet, Debre Zeit and Kulumsa Stations) while the high altitudes (> 2200 m) receive about 921 mm/annum (average for Mota, Bekoji, Debre Tabor, Fiche, Holetta, Robe, Sinana and Wereilu stations) during faba bean and field pea growing periods (NMSA 1993). However, mean annual rainfall does not indicate the intensity, which is high in lowlands and low in the highlands (Daniel 1977). Furthermore, it is not the high total amount but an even distribution of rainfall that is required during the crop growth period. The shortage of moisture affects plant characters (excessive flower drop, plant height, total aboveground biological yield, number of pods/plant, 1000-seed weight) and shortens maturity period (Amare 1990). At Robe a shortage of moisture at the flowering stage resulted in a complete loss of yield of one sowing date in the 1991 crop season (BADE 1989-91).

In Vertisols characterized by high moisture situations black root rot (*Fusarium solani*) is a major factor limiting faba bean production. The inadequate rainfall received during the crop season, particularly in midaltitudes, results in the build-up of *Aphis* spp. (Amare 1990).

Land Requirement and Preparation

Faba bean requires deep, fertile and well-drained soils for high seed yield; clays, silt or heavy loams are all satisfactory provided the pH = 6.0-7.0 (preferably 6.5) and there are adequate reserves of organic matter. Faba bean cannot tolerate waterlogging and saline conditions (Kay 1979; Amare 1990), whereas field pea can be cultivated on a wide range of soil types with a reasonable level of fertility with pH range between 5.5 and 6.5 although some cultivars can tolerate pH = 6.9-7.5. The crop does not tolerate waterlogging (Kay 1979).

In Ethiopia one of the most important causes of low yields of faba bean and field pea is inadequate seedbed preparation (Asfaw 1985; Amare and Beniwal 1988; Amare 1990). Surveys indicated that field preparations are relatively minimal for field pea compared with faba bean (IAR 1986; Aleligne 1988; Chilot *et al.* 1992). Faba bean is sensitive to compacted soil layers as well as surface compaction, and hence any pans present should be broken (Hebblethwaite *et al.* 1983; Amare 1990). Since faba bean and field pea have similar tap root systems and grow in more or less similar ecological niches the recommendations for faba bean also hold true for field pea.

The crops do not require a fine seedbed; 2-3 plowings with the local plow or one disc plowing followed by two disc harrowings have been recommended (EPID 1975; Asfaw 1985). It is an advantage if land preparation can start early to encourage weed seeds to germinate so that they can be destroyed in subsequent cultivation (EPID 1975). These recommendations are based on general practices for most crops. The research findings for each crop show the following.

Faba Bean

Investigations at Holetta (during 1979, 1982 and 1983 crop seasons) showed that repeated plowings with either tractor or oxen significantly increased faba bean seed yields compared with one plowing (Fig. 1). This was presumably due to better control of weeds in all treatments. Repeated plowings at some locations, with most of the agronomic components in the faba bean on-farm trials, increased yields during the 1985 crop season (Amare 1986a). At Holetta from 1989-91 yield differences between tillage practices were nonsignificant (Rezene 1992). On the other hand, comparison of the improved Nazret Moldboard Plow with the local plow (*maresha*) indicated that the former gave higher yields than the latter and reduced weed populations (Rezene 1992).

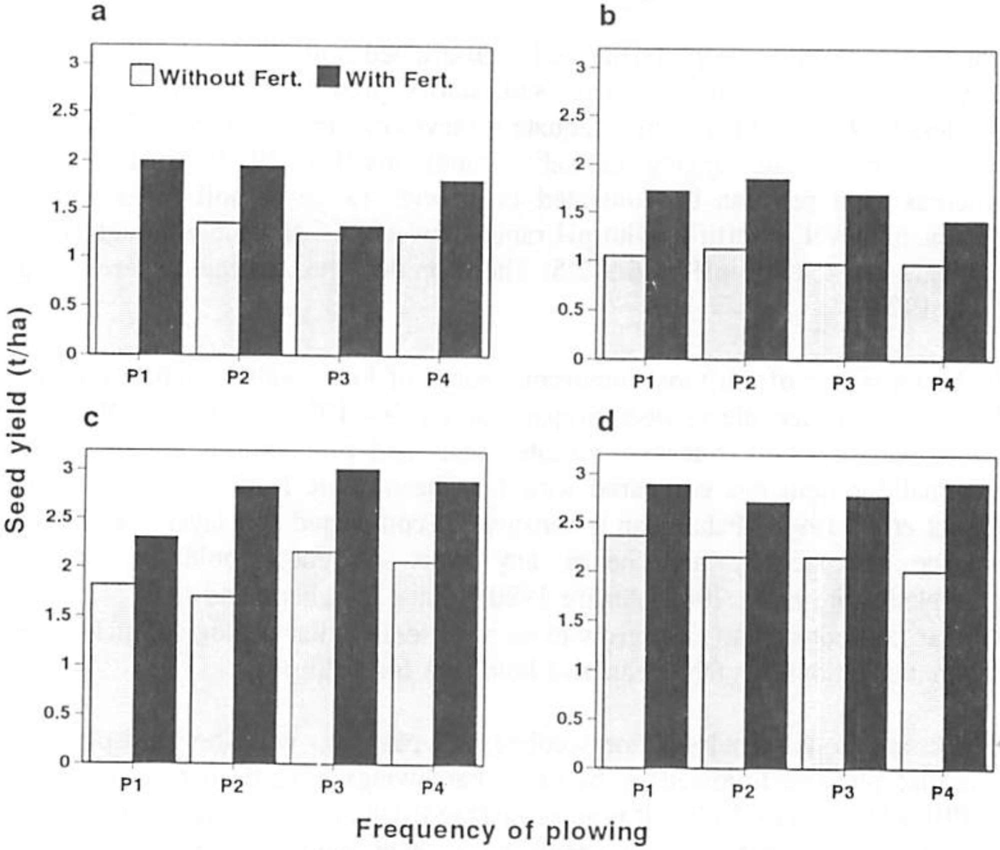

Fig. 1. Effect of tillage operations and fertilizer (0 or 46 kg/ha of N and P_2O_5) on seed yields of faba bean at Holetta, 1979, 1982-83 crop seasons: (a) oxen and plow, black soil; (b) tractor, black soil; (c) oxen and plow, red soil; (d) tractor, red soil (IAR 1979-83; Amare 1985).

The poor performance of the *maresha* compared with modern plows is shown in Table 4. Deep plowing with moldboard plow resulted in substantial yield increase of faba bean compared with other treatments (Mesfin 1979).

Table 4. Seedbed preparation effects on faba bean seed yield (t/ha) at Sheno, 1976-78 crop seasons, Shewa administration region, Ethiopia.

Treatment	1976	1977	1978	Mean
Local plow (*maresha*)	1.22	0.92	0.55	0.90
Local plow + *guie*†	1.04	1.21	0.62	0.96
6-meter camber	2.05	2.14	0.90	1.40
Moldboard plow	2.13	1.53	1.07	1.58
Chisel plow	1.22	1.20	0.75	1.05
Disc plow	1.48	1.02	0.76	1.09
Mean	1.52	1.34	0.78	1.16

† In 1976 only.
Source: Mesfin 1979.

Field Pea

Experimental findings on the effect of frequency of plowings by using oxen and gweedings on seed yields of field pea showed highly significant yield differences among the plowing treatments (Table 5). The highest field pea seed yields with yield advantages of 62 and 37% over the control were obtained from two and three plowings, respectively.

Table 5. Influence of frequency of plowing and weeding on seed yields (10% grain moisture) of field pea (t/ha) at Holetta, 1986 crop season.

	Plowing treatment‡				Mean yield
Weeding†	P1	P2	P3	P4	(weeding)
W0	1.05	1.41	1.69	1.39	1.39
W1	1.14	1.57	1.68	1.23	1.41
W2	0.95	1.32	1.70	1.30	1.32
Mean yield (plowing)	1.05	1.43	1.69	1.31	
Frequency of	Plowing		Weeding	Weeding × Plowing	
LSD	0.4		NS	NS	
CV %	15.1				

† W0, W1 and W2 denote none, one and two weedings, respectively.
‡ P1, P2, P3 and P4 denote plowing once, twice, three and four times, respectively.
Source: Amare 1986b.

Method of Sowing and Seeding Depth

Traditionally Ethiopian farmers broadcast faba bean and field pea and cover by local plow (Asfaw 1985; Amare 1990), but farmers in Angacha *awraja* in southern Shewa dibble seed behind the plow (Hailu 1992).

Limited research work on method of sowing has been done. The work at Kulumsa for 3 years (1978-80) on faba bean indicated that row planting and hand-weeding increased seed yield over broadcast and unweeded treatments (Fig. 2). In trials conducted in 1967/68 at Kulumsa, faba bean yields increased greatly when the beans were row planted and weeded properly (CADU 1969a, 1969b; Amare 1985).

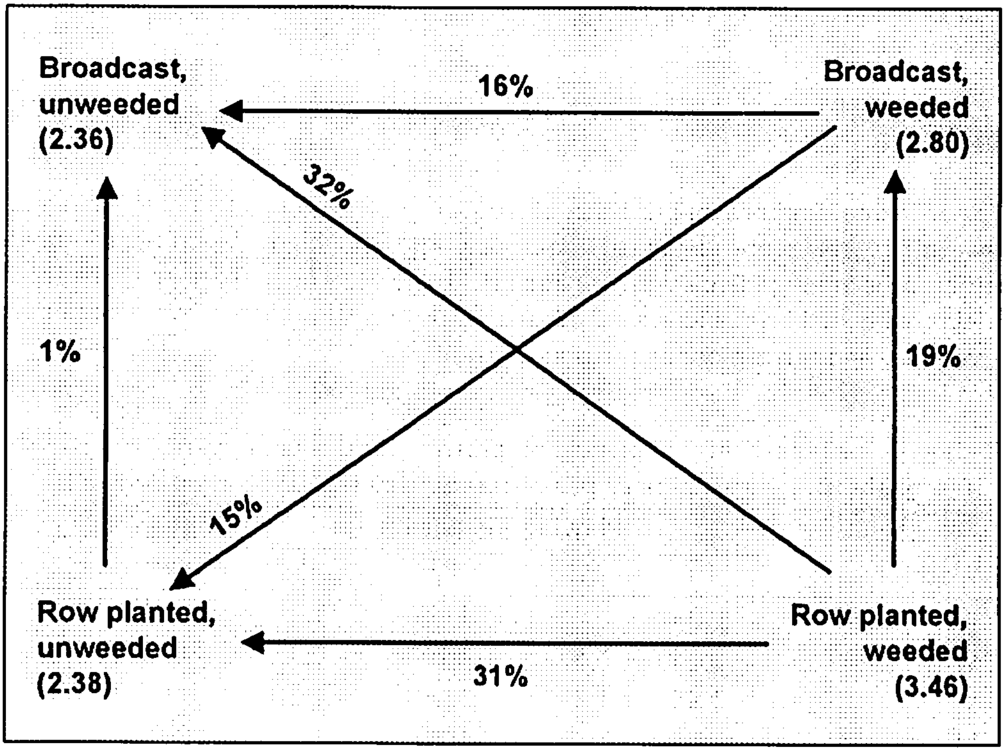

Fig. 2. Effect of method of sowing and weed control on faba bean seed yield at Kulumsa in 1978-80. Mean yields (t/ha) in brackets and yield reductions in percentage (Tarekegne 1980; Amare 1985).

Combined data (1990/91) indicated that faba bean seed yields were highly significantly affected by interaction of year, location and method of sowing (Table 6).

Table 6. Seed yield (t/ha) of faba bean as affected by crop season, location and method of sowing in 1990 and in 1991 crop seasons.

	Kulumsa		Bekoji	
Year	Broadcast	Row sowing	Broadcast	Row sowing
1990	2.03	2.06	2.34	3.77
1991	3.65	3.79	3.30	3.03
CV (%)	15.3			
LSD (1%)	0.8			

Source: Amare *et al.* 1993b.

At Kulumsa, row planting gave slightly better seed yield than broadcast sowing. At Bekoji during the 1990 crop season, row planting gave a yield advantage of about 62% over broadcast sowing while in the subsequent crop season broadcast sowing yielded more than row planting by about 9% (Amare *et al.* 1993a). The advantage of row sowing over broadcast sowing was also reported by Mekonnen (1992). At Holetta and Dembi row sowing gave significantly higher seed yields than broadcast sowing (Table 7).

Table 7. Effect of method of sowing on faba bean seed and total biological yield (TBY) in t/ha at Holetta and Dembi, 1987-90 crop seasons.

	Holetta		Dembi	
Method	TBY	Seed yield	TBY	Seed yield
Row sowing	2.56	1.34	4.63	1.85
Broadcast	5.23	1.18	4.22	1.70
LSD (1%)	NS	0.09	0.32	
LSD (5%)				0.12
CV (%)	13.10	14.93	15.19	19.14

No experimental work on seeding depth of faba bean and field pea has been done in Ethiopia. However, research done on row planting places the seeds of both crops at a depth of about 5 cm. Traditionally, farmers broadcast the seeds and cover using the local plow, which places most seeds at depths of 10-15 cm where the soil moisture is adequate for germination. It is not uncommon to see uncovered seeds in most fields; this affects the field stand and contributes to low yields of both crops.

Date of Sowing

Traditionally, faba bean and field pea in Ethiopia are sown from early June to mid-July depending on the soil type, i.e., early June to first week of July in light soils and from the third week of June to the second week of July in Vertisols (Asfaw 1985, 1988; Amare and Beniwal 1988; Amare 1990). In addition, depending on the moisture availability some regions are known to grow faba bean and field pea during the *belg* season (a season with small rains from February to April) and the *tseday* season (at the end of the main rainy season in September) (Amare 1990). However, production area in these seasons is negligible compared with the main season (CSA 1979-87; Amare 1990). Experimental evidence from various places indicated that date of sowing has a profound influence on the crop performance because it determines the kind of environmental conditions to which the various phenological stages of the crop will be exposed (Saxena 1987).

Faba Bean

At Holetta, sowing date trials conducted from 1970-72 showed that 25 June and 5 July were the best sowing dates on Vertisols and Nitosols, respectively (Fig. 3). Late-sown crops suffered from frost and earlier ones from root rot and chocolate spot diseases (IAR 1975; Amare 1985, 1990). Experiments carried out from 1980-82 on Nitosols using cv. CS 20DK showed 6 June as the best sowing date (Fig. 3). At Bekoji sowing during the last week of June seemed optimum and chocolate spot severity was reduced as sowing was delayed. In sowing date trials conducted during 1980-82 seasons, 14 and 18 June gave the highest seed yields with cv. KUSE 2-27-33 at Gondi and with cv. NC58 at Debre Zeit, respectively. At all sites there was a significant drop in seed yields with delay in sowing from respective optimum sowing times (Fig. 3).

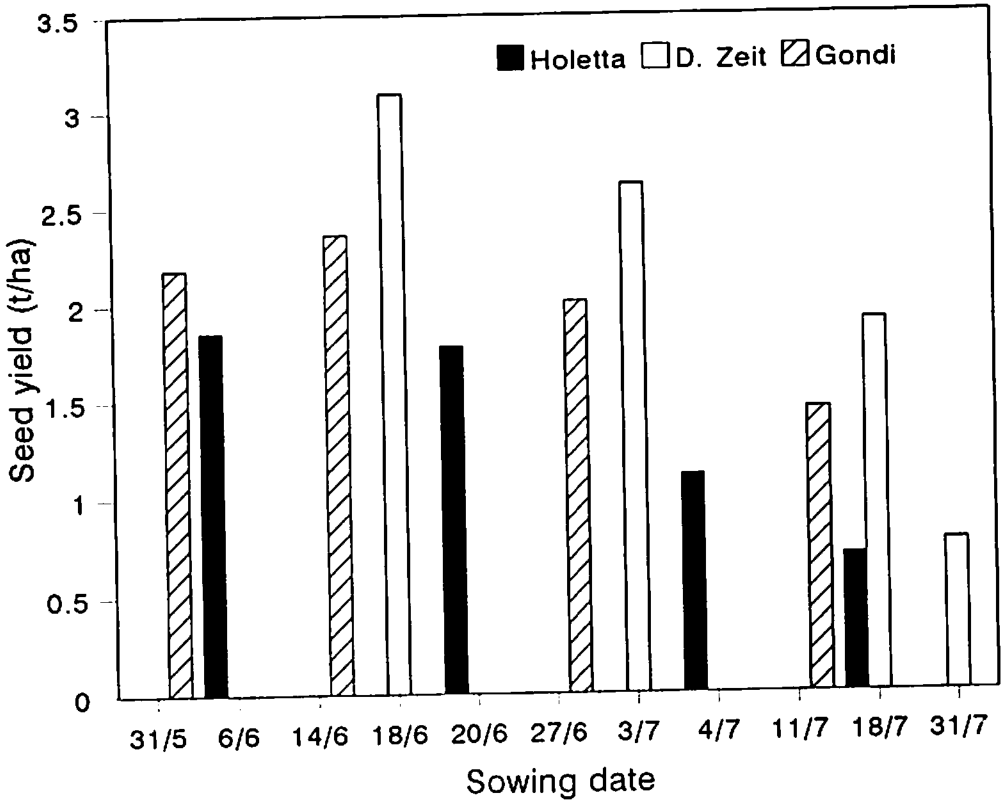

Fig. 3. Effect of sowing date on seed yield of faba bean at different locations in Ethiopia (IAR 1984a, 1984b; Amare 1985).

At Kokate 2 years of trials showed that highest yields were obtained from the earliest sowing date of mid-June (WADU 1977a; Amare 1985). In recent work at Sheno (1989, 1990 and 1992) using faba bean cv. CS 20DK, late sowing exposed the crop to frost. Sowing faba bean starting from the last week of May to the first week of June gave better grain and straw yields (Fig. 3). A sowing date trial conducted at Adet in 1986/87 crop season using cv. CS 20DK and the local landrace revealed that there were significant differences between sowing dates; the best dates were end of May and early June (Fig. 3). The late sowings of both CS 20DK and the local landrace suffered from rust diseases. Chocolate spot was severe for late-sown cv. CS 20DK but not for the local landrace (IAR 1987).

Sowing date trials conducted by Bale Agricultural Development Enterprise in *belg* cropping season showed that sowing date from end of February (1989/90), mid- to end of February (1990/91) and last week of March to mid-April (1991/92) resulted in relatively higher seed yields of faba bean at Sinana than did other sowing dates (BADE 1989-91). At Robe State Farm sowing in the first week of February (1989/90), mid-April (1990/91), and last week of March to mid-April (1991/92) gave higher yields than other sowing dates (BADE 1989-91). In *mehere* season, sowing faba bean in early to the last week of July was optimum at Sinana State Farm (BADE 1989-91). At Gololcha sowing early to mid-March resulted in high yields but a further delay in sowing reduced seed yields of faba bean (BADE 1989-91).

Field Pea

At Holetta sowing date trials using cv. FPexDZ conducted for 3 years (1970-72) indicated that 25 June on red soil and 5 July on bottom dark grey soil were the best sowing dates (Fig. 4). These findings were confirmed in 1981/82 trials when early July was the best sowing time. At Bekoji trials from 1980-82 indicated that date of planting was important and seed yields were highly depressed with delay in sowing from optimum sowing date (Fig. 4). At Debre Zeit 3 years of trials (1980-82) using cv. Mohanderfer showed that the highest yield was obtained when sown end of June to early July and seed yields were depressed by almost 55% when sown during the last week of July (Fig. 4). A sowing date trial conducted at Adet in the 1986/87 crop season using cv. G22763-2C and the local landrace showed that seed yields increased as sowing date was delayed and sowing from third week to end of June increased seed yields significantly over earlier sowing dates although the severity of Aschochyta was high (IAR 1987). At Kokate sowing date trials carried out using cultivars FPexDZ and Prussian Blue for 1-3 years (WADU 1977b) showed the best yields were from early sowing (mid-June).

Seeding Rate

Ethiopian farmers generally use lower seeding rates than research recommendations, which could contribute to low seed yields (Asfaw 1985; Amare and Beniwal 1988; Amare 1990). The research findings of faba bean and field pea are presented separately as follows.

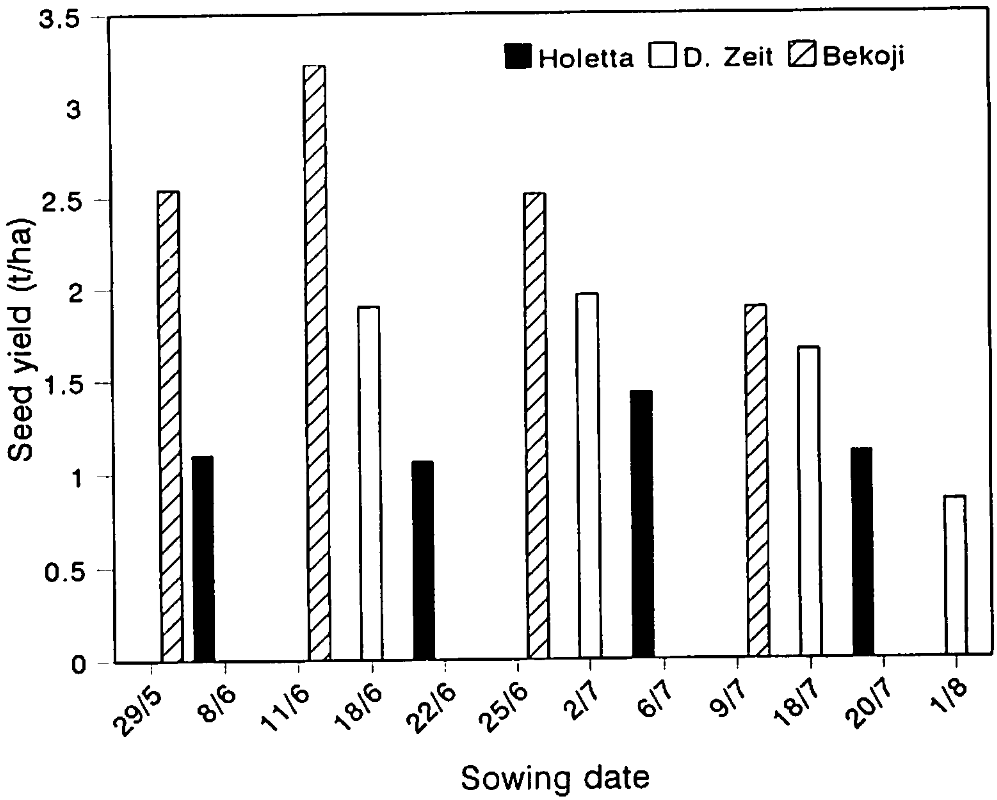

Fig. 4. Effect of sowing date on seed yield of field pea at different locations. Cultivars were: Holetta, CS 20DK; Debre Zeit, NC58; Bekoji, KUSE2-27-33 (IAR 1975, 1984a, 1984b, 1987; Amare 1985).

Faba Bean

Plant population studies carried out for 3 years (1970-72) at Holetta using the local landraces showed that optimum seeding rates varied from year to year and plant population giving the best yields varied greatly (IAR 1975; Amare 1985). Although it is very difficult to draw conclusions with the available information, seed yields in most cases responded favorably to increased seeding rates. Broadcasting of 250 kg/ha seed on Nitosols and drilling 350 kg/ha seed on cambered Vertisols gave the highest yields (IAR 1975; Amare 1985). With the seed drilled on cambered Vertisols the maximum seed yields for each trial period were obtained by the highest seeding rate of 350 kg/ha (IAR 1975; Amare 1985). Hence, seeding rate in a range of 250-350 kg/ha gave the best results. However, studies conducted using CS 20DK in row seeding during 1980-82 seasons showed that a population of 50 plants/m^2 (40x5 cm) gave the highest seed yields followed by 67 plants/m^2 (30x5 cm) (Fig. 5). At Gondi, a plant population of 40 plants/m^2 (50x5 cm) provided the highest seed yields with KUSE 2-27-33. At Debre Zeit 50 plants/m^2 followed by 40 plants/m^2 gave the best seed yields with cv. NC58 (Fig. 5).

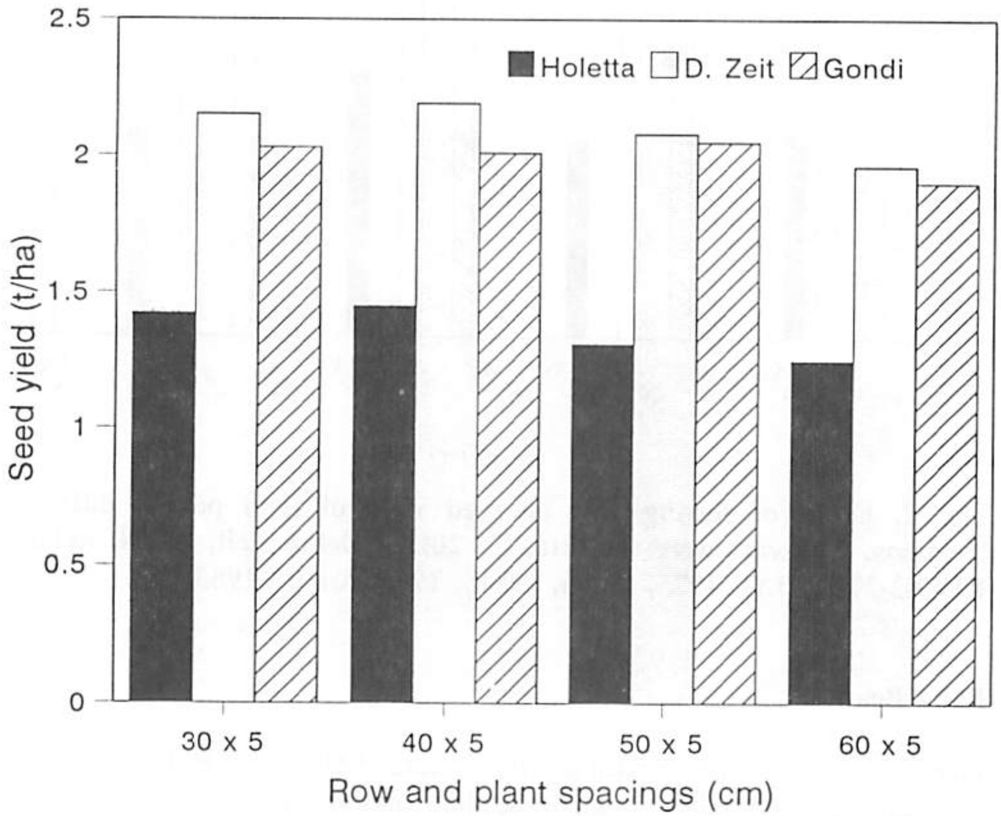

Fig. 5. Effect of plant population on seed yield of faba bean, 1980-82 crop seasons at three locations in Ethiopia (IAR 1984a, 1984b; Amare 1985).

In faba bean spacing trials conducted at Kulumsa during 1968/69 the best seed yields were obtained from a spacing of 20 cm between rows and 5 cm between plants although it resulted in more lodging and reduced 1000-seed weight. In similar trials carried out at Kulumsa (1970/71) with two broadcast rates (125 and 375 kg/ha) as additional treatments the closest spacing (20x5 cm) using a seeding rate of 375 kg/ha gave a significantly higher seed yield than the wider spacings (CADU 1969b, 1969c; Amare 1985). Recent work with CS 20DK at Holetta revealed that both the seed and total biological yields of faba bean were favorably increased from 30 to 50 plants/m² (Fig. 6). In a similar study at Dembi with NC58, plant population did not affect faba bean seed and total biological yields (Fig. 6).

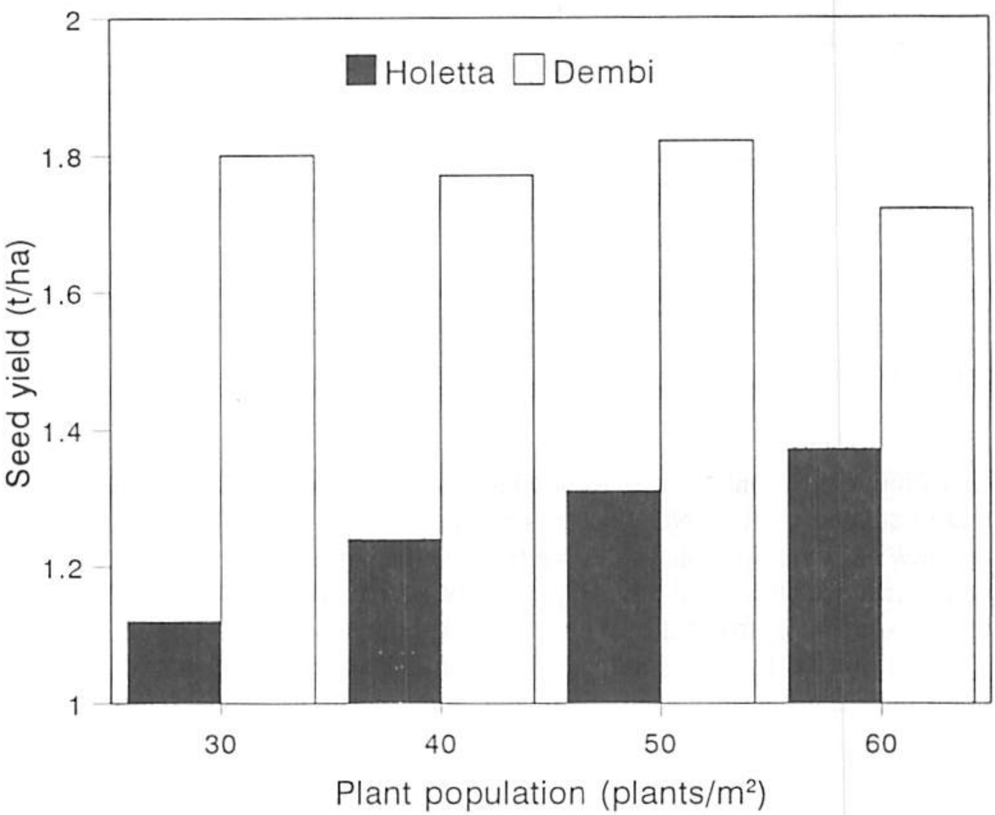

Fig. 6. Effect of plant population on seed yield of faba bean at Holetta and Dembi, 1987-90 crop seasons.

At Sheno seeding rate trials with broadcast sowing were conducted for 3 years (1989-92) and the results showed that sowing 260-370 kg/ha seed of CS 20DK gave the best seed and straw yield (Table 8). At Sinana State Farm experiments conducted for 3 years (1989-91) in *belg* crop season using eight seeding rates (from 100 to 275 kg/ha) showed that the mean highest seed yield of 1.91 t/ha was obtained from a seeding rate of 250 kg/ha, which resulted in yield advantages of 72 and 56 kg/ha over seeding rates of 125 and 200 kg/ha, respectively (BADE 1989-91). In *mehere* season the highest yield of 2.78 t/ha was obtained from a seeding rate of 275 kg/ha which resulted in yield advantages of 532 and 516 kg/ha over seeding rates of 125 and 300 kg/ha, respectively (Table 9).

Table 8. Effect of seeding rate on faba bean seed and straw yields (t/ha) at Sheno, 1989-90 and 1992 crop seasons.

Seeding rate (kg/ha)	Population (plants/m^2)	Seed yield	Straw yield
150	30	1.36	1.87
260	52	1.78	2.57
370	74	2.03	3.35

Source: IAR 1988.

In a similar trial conducted at Robe State Farm nonsignificant yield differences were obtained in the 1990/91 crop season (Table 9). At Gololcha State Farm in 1989/90, a seeding rate of 200 kg/ha gave the highest seed yield of 1.40 t/ha which resulted in a yield advantage of 339 kg/ha over the lowest rate of 100 kg/ha. Seed yield dropped by 31 kg/ha using both seeding rates of 250 and 275 kg/ha (Table 9). In trials conducted at Sinana Research Center seeding rate did not significantly affect seed yield and other agronomic characters (Zewdu 1992a). The recent work at Kulumsa and Bekoji using five seeding rates (ranging from 100 to 300 kg/ha) showed that the interaction of location and plant density was significant (Amare *et al.* 1993b). At both locations, seed yield increased with increased seeding rates except at 200 kg/ha at Kulumsa and 250 kg/ha at Bekoji which resulted in lower yields than the corresponding lower rates (Table 10). Lack of proportional increase in seed yield with increasing plant density reflects a higher degree of plasticity in the local cultivars (Salih 1989).

Table 9. Effect of seeding rate on faba bean seed yield (t/ha) in different seasons at Sinana, Golelcha and Robe State Farms in Bale Administration Region.

Seeding rate (kg/ha)	Sinana		Golelcha		Robe
	Belg (1989-91)	*Mehere* (1989/90)	*Belg* (1989)	*Mehere* (1989)	*Belg* (1990)
100	1.50	1.89	1.06	0.86	0.51
125	1.84	2.14	1.29	0.98	0.74
150	1.46	1.70	1.15	0.95	0.61
175	1.66	2.60	1.13	1.11	0.58
200	1.85	2.46	1.40	1.36	0.56
225	1.90	2.73	1.35	1.96	0.59
250	1.91	2.49	1.37	0.79	0.58
275	1.87	2.78	1.37	0.73	0.68

Source: BADE 1989-91.

Table 10. The interaction effects of location and seeding rate on faba bean seed yields (t/ha) at Kulumsa and Bekoji in Ethiopia.

Location	Seeding rate (kg/ha)				
	100	150	200	250	300
Kulumsa	2.65	2.89	2.88	2.95	3.04
Bekoji	2.62	2.88	3.36	3.15	3.53
LSD (5%)			0.37		
CV (%)			15.30		

Source: Amare *et al.* 1993b.

In a well-prepared seedbed with low incidence of soil-borne diseases, a seeding rate of 260 kg/ha (52 plants/m^2) is recommended; otherwise, 370 kg/ha (74 plants/m^2) is optimum at Sheno when seed is covered and buried unevenly by plowing with local plow (*maresha*) and the temperature is low (IAR 1988).

Field Pea

Three years (1970-72) of seeding rate studies at Holetta showed that optimum seeding rates varied from year to year (IAR 1975; Amare 1985). Hence, it is very difficult to draw conclusions. Broadcast sowing at high seeding rates on red clay soil gave the best seed yields in all cases but seed drilled on dark grey cambered soil at the lowest seeding rate (50 kg/ha) gave better yield than the high seeding rates. In general seeding rates in a range of 100-150 kg/ha were recommended (IAR 1975; Amare 1985). In trials conducted from 1980-82 using cv. FPexDZ, seed yields decreased progressively as the spacings between rows increased (Fig. 7). In the same period, experiments conducted at Debre Zeit using the improved cultivar Mohanderfer showed that differences between populations were not significant (Fig. 7). Another set of experiments conducted at Sinana indicated that seed yield and agronomic characters were not significantly affected by five seeding rates (ranging from 75 to 175 kg/ha) (Zewdu 1992b).

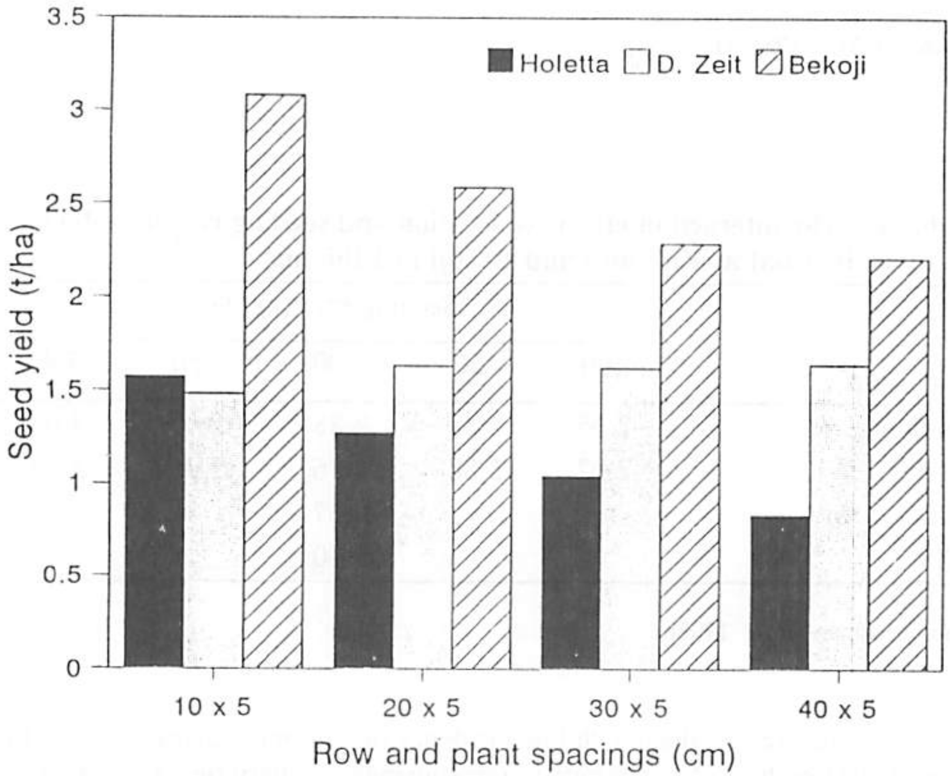

Fig. 7. Effect of plant population on seed yield of field pea, 1980-82 crop seasons at three locations in Ethiopia. Cultivars were: Holetta and Bekoji, FPexDZ; Debre Zeit, Mohanderfer (IAR 1984a, 1984b; Amare 1985).

Vertisol Management

Several investigators reported impeded drainage as a major problem in the highland hydromorphic Vertisols of Ethiopia receiving high rainfall (>600 mm) during the main rainy season, June to August (Berhanu 1984; Jutzi and Mesfin 1989; Hailu 1988; Jutzi 1988; Abate and Abiye 1989; Saxena *et al.* 1992). In order to overcome this constraint farmers traditionally construct various structures to improve surface drainage (Berhanu 1984; Getachew *et al.* 1988; Mesfin and Jutzi 1989; Saxena *et al.* 1992). Farmers cultivate different crops by constructing narrow ridges and furrows after seeds are broadcast. The crops grow on the ridges while the excess water drains through the furrow. The local plow drawn at varying distances across the contours forms a raised seedbed. Another traditional method in the high elevations is a hand-constructed broad bed of about 1-2 m width and furrows, widely used in Inewari of Shewa region (Berhanu 1984; Jutzi and Mesfin 1989; Getachew *et al.* 1988; Jutzi 1988; Abate and Abiye 1989; Mesfin and Jutzi 1989; Saxena *et al.* 1992). Of the various traditional surface drainage methods the technical efficiency of the latter has been emphasized (Getachew *et al.* 1988; Jutzi 1988).

At high altitudes (>2400 m asl) where considerable organic matter accumulates over extended fallow periods of 10-15/20 years, soil burning (locally known as *guie*) is extensively practised (Mesfin 1979, 1981; Berhanu 1984; Hailu 1988; Jutzi 1988; Mesfin and Jutzi 1989; Saxena *et al.* 1992). An estimated 540 000 ha is put under *guie* practice where barley is invariably grown for the first year. Depending on the location and fertility status of the soil, barley, faba bean or wheat may follow in the second year with a drastic drop in yield (Mesfin 1979, 1981, 1982; Mesfin and Jutzi 1989; Saxena *et al.* 1992). In most cases the third year is left fallow. The first-year yields from *guie* seedbeds are usually high owing to fusion of clay into sand-sized particles, which improve drainage, and the increased availability of macro- and micronutrients through mineralization. Phosphorus is the nutrient element that increases most by soil burning. Studies further indicated that CEC and exchangeable Ca^{++} and Mg^{++} decreased considerably. Several reports indicated the disadvantages of soil burning because of the loss of organic matter and total nitrogen (Mesfin 1979, 1981, 1982; Mesfin and Jutzi 1989).

Experimental evidence in Ethiopia showed that the productivity of crops grown in Vertisols markedly increased by improved surface drainage compared with flat conditions (Mesfin 1979, 1982; Berhanu 1984; Jutzi and Mesfin 1989; Haque *et al.* 1988; Jutzi 1988; Abate and Abiye 1989; Mesfin and Jutzi 1989; Saxena *et al.* 1992). The experience of the International Livestock Center for

Africa with broad bed and furrows (BBF) constructed with the animal-drawn implement known as broad bed maker (BBM) showed that both seed and straw yields of faba bean from Vertisols of Inewari plateau (2600 m) in the northern Shewa region were increased (Fig. 8) dramatically (ILCA 1990). This was presumably due to the greater uniformity of drainage structure established, compared with faba bean grown on traditionally hand-made BBF which is commonly used on about 20 000 ha of crop land (Getachew *et al.* 1988; Jutzi 1988).

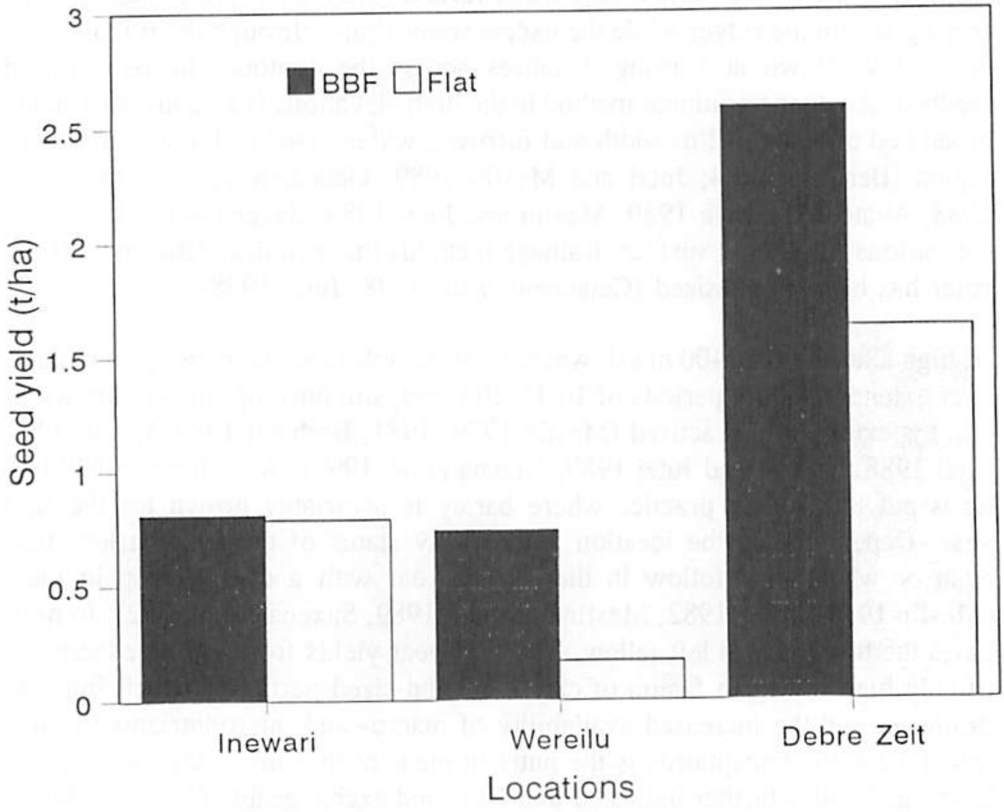

Fig. 8. Effect of drainage (broad bed and furrow vs. flat) on seed yield of faba bean at three Vertisol locations in Ethiopia.

The BBF/BBM has a return to labor of 43% increment over traditional methods (Table 11). The highest seed yield increment (335%) using the BBF over the flat conditions was reported from Wereilu (2600 m) in Welo region (Fig. 8) where similar increments to crop residues were recorded (Getachew *et al.*

1988; Jutzi 1988). It was further reported that the return to labor, land and net return of BBF were spectacularly high compared with traditional practices (Table 11). At Debre Zeit (1900 m) the BBF resulted in 58 and 73% seed and straw yield increments, respectively, compared with undrained flat conditions because of the reduction in waterlogging damage (Haque *et al.* 1988).

Table 11. Economic evaluation of improved animal-powered surface drainage at Inewari (northern Shewa) and Wereilu (southern Welo), 1986 faba bean crop season.

	Inewari		Wereilu	
	BBF/BBN	Trad.†	BBF/BBN	Trad.†
Avg. yield (t/ha)	0.810	0.709	0.736*	0.171
Gross revenue (EB/ha)‡	475	436	398*	89
Total cost (EB/ha)§	224	264	206	162
Return to labor (EB/ha)¶	1.0	0.7	0.62*	-0.07
Return to land (EB/ha)			202	-63
Net return (EB/ha)			192*	-73
Change over traditional land preparation	+43			

Source: Getachew *et al.* 1988; Jutzi 1988.
† Inewari = hand-made BBF; Wereilu = ridge and furrows made with conventional plow.
‡ 1 US$ = 2.07 EB. Includes value of grain and straw.
§ Operational and fixed costs.
¶ After deducting all costs except labor.
* Difference between BBF and ridge and furrows significant at P=1% level.

Experiments demonstrated the spectacular increase in seed and straw yield as a result of dry sowing of faba bean compared with the wet conditions at Debre Zeit. Seed yields from dry planting on 10 June were 1.68 t/ha vs. yields of 0.22 t/ha from wet planting on 6 July. Straw yields were 3.49 and 1.85 t/ha for dry and wet planting, respectively. The advance of sowing date permits the use of stored soil moisture and better nutrient utilization. This also provides an early crop cover which substantially reduces soil erosion. It was further reported that dry sowing may contribute to escape from pests, but it does rely on a reasonable dependability of early rainfall in the cropping season (Haque *et al.* 1988).

The Institute of Agricultural Research carried out a series of experiments at Sheno (Mesfin 1979) and Holetta (Desta and Hailu 1989) where substantial yield increments of faba bean seed yields were reported under drained conditions compared with flat conditions.

At Holetta cambered beds increased seed yields of faba bean over the flat conditions by about 49 and 50% under unfertilized and fertlized conditions, respectively (Desta and Hailu 1989). At Sheno deep plowing with a mold board to produce a bed 6 m wide resulted in substantial yield increase of faba bean compared with other treatments (Mesfin 1979). It was concluded that with the above drainage methods and with judicious soil fertility management, the tedious process of soil burning could be replaced (Mesfin 1979, 1981, 1982). However, it appears that the technologies are beyond the economic reach of the smallholder as no adoption by farmers was recorded (Jutzi 1988).

On-farm Technology Verification

The evaluation of faba bean production packages on farmers' fields with respect to their application and feasibility for adoption was started in the 1985/86 crop season under the IAR/ICARDA/IFAD Nile Valley Project on faba bean in Menagesha and Yerer-Keryu (Debre Zeit) zones of the Shewa region (Amare 1986a, 1990; Amare and Beniwal 1988). Of the seven agronomic factors tested, four, namely improved cultivar, early sowing, weed control and fertilizer application, were found relatively more important in increasing faba bean seed yields (Amare 1986a, 1990; Amare and Beniwal 1988). In Holetta zone, early sowing proved to be the most important factor for increasing faba bean seed yields, total biological yields and pods/plant followed by the use of the improved cultivar (CS 20DK) and weed control by two hand-weedings (Alem *et al.* 1990; Amare 1990). In economic terms the use of the improved cultivar was the most profitable factor, followed by early sowing and weed control. Among the two-factor combinations made from the recommended levels of four factors, early sowing of the improved cultivar with weed control gave the highest net returns (Alem *et al.* 1990).

Four factors (sowing date 15-30 June vs. after 30 June, CS 20DK vs. local landrace, fertilizer 100 kg/ha DAP vs. no fertilizer, and weed control by hand-weeding 25-30 and 45-50 days after emergence vs. no weeding) were tested in Chilalo zone, 1987-90 (Amare 1990). In the 1987/88 crop season statistically significant contributions to faba bean seed yields were made across locations by the researcher-recommended practices of weed control, cultivar, fertilizer and sowing date with an increase of 54, 33, 21 and 13%, respectively over their respective low-input practices (Amare 1990). In the 1988/89 crop seasons the use of fertilizer, weed control and cultivar at the researcher-recommended levels increased faba bean seed yields by 75, 43 and 19%, respectively and during the 1989/90 crop season weed control, cultivar and fertilizer increased faba bean seed yield by 69, 31 and 29%, respectively (Amare 1990). In economic terms, considering the 1987/88 crop season results for sowing date and the mean of the three seasons for fertilizer, cultivar and weed control, only the improved cultivar and early sowing date provided good net benefits with high marginal rate of returns (MRR) which are acceptable (above 50%) (Amare 1990). In general, fertilizer and control of weeds had positive net returns but unacceptable MRR (below 50%) (Amare 1990). On-farm verification of faba bean cultivars in west Gojam indicated that all the improved cultivars outyielded the local landrace. The improved cv. CS 20DK ranked first with high net benefits (Regassa and Asmare 1992).

Future Research Directions

The suggested research priority areas in faba bean and field pea include studies in different soil orders on the effect of tillage and no-tillage systems in different agroecological conditions; seeding depth studies; cropping systems research which includes green manuring, intercropping and rotational studies, and the impact of drainage in Vertisols and supplemental irrigation, particularly on soils having low water-holding capacity.

For newly developed genotypes, trials should be run on planting dates, spacing, planting densities and fertilization (inorganic vs. organic).

Improved production technologies should be developed, such as appropriate mechanization for land preparation, sowing, cultivation/weeding, harvesting and threshing. Production packages specifically for *belg* season production in different regions are required. On-farm verification of improved technologies will be necessary in different agroecological zones.

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Discussion

Dr Asnakene
At Holetta there is a large variation in yield from one year to the other. Reasons for such a variation should have been narrated.

Ato Amare
These are related to early and late sowing of the crop which is chiefly due to rains. The early sown crop is invariably attacked by diseases whereas the late-sown crop is hit by frost.

Ato Kiflu
It is known that legumes fix nitrogen and also leave N for the subsequent crop. How much N do they leave and what is the residual N? We need to know this to know how much to apply to the subsequent crop. Is there a study on this issue?

Ato Amare
No research has been done on how much N is left for subsequent crops under Ethiopian condition, but research results indicated that including legumes in rotation is advantageous. Yields of cereals following legumes increased compared with cereals after cereals. In fact, the issue is related more to a soil fertility study which needs further investigation.

Dr Eylachew
Does your seeding rate recommendation include the viability of seeds?

Ato Amare
Yes, the recommendation of seeding rates includes the viability of seeds. Seeding rates ranging from 180 to 250 kg/ha for faba bean have been recommended based on seed size and considering the viability of seeds (i.e., more than 80% germination capacity). The smaller the seed size, the lower the recommended seeding rate and vice versa.

Dr Eylachew
The closest spacings would lead to competition but your results showed the reverse; why is that?

Ato Amare
The crop doesn't have a flowering problem; rather, shedding is the major constraint. The crop is sensitive to plant density. It compensates for the shedding of flowers and pods by increased number of plants per unit area.

Dr Saxena
Plant stands at harvest should be recorded and be given due consideration while interpreting the data. The optimum plant populations may be worked out for different situations.

Chickpea and Lentil Agronomy Research

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Abstract

Chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) are important cool-season food legumes and rotation crops in Ethiopia. Beginning in the late 1960s agronomic trials were conducted at the different research centers located in chickpea and lentil-growing areas. Sowing date experiments indicated that the optimum sowing dates for chickpea and lentil vary with location and depend upon site-specific seasonal rainfall and the maturity period of specific chickpea cultivars. Seeding rate studies on chickpea showed no or minimal yield differences. However, it is reasonable to use seeding rates high enough to ensure good plant stand even under adverse environments for seedling growth. With this consideration in mind, seeding rates of 70-80 kg/ha have been recommended for chickpea. Little work has been done on the response of chickpea to fertilizer application. The use of broad bed and furrows (BBF) for chickpea was found more advantageous than the flat seedbed on Vertisols, but chickpea showed no marked response to the various production practice combinations in the country. For lentil, sowing from the last week of June to mid-July is advantageous over later dates. For broadcast seeding, a seeding rate of 50-60 kg/ha for small-seeded and 65-75 kg/ha for large-seeded lentil cultivars is optimum. Fertilizer application on lentil had no marked effects on seed yield of lentil. A seedbed preparation study on lentil indicated that BBF surface drainage practice was more effective in draining excess water than the farmers' practice, ridge and furrows conventional drainage. Production practice combinations showed no marked effects on lentil.

Introduction

Chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) are important cool-season food legumes in Ethiopia and are mainly cultivated between 1700 and 2400 m asl where the mean annual rainfall ranges from 700 to 2000 mm (Westphal 1974). Among the highland pulses, these crops have occupied a prominant place in terms of production and hectarage. Prior to 1975, chickpea was the number one pulse crop followed by faba bean (*Vicia faba* L.), lentil and field pea (*Pisum sativum* L.). Later on, however, the area and production of these crops declined. Presently, chickpea and lentil rank second and fourth in production and hectarage, respectively (CSA 1990).

Chickpea and lentil are predominantly grown as rain-fed crops mainly on the Vertisols of the central, northern, northwestern, southern and eastern highlands. Chickpea is generally raised on the conserved soil moisture, beginning from September to October, depending upon the growing environment of specific locations. Lentil is planted much earlier than chickpea and therefore does not face moisture stress as does chickpea. However, yield fluctuations are common due to the rainfall intensity and distribution. In general, the bulk of chickpea and lentil production in the country comes from farmers' fields where poor agronomic management practices are exercised.

Research on the agronomic aspects of chickpea and lentil began in the late 1960s and early 1970s in the central highlands of the country. During the past three decades, different aspects of agronomic problems of the crops have been investigated to develop a package of production practices. So far, it has not been possible to cover the whole range of agroecological zones in which the crops are grown. Within this background, this paper reviews the agronomy research of chickpea and lentil in Ethiopia.

Chickpea

Production Practices

Chickpea is mainly grown in the central, north, northwest, south and eastern highlands of Ethiopia. In the north and central highlands, the predominantly desi type of chickpea has been in cultivation since ancient times and is of considerable economic importance. The crop has, however, only recently been introduced in the south and is of minor importance there. The crops with which chickpea is commonly rotated in Ethiopia include tef (*Ergrostic tef*), barley (*Hordeum vulgare*) and wheat (*Triticum* spp.) and it is grown on stored soil moisture after the end of the rainy season on clay soil with neutral to alkaline pH. The chickpea in this area is generally grown as a sole crop (Smithson *et al.* 1985) along with grain cereals. In Yerer and Keryu highlands of Shewa, barley and sorghum are sown during the small rainy season (March to April), followed by chickpea and horse bean, and in July quite often by other crops (Westphal 1974). In the southwest, chickpea is mainly rotated with wheat, whereas in part of Tigray and Welo, northern Ethiopia, irrigated chickpea is frequently grown as a second crop after cereal harvest (Westphal 1974). Mixtures of chickpea and other crops also can be seen in the country. According to Westphal (1974), the most common mixtures in Gonder region are chickpea/sorghum and chickpea/safflower, whereas in Harerge region, the mixture of chickpea/sweet potato is common. Chickpea is also grown in mixture with groundnuts in eastern regions, with safflower in the central highlands of Ethiopia, and with noug (*Guzoita abyssinica* L.) in the Gonder region (Geletu and Abebe 1993).

In the northeast (Chercher highlands) and central Ethiopia, where chickpea-growing fields on Vertisols remain waterlogged during the main rainy season (June to August), chickpea is mainly sown after this season (end of September), and harvesting takes place in or around January (Westphal 1974). In part of northern Ethiopia (Tigray and western Welo) where the soils have been extensively used and eroded for many centuries, the crop is planted in July (Geletu 1980). This has been attributed to the poor nutritional status of the soils and shorter growing rainy season than in the central highlands of Shewa and Gojam administrative regions. In Yerer and Keryu highlands of Shewa a second chickpea crop is sown on the same field after the onset of small rains at the end of April.

In most cases, a flat seedbed and broadcast seeding are used for the crop. Chickpea is planted by using a local plow, which is pulled by oxen or tractor. The use of tractors, however, is limited since on most chickpea-growing fields these soils are very sticky and not easy to work with. Chickpea is usually harvested by pulling out the mature plant by hand, and then threshed by driving oxen over the produce.

Sowing Date

Sowing date is an important factor in optimizing the seed yields of chickpea. Optimum date varies among locations and is dependent upon both the pattern and total amount of rainfall and on maturity period of the specific chickpea cultivar. Sowing date experiments on chickpea were carried out in the early and mid-1970s at the Debre Zeit Agricultural Research Center (DZARC). In the first experiment (1972-73), where three sowing dates (starting on 1 September at 10-day intervals) and six different cultivars were involved, the earliest planting date across all the cultivars showed a 35% yield advantage over the later two sowing dates (Table 1). However, no statistically significant evidence was given for the results. Results from two subsequent studies further showed that the optimum sowing date for a medium-maturing chickpea cultivar on black soils was September 9 (IAR 1974), whereas in light soils, the optimum sowing time for medium- to late-maturing cultivars was from 21 July to August (IAR 1976).

Table 1. Seed yield (t/ha) of six chickpea cultivars planted on three dates at Debre Zeit.

	Planting date			
Cultivar	1 Sept	10 Sept	20 Sept	Mean
Dubie	4.24	3.29	3.26	3.60
DZ-10-11	4.82	3.14	3.08	3.67
DZ-10-2	4.67	3.80	3.46	3.98
24-B	4.34	3.08	3.41	3.61
H-26-12	4.17	3.12	2.85	3.58
4-54-10	3.64	4.07	3.30	3.48
Mean	4.48	3.41	3.22	3.70

Source: DZARC 1972-73.

A series of experiments was conducted during 1978-81 at DZARC to examine the effects of dates of planting on the yields of three chickpea cultivars. The results (Table 2) have shown that higher yields can be obtained when chickpea is planted from early August to early September at Debre Zeit, provided that the cultivars are tolerant or resistant to root-rots and wilt diseases. Delaying the sowing time beyond this limit resulted in a 50% reduction in seed yields (Geletu and Abebe 1982).

The responses of chickpea to planting dates have been studied at other chickpea-growing locations. In one season at Mekele, of the five sowing dates (beginning in early July at 14-day intervals) the earliest planting date (1 July) was best to grow chickpea (IAR 1974). Likewise, the results from one season of sowing dates showed that the optimum sowing times at Chefe Donsa and Akaki locations were 3 August and 12 September, respectively (DZARC 1977-82). However, no statistical analysis was presented to substantiate the results.

Table 2. Grain yield (t/ha) of three chickpea genotypes as affected by date of planting at Debre Zeit.

	Genotype			
Planting date	NEC-756	DZ-10-2	Dubie	Mean
1978†				
31 July	5.34	4.28	2.23	3.95
14 Aug	5.09	3.16	3.51	3.92
29 Aug	4.67	4.32	2.33	3.77
14 Sept	3.65	3.29	2.58	3.17
28 Sept	2.74	1.96	2.00	2.23
Mean	4.30	3.40	2.53	
1980‡				
15 Aug	1.62	1.68	1.42	1.57
25 Aug	1.95	2.11	1.71	1.93
5 Sept	1.00	1.15	0.43	0.86
15 Sept	0.92	0.89	0.58	0.80
28 Sept	0.24			
Mean	1.15	1.46	1.04	
1981§				
18 Aug	3.12	2.13	1.80	2.35
28 Aug	2.06	2.04	1.67	1.92
7 Sept	2.36	2.34	1.87	2.19
17 Sept	2.23	2.16	1.50	1.96
Mean	2.45	2.17	1.71	

† LSD at 5% for cultivars = 1.23; LSD at 5% for dates = 0.82.
‡ LSD at 5% for cultivars = 0.43; LSD at 5% for dates = 0.41.
§ LSD at 5% for cultivars = 0.18; LSD at 5% for dates = 0.25.
Source: Geletu and Abebe 1982.

Seeding Rate

Optimum planting density for chickpea appears to differ from location to location depending upon the growing environment. Seeding rate studies on chickpea were carried out in the late 1970s and early 1980s at Debre Zeit and Akaki stations. In a two-season (1978 and 1979) seeding rate study, with nine seeding rates (50-85 kg/ha with 5 kg/ha intervals) and three chickpea cultivars (DZ-10-2, NEC-756 and Dubie), the seeding rates (across all cultivars) showed no marked differences for the seed yield studied at Debre Zeit (Table 3). Results from another two-season (1980 and 1981) seeding rate study further indicated that seeding rates had no significant effect on chickpea seed yields at Debre Zeit (DZARC 1977-82). Results from a 1981/82 seeding rate study further showed that the seeding rate effects on the seed yield of chickpea were nonsignificant at Akaki (DZARC 1977-82). However, it was found reasonable to use high seeding rates to ensure good plant stand under adverse environments. With this consideration in mind, seeding rates between 65 and 85 kg/ha have been recommended for chickpea (Million and Beniwal 1988). In an experiment where the effects of row spacings (20, 40 and 60 cm) on yields of two chickpea cultivars (1701 and C410) were examined, the highest yields for both cultivars were obtained from 40 and 60 cm spacings (CADU 1969). This could be attributed to the better elasticity of the genotypes used. However, our experience with cultivar Mariye (medium seed size, 100-seed weight = 22-26 g) showed that even the 100 kg/ha seeding rate often resulted in low plant populations.

Table 3. Seed yield (t/ha) of chickpea genotypes as affected by seeding rate at Debre Zeit.

	Genotype							
Seeding rate	DZ-10-2		NEC-756		Dubie		Mean	
(kg/ha)	1978	1979	1978	1979	1978	1979	1978	1979
50	0.87	1.87	1.09	3.24	0.93	1.13	0.96	2.08
55	1.19	1.69	1.25	3.08	1.15	2.05	1.20	2.27
60	1.22	1.60	0.77	3.19	1.22	1.49	1.07	2.09
65	1.28	1.63	1.22	3.34	1.71	2.05	1.40	2.34
70	1.02	2.36	1.09	3.17	0.88	1.54	1.00	2.35
75	0.71	1.85	1.05	3.20	0.90	1.60	0.89	2.22
80	1.32	2.80	1.07	3.03	1.19	2.46	1.19	2.76
85	0.96	2.42	1.31	2.83	1.15	2.03	1.14	2.43
Mean	1.07	2.03	1.11	3.13	1.14		1.79	
LSD (5%)	1978	1979						
Genotype	NS	0.34						
Rate	0.87	NS						
Interaction	NS	NS						

Source: DZARC 1977-82.

Response to Fertilizer

Not much work has been done on the response of chickpea to fertilizer applications. In a one-season experiment at Debre Zeit, where three rates and two sources of phosphorus (DAP and TSP) were used, the different rates of P_2O_5 showed no marked effect on the seed yield (Table 4). However, chickpea seed yields showed a trend of increasing as the level of phosphate increased. Despite the above facts, the use of 100 kg/ha DAP (diammonium phosphate) was recommend as optimum for chickpea in the country (Million and Beniwal 1988).

Table 4. Response of chickpea to rate and source of phosphate fertilizer, Debre Zeit, 1978/79.

Fertilizer rate (kg P_2O_5 /ha)	Source	Yield (t/ha)
30	TSP	1.47
30	DAP	1.45
60	TSP	2.12
60	DAP	1.78
90	TSP	1.93
90	DAP	1.94
Check (no fertilizer)		1.91
Mean		1.91
LSD (5%)		N.S
CV (%)		48

Source: DZARC 1977-82.

Seedbed Preparation

An experiment involving surface (cambered and open trench) and subsurface (trench filled with eucalyptus poles) drainage systems with three drainage spacings (4, 6 and 8 m), three cultivars and two levels of fertilizer (no application and recommended rates) was carried out for 3 years (1975-77) at

Ginchi. Improved drainage increased yields of chickpea by 56% under fertilization and by 44% under unfertilized conditions (Table 5). Average seed yields from drained plots were generally higher than those from the undrained ones (Table 6). The widest drainage spacing (8 m) appeared to be suitable for chickpea (Hiruy 1987).

Table 5. The influence of fertilizer on the grain yield (t/ha) of chickpea cultivars grown under drained and undrained conditions at Ginchi, 1975-77.

	Undrained		Drained		
Cultivar	F0	F1	F0	F1	Cultivar mean
41B	0.93	0.93	1.40	1.40	1.17
Local	0.76	0.86	1.03	1.30	1.01
Mean	0.85	0.90	1.20	1.40	1.09

F0 and F1 denote unfertilized and fertilized with 100 kg DAP/ha, respectively.
Source: Hiruy 1987.

Table 6. The influence of drainage systems on the grain yield (t/ha) of chickpea cultivars grown at Ginchi, 1975-77.

Cultivar	Camber bed	Open trenches	Subsurface drains	Control
41B	1.34	1.23	1.63	0.93
Local	1.16	1.17	1.32	0.81
Mean	1.25	1.20	1.40	0.87

Source: Hiruy 1987.

A seedbed preparation study using moldboard plow + disk harrow, chisel plow + disk harrow, disk plow + disk harrow and local plow on the Vertisols of Ginchi showed that the highest yield of chickpea was obtained from seedbeds prepared by the local plow (IAR 1977). An experiment was conducted for two seasons (1989-91) on farmers' fields at Akaki and Keteba to assess the impact of improved drainage practice (broad bed and furrows, BBF) under early sowing conditions, as opposed to planting on flat land late in the season, on yield of chickpea grown on Vertisols. The mean of the 2 years' results revealed that the use of BBF increased grain and straw yields of chickpeas significantly at both Akaki and Keteba. Grain and straw yield increments of 120 and 63% at Akaki and of 94 and 93% at Keteba were obtained by using the BBF land preparation method, compared with the traditional farmers' practice of flat planting late in the season (DZARC 1990).

Interaction among Agronomic Factors

Studies on the effects of combined agronomic factors were carried out in the early 1970s at Welenkomi research site. In one of these experiments, the effects of the main factors as well as the interaction of three sowing dates (6 and 20 September and 4 October), two insecticides (Aldrin and Thiram) and two chickpea cultivars (Welenkomi local and DZ-10-2) on seed yield and plant density of chickpea were examined. The sowing dates, unlike the other treatments, showed significant differences for seed yield (Table 7).

Table 7. Sowing date, seed dressing and chickpea cultivar trial at Welenkomi, 1972.

		Yield (t/ha)				Plants/m²		
		Sowing date				Sowing date		
Cultivar	Seed dressing	6 Sept	20 Sept	4 Oct	Mean	6 Sept	20 Sept	Mean
Welenkomi local	Nil	1.33	1.10	0.37	0.93	48	52	50
	Aldrin	1.48	1.50	0.46	1.14	57	45	51
	Thiram	1.45	1.38	0.22	1.02	43	47	45
	Mean	1.42	1.32	0.35		49	48	
DZ-10-2	Nil	1.89	1.37	0.22	1.16	51	43	47
	Aldrin	1.69	1.27	0.47	1.14	46	44	45
	Thiram	1.74	1.21	0.30	1.09	47	43	45
	Mean	1.77	1.28	0.33		48		

Source: IAR 1973.

In a similar experiment where two methods of planting (broadcast and drill), two chickpea cultivars (DZ-10-1 and DZ-102) and three planting densities (12.5, 25 and 50 plants/m^2) were involved, planting density significantly influenced seed yield. The highest seed yield (2.14 t/ha) was obtained from the highest planting density (50 plants/m^2) (Table 8). Neither the planting methods nor the interactions (planting density × planting methods, planting density × cultivar and planting method × density) had a great influence on the seed yield at Welenkomi. The mean differences for the planting methods and cultivars were found to be nonsignificant; interactions also were nonsignificant.

Table 8. Seed yields (t/ha) of chickpea cultivars in a planting density by planting methods trial, Welenkomi, 1973.

Planting method	Cultivar	Planting density (plants/m^2)			
		12.5	25	50	Mean
Broadcast	DZ-10-1	1.13	1.42	1.93	1.49
	DZ-10-2	1.40	1.40	2.23	1.68
	Mean	1.26	1.41	2.08	1.59
Drill	DZ-10-1	1.00	0.85	2.14	1.33
	DZ-10-2	0.60	1.31	2.14	1.35
	Mean	0.80	1.09	2.14	1.34

Source: IAR 1976.

An experiment dealing with sowing date and seeding rate interactions was undertaken in the early 1980s at DZARC. The results of 2 years' studies showed that the seed yield was greatly influenced by sowing date effects (DZARC 1982, 1983). The seeding rate and planting date interaction, however, was nonsignificant. In a similar study where the effects of sowing dates and seeding rates on seed yield of two chickpea cultivars were examined for three consecutive years (1986-88), the results revealed that the period up to 18 August appeared to be optimum for planting chickpea on the Vertisols of Akaki and Debre Zeit (Table 9). The results further indicated that a seeding rate of 65-85 kg/ha is sufficient, the higher rates being recommended for areas where soil-borne diseases pose a threat to the survival of seedlings. However, the mean differences for seeding rates were nonsignificant at both locations as were the differences for seeding rate × sowing date and seeding rate × cultivar interactions.

Table 9. Mean yield (t/ha) of chickpea cultivars as influenced by dates and rates of sowing at two locations, 1986-88.

Location and cultivar	Date	Seeding rate (kg/ha) 65	75	85	Mean
Debre Zeit					
Mariye	12-18 Aug	1.85	1.79	2.04	1.89
	23-28 Aug	1.72	1.97	1.77	1.82
	2- 8 Sept	1.38	1.47	1.47	1.44
	13-18 Sept†	1.38	1.06	1.16	1.20
	Mean	1.58	1.57	1.61	
JG-62 × Radhy	12-18 Aug	1.54	1.77	1.75	1.68
	23-28 Aug	1.68	1.53	1.70	1.64
	2- 8 Sept	1.40	1.32	1.50	1.41
	13-18 Sept†	1.26	1.40	1.57	1.41
	Mean‡	1.47	1.50	1.63	
Akaki					
Mariye	14-16 Aug	2.36	2.22	2.46	2.35
	22-27 Aug	1.74	1.93	2.20	1.96
	6- 7 Sept	1.79	1.57	1.99	1.78
	15-17 Sept	1.49	1.31	1.27	1.33
	Mean§	1.83	1.90	1.78	

† Mean of 2 years only.
‡ LSD (1%) for dates = 0.71; LSD (5%) for cultivar × dates = 0.46 (significant only in 1986).
§ LSD (1%) for dates = 0.92.
Source: DZARC 1990.

In another study where the main effects as well as the interactions of three planting dates (beginning in early August at 10-day intervals) and three seedbed types (BBF, ridge and furrows (RF) and flat) on yields of chickpea were examined, early planting was associated with increased seed yields in all of the seedbed types studied at Debre Zeit and Akaki (DZARC 1991). The combined statistical analysis showed that dates affected seed yield significantly while the seedbed types had no significant influence on seed yield. The interaction effect of seedbeds and planting dates, however, was nonsignificant.

The response of chickpea to the combinations of various agronomic variables was studied in the early 1990s. In one such study, where the main effects and interaction of four sowing dates and three seedbed types (BBF, RF and flat) on yield and other characters of the crop were examined, the seed and biological yields of chickpea were substantially increased as a result of early sowing at the three locations (Million 1993). The results from this study further showed that the seed yield of chickpea was greatly influenced by the seedbed effects. Compared with that of the flat bed, the mean seed yield of BBF-grown chickpea showed a 42 and 21% seed yield advantage at Akaki and Ejere, respectively. No marked interaction effects were obtained in the study. The response of broadcast chickpea to seeding rates and cultivars was studied in an experiment conducted at Debre Zeit and Akaki. The results from both locations (Table 10) indicated that neither seed yield nor the other characters of chickpea were greatly influenced by the seeding rates, cultivars and interaction effects. Likewise, the results of two years (1991-92) of study on the Vertisols of Debre Zeit and Akaki revealed that seeding rate, except at Akaki in 1991, had no considerable effect on seed yields of chickpea grown on BBF and RF plots (Table 11).

Table 10. Effect of seeding rates on seed yield (t/ha) of broadcast planted chickpea cultivars at two locations, 1991/92.

Location and cultivar	Seeding rate (kg/ha) 70		80		90		100		Mean	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
Debre Zeit†										
Mariye	2.28	1.16	1.85	1.13	1.62	1.14	1.32	1.37	1.72	1.20
DZ-10-11	1.98	2.23	1.74	1.99	1.69	1.86	1.69	2.23	1.78	2.08
Mean	2.14	1.71	1.70	1.56	1.56	1.66	1.50	18.0	1.75	1.59
Akaki‡										
Mariye	2.42	2.72	1.92	2.82	1.70	2.35	2.19	2.60	2.01	2.62
DZ-10-11	2.13	3.25	2.30	3.15	2.90	2.94	2.01	3.08	2.37	3.11
Mean	2.27	2.98	2.11	2.98	2.30	2.64	2.10	2.84	2.19	2.86

† SEM (seed yield)	**1991**	**1992**	‡ SEM (seed yield)	**1991**	**1992**
Seeding rate	0.24	0.15	Seeding rate	0.51	0.18
Cultivar	0.15	0.10	Cultivar	0.23	0.14
Interaction	0.34	0.21	Interaction	0.39	0.25
CV (%)	38.6	26.1	CV (%)	34.0	17.7

Source: DZARC, unpublished data, 1991-92.

Table 11. Effect of seeding rates and seedbed types on seed yield (t/ha) of chickpea at two locations, 1991/92.

Location and seedbed	Seeding rate (kg/ha) 70		80		90		100		Mean	
	1991	1992	1991	1992	1991	1992	1991	1992	1991	1992
Debre Zeit†										
BBF	1.26	2.69	1.09	2.85	0.66	2.96	1.23	2.92	1.06	2.85
RF	2.14	2.21	1.14	2.48	1.29	2.41	1.75	2.20	1.58	2.33
Mean	1.70a		1.11c	2.67	0.97c	2.59	1.49ab	2.56		
Akaki‡										
BBF	3.03	3.65	2.77	3.62	2.65	3.44	2.46	4.07	2.60	3.70
RF	3.12	2.84	2.60	3.09	2.29	3.53	3.14	3.14	2.79	3.12
Mean	3.08	3.25	2.44	3.36	2.47	3.49	2.80	3.61		

† SEM (seed yield)	**1991**	**1992**	‡ SEM (seed yield)	**1991**	**1992**
Seeding rate	0.09	0.14	Seeding rate	0.19	0.16
Seedbed	0.16	0.10	Seedbed	0.29	0.08
Interaction	0.08	0.19	Interaction	0.42	0.23
CV (%)	33.3	14.9	CV (%)	30.8	13.4

Source: DZARC, unpublished data, 1991-92.

Lentil

Production Practices

Lentil is predominantly grown as a rain-fed crop like chickpea, but is planted much earlier than chickpea, and therefore does not face moisture stress. Cultivation of lentil in Ethiopia is generally limited to higher regions, in Begemdir, Semen, Gojam and Shewa, where the crop is sown with the onset of rains in June and harvested in October (Saxena 1981). In Yerer and Keryu highlands of Ethiopia, where the crop is grown under rain-fed conditions, the growing seasons are April to July and September to December (Westphal 1974). Double cropping is practised in parts of Ethiopia where lentils are often planted in *wyndega* as a second crop after the harvest of wheat and barley (Westphal 1974).

The bulk of lentil production in the country comes from farmers' field where traditional production practices are used. Flat and/or ridge and furrow seedbeds, oxen-drawn local *maresha* for land preparation and broadcast seeding are used by farmers. Planting, weeding and harvesting of lentil in Ethiopia are mostly done manually.

Sowing Date

Sowing date is an important agronomic variable in optimizing the seed yields of lentil. Optimum date varies with location and is dependent upon both the meteorological conditions and the specific lentil cultivar. Sowing date experiments on lentil were carried out in the late 1970s and early 1980s at several sites of DZARC and the Institute of Agricultural Research (IAR). In the first experiment, where six sowing dates (starting 6 August at 10-day intervals) and two lentil cultivars (small- and large-seeded) were involved, the second fortnight of August was found best for planting lentils at Welenkomi area (IAR 1976). A later study at Kulumsa, on the other hand, showed that the mid-July planting was the optimum time for growing lentils in that area (DZARC 1977-82).

In a similar experiment, where the main and interaction effects of sowing dates and cultivars were examined for two consecutive years (1978 and 1979) at Debre Zeit, the late June to early July planting was more advantageous than the late sowing (Table 12). At Akaki, the results of a two-season (1979 and 1980) study further indicated that the late June to mid-July planting was the optimum time for both small- and large-seeded lentils (Table 12). In a similar study, where the main as well as the interactive effects of sowing dates and cultivars were examined, planting lentils from late June to early July was advantageous over later sowings under Ejere conditions (Table 12). The study carried out during the 1982/83 cropping season further indicated that the second fortnight of July was the optimum time for planting exotic lentils at Chefe Donsa (DZARC 1977-82). The effect of planting date on yields of different lentil cultivars also was studied in the IAR sites. In the experiment (1982-84) where five sowing dates (beginning in early July at 10-day intervals) and local and exotic lentil cultivars were used, the early July to mid-August planting was optimum for planting the local and exotic lentils, at Tefki (Table 13) and Inenwari (Table 14). In general, it can be concluded that the late June to mid-July planting was the optimum time for planting lentils in the central highland areas of the country.

Table 12. **Seed yield (t/ha) of different lentil cultivars as affected by sowing dates at three locations, 1978-80.**

Location and sowing date	Cultivar					
	EL-142		R-186		Mean	
Debre Zeit†	**1978**	**1979**	**1978**	**1979**	**1978**	**1979**
23 June	1.98	1.33	0.66	1.31	1.32	1.32
7 July	2.07	1.06	0.91	1.09	1.49	1.09
21 July	1.65	0.71	0.91	0.55	1.28	0.58
13 Aug	1.05	0.19	0.69	0.29	0.87	0.24
27 Aug	0.22	0.04	0.15	0.77	0.19	0.06
Mean	1.39	0.66	0.66	0.65		
Akaki‡	**1979**	**1980**	**1979**	**1980**	**1979**	**1980**
30 June	0.68	0.95	0.91	1.18	0.79	1.07
15 July	0.85	0.63	0.89	0.87	0.87	0.76
29 July	0.41	0.91	0.48	0.73	0.45	0.82
13 Aug	0.26	0.56	0.52	0.36	0.39	0.46
26 Aug	0.16	0.32	0.69			
Mean	0.47	0.68				
Ejere§	**1978**	**1979**	**1978**	**1979**	**1978**	**1979**
29 June	0.73	0.21	1.71	0.64	1.22	0.42
9 July	0.79	0.37	2.23	0.57	1.51	0.47
19 July	0.75	0.23	1.64	0.50	1.20	0.37
29 July	0.67	0.08	1.63	0.33	1.15	0.21
9 Aug	0.21	0.10	0.89	0.12	0.55	0.11
Mean	0.63	0.02	1.62	0.43		

† LSD (5%)	1978	1979
Cultivars	0.38	-
Dates	0.59	-

‡ LSD (5%)	1979	1980
Cultivars	NS	NS
Dates	0.13	0.28
Interaction	0.33	0.40

§ LSD (5%)	1978	1979
Cultivars	0.52	0.10
Dates	0.42	0.01
Interaction	-	0.01

Source: DZARC 1977-82.

Table 13. Seed yields (t/ha) of lentil cultivars NEL-358 and EL-142 as influenced by sowing dates at Tefki, 1983/84.

Date	NEL-358	EL-142	Mean
7 July	1.46	1.86	1.66
31 July	1.18	1.81	1.50
10 Aug	1.54	1.60	1.57
19 Aug	1.26	1.51	1.39
31 Aug	0.64	1.31	0.97

LSD (5%) for dates= 0.42.
Source: DZARC 1990.

Table 14. Seed yields (t/ha) of lentil cultivars NEL-355, NEL-358 and EL-142 as affected by sowing dates at Inenwari, 1982/83.

Date	NEL-358	NEL-355	EL-142	Mean
7 July	2.58	2.60	1.84	2.35
30 July	2.71	2.59	2.14	2.48
6 Aug	2.64	2.71	2.22	2.52
16 Aug	2.25	2.32	2.13	2.23
26 Aug	1.88	1.83	1.43	1.71
Mean	2.41	2.41	1.95	

LSD (5%) for dates = 0.23; LSD (5%) for cultivars = 0.18.
Source: DZARC 1990.

Seeding Rate

Optimum sowing density of lentil appears to differ from location to location depending upon the growing conditions. Seeding rate studies, like those of sowing dates, were carried out in the late 1970s and early and mid-1980s at several sites of DZARC and IAR. The first seeding rate study on lentil was at Kulumsa, followed by studies at Debre Zeit and Chefe Donsa. Results from Kulumsa in 1978 indicated that the highest seed yield of lentil was obtained from the middle two seeding rates (50-55 kg/ha) (DZARC 1977-82). In the other one-season (1980/81) study where 10 seeding rates (starting from 35 kg/ha with 5 kg/ha intervals) and two cultivars of lentils (EL-142 and EMT-66) were involved, however, the seeding rates showed no marked differences for the seed yield at Debre Zeit (DZARC 1977-82). In 1981/82, when the main as well as the interaction effects of 10 seeding rates (35-80 kg/ha with 5 kg/ha intervals) and two lentil cultivars (EL-142 and NEL-360) on seed yield of lentil were examined, the highest seed yields at Debre Zeit and Chefe Donsa sites, respectively, were obtained from 70 and 75 kg/ha seeding rates (DZARC 1977-82). The mean differences for the seeding rates were found to be nonsignificant at each of these locations. Thus, variation in seeding rate seems unimportant at the locations considered. In similar studies (1985-87), where five seeding rates and two cultivars of lentils were involved, neither the main factors nor their interaction showed marked effects on the seed yield studied at Debre Zeit and Akaki locations (Table 15). In this study, however, the use of 70 kg seed/ha was advantageous over the other seeding densities. On the basis of the above results, it has been concluded that a seeding rate of 50-65 kg/ha for small-seeded and 65-75 kg/ha for large-seeded lentil cultivars is optimum, for broadcast seeding of lentil (Million and Benwal 1988).

Table 15. Seed yields (t/ha) of lentil cultivars NEL-355 and NEL-358 as influenced by seeding rates using row sowing at Debre Zeit and Akaki, 1985-87.

Seeding rate (kg/ha)	NEL-355	NEL-358	Mean
50	1.27	1.03	1.15
60	1.21	1.08	1.14
70	1.21	1.28	1.25
80	1.13	1.21	1.17
90	1.31	1.18	1.24
Mean	1.23	1.16	

Source: DZARC 1990.

Response to Fertilizer

Not much work has been done on the response of lentil to fertilizer application. Nevertheless, in one study where three rates (45, 90 and 135 kg/ha) and two sources of P_2O_5 (TSP and DAP) were used, neither the rates nor the sources showed marked differences for seed yield at Debre Zeit (Table 16). Although neither supported nor confirmed by the research results, the use of 100 kg/ha of DAP has been recommended as optimum for lentil (DZARC 1977-82).

Table 16. Effect of rate and source of phosphate fertilizer on seed yields of lentil at Debre Zeit.

Fertilizer rate (kg P_2O_5/ha)	Source	Yield (t/ha)
45	TSP	0.51
90	TSP	0.47
135	TSP	0.58
45	DAP	0.63
90	DAP	0.63
135	DAP	0.42
Control		0.51
Mean		0.53
LSD (5%)		NS

Source: DZARC 1977-82.

Seedbed Preparation

The method of seedbed preparation has a profound affect on seed yields of lentils on Vertisols. In an experiment where the effects of seedbed types, i.e., broad bed and furrow (BBF) and ridge and furrow (RF), on seed and straw yields of lentils were examined for two consecutive years (1989/90 and 1990/91), the BBF method was more effective in draining excess water than the farmers' ridge and furrows method. At all the locations, highly significant grain and straw yield increases were obtained by planting lentil on BBF. The BBF planting gave 59, 102 and 99% seed yield and 28, 27 and 59% straw yield increases at Akaki, Dibandiba and Keteba, respectively (Table 17).

Table 17. Seed and straw yields of lentil as affected by drainage systems at three locations, 1989/90 and 1990/91.

Location†	Seedbed‡	Grain yield (t/ha)	Increase (%)	Straw yield (t/ha)	Increase (%)
Akaki	BBF	2.32b	59	4.65a	28
	RF	1.46a		2.63a	
	LSD (1%)	0.48		NS	
	CV (%)	9.5		22	
Dibandiba	BBF	1.87b	102	4.35b	27
	RF	0.92a		3.42a	
	LSD (5%)	0.28		0.51	
	CV (%)	7.5		5.0	
Keteba	BBF	1.61b	99	4.88b	59
	RF	0.81a		3.07a	
	LSD (1%)	0.26		1.14	
	CV (%)	7.9		10.6	

† For each location, mean values within a variable (grain or straw) followed by the same letter are not statistically different at P=1%.
‡ BBF = broad bed and furrows; RF = ridge and furrows.
Source: DZARC 1991.

Combinations of Agronomic Variables

The responses of lentils to a combination of agronomic variable have been examined. In one study (in 1972), where three planting densities (20, 40 and 60 plants/m^2), two planting dates (8 and 20 September) and five cultivars of lentils (Ethiopian small brown, Debre Zeit large, Jack Robit, Italian large and Welenkomi local) were used, the earlier sowing date (8 September), compared with the later, gave better yields for all the cultivars studied at Welenkomi (IAR 1972). The results from this study further indicated that 60 plants/m^2 was the optimum planting density for the top-yielding cultivars: Ethiopian small brown and Welenkomi local. Of all sowing dates and planting density combinations, early planting with higher planting density gave the best yield, at Welenkomi. Nevertheless, no statistical analysis has been done for the results obtained at Welenkomi. In a similar study, which consisted of two sowing dates, three seeding rates and four cultivars, the use of higher seeding rates and early planting resulted in appreciable increase in seed yield of lentil (IAR 1973).

In subsequent studies, where the main and interaction effects of sowing dates and seeding rates were examined for two seasons (1981/82), neither the seeding rate nor seeding rates × date interaction showed significant influence on the seed yield of lentil, at Debre Zeit (DZARC 1977-82). However, sowing date effects on seed yield were significant at Debre Zeit for the seasons considered. Likewise, the results from three seasons (1984-87) at Debre Zeit and Akaki showed that the seeding rates, cultivars (except in 1987) and interaction effects on seed yield of lentil were nonsignificant at both locations (Table 18). By involving two cultivars (EL-142 and NEL-358) and two seedbed types (flat, and RF) DZARC showed a 65% seed yield advantage on RF plots, compared with flat plots, at Akaki. In a similar experiment in 1989, where three sowing dates (starting on 12 July at 20-day intervals) and three seedbed types (BBF, RF and flat) were involved, neither the seedbeds nor seedbed × sowing date interaction significantly influenced seed yield at Debre Zeit and Akaki locations (DZARC 1990).

Table 18. Seed yields (t/ha) of two broadcast-sown lentil cultivars as affected by five seeding rates at two sites, 1984, 1986/87.

Seeding rate (kg/ha)	Debre Zeit			Akaki		
	EL-142	NEL-358	Mean	EL-142	NEL-358	Mean
30	1.19	0.80	0.99			
50				1.05	1.72	1.39
60	1.22	0.80	1.01	1.20	1.72	1.46
70	1.06	0.86	0.96	1.23	1.68	1.46
80	1.01	0.90	0.96	1.12	1.83	1.48
90	1.12	0.89	1.01	1.15	1.87	1.51
LSD (5%)			NS			NS

Source: DZARC 1990.

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Discussion

Dr Tekalegne
At Debre Zeit a study was conducted on why chickpea or lentil don't respond to phosphorus. The reason was waterlogging. But, even after removing waterlogging, there was no response to phosphorus. So, further studies are needed.

Dr Saxena
Work carried out elsewhere shows that P requirements for legumes are quite low. If the available P in the soil is sufficient, response to P can't be expected.

Dr Asnakene
There is a general recommendation of 100 kg DAP/ha for lentil and chickpea. In view of there being no response of these crops to fertilizer do we still need to recommend this dose?

Ato Million
No. We have not recommended this in our case, and we are still verifying.

Weed Research in Cool-season Food Legumes

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Abstract

Weeds occurring in faba bean, field pea, lentil and chickpea cause a major production loss in these cool-season food legumes (CSFL). Available survey records indicated that there are up to 61 weed species in 47 genera and 20 plant families known to be problematic on CSFL. Of the species recorded, 17 are the most troublesome and widespread. These include annual and perennial grasses and broadleaves. The critical period of weed competition in CSFL varies from 3 to 8 weeks after crop emergence. Faba bean and lentil are very sensitive to weed competition from seedling establishment to early flowering stage. Hence, two properly timed hand-weedings within 6 weeks after planting for faba bean and lentil, and one early weeding 3-4 weeks after crop emergence for field pea and chickpea, are optimum. In general, full-season weed competition in faba bean, field pea, lentil and chickpea accounted for respective yield reductions of 23.6, 15.3, 50.6 and 30.6%. Pre- and post-emergence herbicides applied to CSFL significantly reduced the time required for weeding without affecting crop stand or yield. Against annual broadleaved and grass weeds, the suitable pre-emergence herbicides are: terbutryn 2.0 kg a.i./ha for faba bean and field pea; metolachlor + metobromuron 5.0, pendimethalin 2.0 and terbutryn + metobromuron 2.0 kg a.i./ha for faba bean; and prometryn 2.0 kg a.i./ha for lentil. Against annual grass weeds fluazifop-butyl at 0.25 kg a.i./ha is effective in post-emergence applications in faba bean and field pea. Economic analysis of results indicated the financial advantage of hand-weeding over pre-emergence herbicides.

Introduction

Research into weed control methods in cool-season food legumes (CSFL) in Ethiopia was initiated in 1967 at CADU's Kulumsa Research Center, in 1969 at IAR's Holetta Research Center and in 1980 at AUA's Debre Zeit Agricultural Research Center. Until 1980 most of the research activities were not well organized and lacked continuity. After the establishment of the CSFL research team, efforts were made to revive the past research activities by refining experimental designs and increasing the number of work and test locations.

This paper presents a review of past research results of weed management practices in four major CSFL: faba bean (*Vicia faba*), field pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*).

The Weed Flora

Weeds occurring in CSFL represent a major production loss. The weed flora in faba bean, field pea, chickpea and lentils were reviewed by Rezene (1986). The list of weed species reported is given in Table 1.

There were two major surveys in six chickpea and lentil-growing regions of Shewa during 1991-93 (Seid *et al.* 1992a, 1993a, 1993b). These provided information on different weed species and their frequency of occurrence on black and light soils of the surveyed areas. In general, more weed species were recorded on black soil than on light soil (Seid *et al.* 1993a, 1993b).

In chickpea the major weed species on black soil were: *Scorpiurus muricatus*, *Cyperus* sp., *Plantago lanceolata*, *Phalaris paradoxa*, *Guizotia scabra*, *Brassica* spp. and *Convolvulus arvensis*. On the light soil, *Scorpiurus muricatus*, *Cyperus* sp., *Argemone mexicana* and *Xanthium abyssinicus* were quite common and the most widespread (Seid *et al.* 1993a, Workneh and Teklu 1992).

In lentil the most frequent and densely populated weed species on the black soil were: *Scorpiurus muricatus*, *Cyperus* sp., *Cynodon dactylon*, *Digitaria* sp. and *Convolvulus arvensis*. On light soil, *Setaria pumila* (= *pallidefusca*), *Scorpiurus muricatus*, *Argemone mexicana* and *Xanthium abyssinicus* were the dominant weed species (Seid *et al.* 1992a, 1993b). Additional survey information on CSFL weed flora was provided by different workers from Arsi, Bale and Gojam regions (Bengtsson 1983; Bekele 1991).

Parasitic weeds are of minor importance although infestation of *Orobanche minor* and *O. ramosa* in faba bean and field pea and *Cuscuta* sp. in lentil were recorded in some localities of Ethiopia (Rezene 1986). In general, the existing survey data showed that there are about 61 weed species in 47 genera and 20 plant families known to be problematic in CSFL.

Table 1. Major weeds of CSFL recorded in Ethiopia†.

Family and species	Life cycle‡	Faba bean	Field pea	Chick-pea	Lentil
ACANTHACEAE					
Hygrophilla auriculata	a	x	x	-	-
AMARANTHACEAE					
Amaranthus hybridus	a	xx	x	xx	xx
ASTERACEAE					
Bidens pachyloma	a	xxx	x	xx	xxx
B. pilosa	a	xxx	xxx	xxx	xx
Cichorium intybus	a	-	-	xxx	xx
Galinsoga parviflora	a	xx	xx	x	x
Guizotia scabra	a	xxx	xxx	xx	xx
Launea cornuta	p	-	-	xx	x
Sonchus arvensis	a	-	-	x	-
S. oleraceus	a	x	x	xx	xx
Tagetes minuta	a	x	x	x	x
Xanthium abyssinicus	p	x	x	xx	x
BRASSICACEAE					
Brassica napus	a	x	x	x	-
CAPPARIDACEAE					
Gynandropsis gynandra	a	-	-	x	x
CAROPHYLLACEAE					
Corrigiola capensis	a	xxx	xxx	-	-
Spergula arvensis	a	xx	xx	-	-
COMMELINACEAE					
Commelina africana	p	xx	xx	-	xxx
C. benghalensis	a/p	xx	xx	x	x
CONVOLVULACEAE					
Convolvulus arvensis	p	xx	xx	xx	xxx
Cuscuta sp.	a	-	-	-	xx
CYPERACEAE					
Cyperus esculentus	p	-	-	xxx	xxx
C. rotundus	p	xx	xx	xxx	xxx
LAMIACEAE					
Leonotis mollissima	a	-	-	x	-
Leucas martinicens	a	-	-	x	xx
LEGUMINOSEAE					
Medicago hispida	a	-	-	x	x
M. polymorpha	a	xxx	xx	xx	xx
Scorpiurus muricatus	a	xxx	xx	xxx	xxx
Trifolium tembense	a	-	-	-	x
OROBANCHACEAE					
Orobanche minor	a	xx	-	-	-
O. ramosa	a	-	x	-	-

Family and species	Life cycle‡	Faba bean	Field pea	Chick-pea	Lentil
PAPAVARACEAE					
Argemone mexicana	a	xx	xx	xxx	xxx
PLANTAGINACEAE					
Plantago lanceolata	b	xxx	xxx	xx	x
POACEAE					
Avena abyssinica	a	xxx	xxx	-	-
A. fatua	a	xxx	xxx	x	xx
Brachiaria eruciformis	a	-	-	-	x
Bromus erectus	a	-	-	-	x
B. pectinatus	a	xx	xx	x	-
Cynodon dactylon	p	x	x	xx	x
Digitaria abyssinica	p	x	x	x	x
D. scalarum	p	x	x	x	x
Dinebra retroflexa	a	-	-	x	x
Eragrostis shimperi	a	-	-	x	x
Lolium temulentum	a	xx	xx	x	x
Phalaris paradoxa	a	xxx	xxx	xx	x
Setaria pumila	a	xxx	xxx	xx	xxx
Snowdenia polystachya	a	-	-	x	x
Sorghum arundinaceum	a	-	-	x	x
POLYGONACEAE					
Oxygonum sinuatum	a	x	-	x	-
Polygonum aviculare	a	xx	xx	-	-
P. convolvulus	a	-	-	x	-
P. nepalense	a	xxx	xxx	xx	xx
Rumex abyssinicus	p	xxx	xxx	x	x
R. bequearttii	p	xxx	xxx	xx	xx
R. crispus	p	-	-	x	x
PRIMULACEAE					
Anagalis arvenis	a	x	x	x	-
RESEDACEAE					
Caylusea abyssinica	a	xxx	xxx	-	-
RUBIACEAE					
Galium spurium	a	xx	xx	-	-
SOLANACEAE					
Datura stramonium	a	xx	xx	xxx	xxx
Nicandra physalodes	a	-	-	xx	xx
Solanum nigrium	a	-	-	x	x
UMBELLIFERAE					
Foeniculum vulgare	a	x	x	xx	xx

† Level of importance: x = low; xx = intermediate; xxx = high; – = not known.
‡ a = annual; p = perennial.
Source: Bengtsson 1983; Rezene 1986; Bekele 1991; Seid *et al.* 1992a, 1993a, 1993b.

Farmers' Weeding Practices

The common method of weeding in CSFL is hand-pulling the weeds. Herbicides are not used to control weeds. In many instances, fields remain unweeded or hand-weeding occurs after the weeds have reduced the crops' yield potential. The major reason for suboptimal weeding is the overlapping of the demand for optimal weeding in CSFL with other crop enterprises (Bengtsson 1983; Rezene 1986; Hailu 1991; Regassa and Asmare 1991; Bekele 1991; Seid *et al.* 1992a, 1993a, 1993b; Workneh and Teklu 1992).

The actual weeding frequency and time of weeding for each crop varies from one ecoregion to another. Major survey information is summarized below.

Faba Bean

Central Shewa region

In Welemera Nitosols and Mollisols 20% of farmers weed faba bean only once. June through August is the busiest time of the year for farmers. Tef planting in July coincides with the weeding of wheat, barley and faba bean (Hailu *et al.* 1992). In Kembatana Hadiya zone one hand-weeding is the most common practice (Hailu 1991).

Adoption of improved faba bean tehnology was assessed in Welemera and Adis Alem zones during 1988/89. The recommended weeding practice for faba bean production in the study area is two hand-weedings at 30-35 and 50-55 days after sowing. More than 75% of host farmers performed at least one hand-weeding. Relatively, the weed control practice (hand-weeding) was better adopted than other components of the improved production package (Chilot and Hailu 1991).

In Inewari, weeds from faba bean fields constitute a major portion of livestock feed. Thus, the crop is weeded late after the weeds are big enough to be fed. Fields are weeded once, over an extended period (mid-September to early November) to secure a continuous and sustained supply of feed for the livestock (Hailu and Chilot 1992).

Gonder region

In the Debre Tabor area one selective hand-weeding is commonly done in August for faba bean, but when the weed infestation is very high two weedings are done, the first in July and the second in August (Aleligne *et al.* 1992).

Arsi region
In Chilalo zone 52% of farmers surveyed weeded their faba bean field twice, starting from August. A second weeding was usually carried about 4 weeks after the first one. All farmers weeded faba bean at least once (Bengtsson 1983).

Gojam region
In Mota and Enesie zones weeding in faba bean is done from late June to early October, with weeding frequency of none to twice, depending on the level of weed infestation and weed situation in the priority crops such as wheat, barley and tef (Regassa and Asmare 1990).

In Adet Nitosol zones faba bean is not usually weeded; farmers claim that weeding is not necessary (Regassa and Asmare 1991).

Field Pea

In Debre Tabor area weeding is not practised for field pea or for mixed cropping with faba bean because of low weed infestation on the poor soil (Aleligne *et al.* 1992).

In Bahir Dar area (Aleligne and Regassa 1992) and Sinana (Alemayehu and Steven 1987) field pea is not weeded; farmers prefer to weed millet and tef.

In Kulumsa mixed farming zone, farmers do not weed their field pea fields because they think that weeding is not necessary (Chilot *et al.* 1989).

Chickpea

In Dembi and part of Adis Alem Vertisol areas chickpea is weeded once in September (Seid *et al.* 1993a).

In Adet zone chickpea is planted late (September to October) and not usually weeded (Regassa and Asmare 1991).

In Bako zone about 55% of farmers weed their chickpea fields, mainly in November (Workneh *et al.* 1993b).

Weed surveys in chickpea-growing areas (Ada, Akaki, Shenkora and Minjar) of Shewa indicated that early planted chickpea (sown in late August to early September) on light soil is weeded once, but no weeding was practised when the crop was planted late (mid-September to early October) in areas with persistent waterlogging problems (Seid *et al.* 1993a).

In Debre Tabor area chickpea is weeded once when the land is prepared poorly, but weeding is not done on a well-prepared field. The most troublesome weed in this area is *Hygrophilla duriculata* (Bekele 1991; Aleligne *et al.* 1992).

Lentil

In Bako zone in Shewa 60% of farmers surveyed weeded their lentil field in November (Workneh *et al.* 1993a).

In Inewari, the late-planted legume crops (lentil, chickpea and field pea) are rarely weeded. Farmers who plant these crops on broad bed and furrows (BBF) pull out the major weeds to feed their livestock, but farmers who plant on the flat Vertisols do not weed at all. In the latter case the land is plowed thoroughly at planting, which kills the weeds (Hailu and Chilot 1992).

Weed Competition

Crop/weed competition studies were conducted during 1980-83 in faba bean and field pea at Holetta and in lentil at Debre Zeit (Rezene 1986). These studies were planned with the objective of determining the critical period of crop/weed competition and the loss incurred when weeds are not controlled. Results of these trials in faba bean, field pea and lentil are presented in Figures 1, 2 and 3.

Full-season weed competition caused yield reduction up to 23.6, 15.3, 50.6 and 30.6% in faba bean, field pea, lentil and chickpea, respectively.

In faba bean the presence of weeds during the first 4, 7 and 10 weeks after sowing accounted for respective yield reductions of 13.1, 15.9 and 22.2%. These results indicate that faba bean is very sensitive to weed competition from its early crop establishment to the early flowering stage (Rezene 1986).

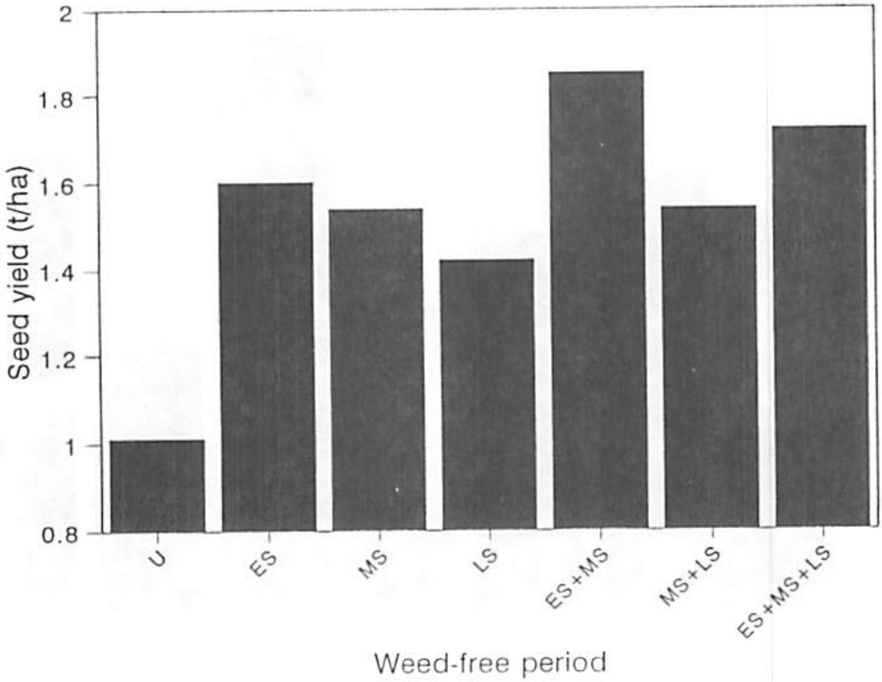

Fig. 1. Effect of weed competition on faba bean yield (Holetta). U = unweeded check; ES = early season weeding to keep crop weed-free 10-30 days after sowing; MS = midseason weeding to keep crop weed-free 35-55 days after sowing; LS = late season weeding to keep crop weed-free 60-80 days after sowing.

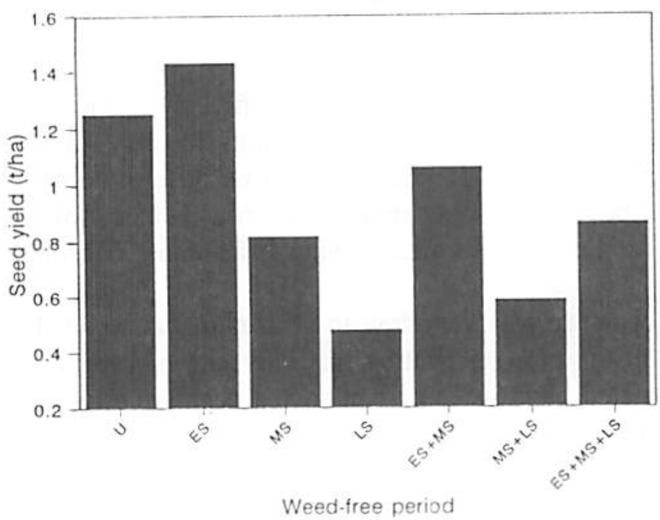

Fig. 2. Effect of weed competition on field pea yield (Holetta). See Fig. 1 for explanation of U, ES, MS and LS.

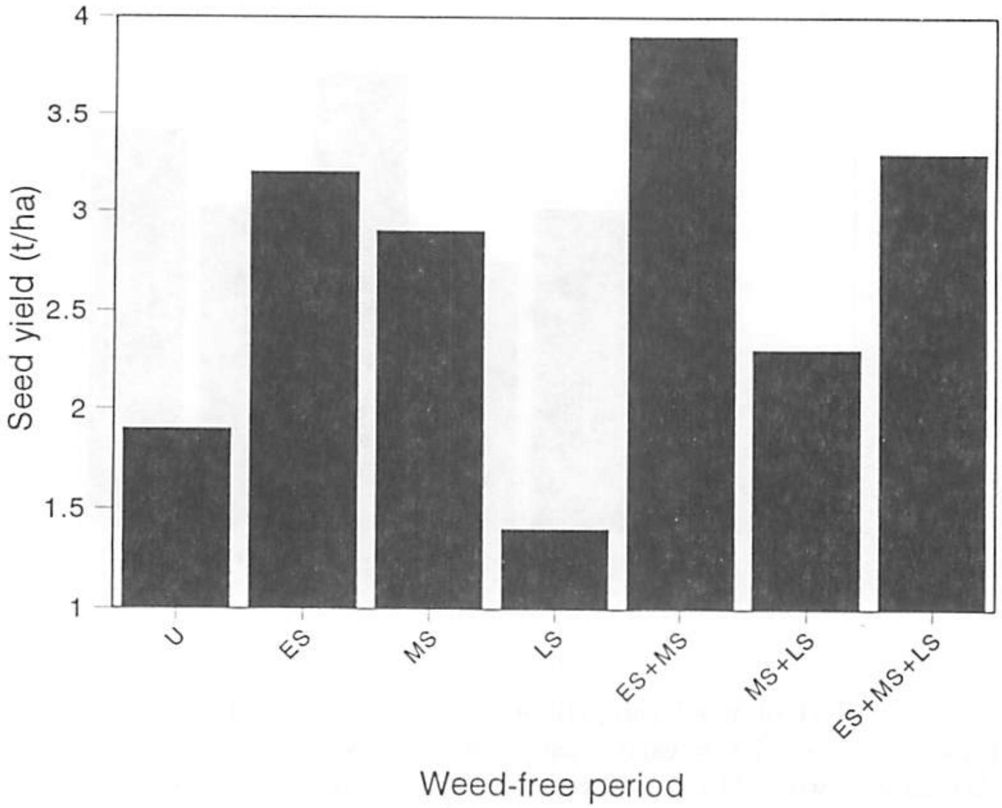

Fig. 3. Effect of weed competition on lentil yield (Debre Zeit). See Fig. 1 for explanation of U, ES, MS and LS.

In field pea the presence of weeds during the first 4, 7 and 10 weeks after sowing accounted for respective yield reductions of 0.0, 43.3 and 66.9%. Significant reduction in yield potential occurred because of competition during the beginning and post-flowering stages of the crop. Hence, for field pea, one early season weeding 3-4 weeks after sowing is adequate (Rezene 1986).

Lentil yield performance was very low in all treatments weeded during post-flowering stages of the crop, indicating that late-season weeding or weed-free conditions by repeated hand-weeding can have a negative effect of mechanical injury to the crop. The critical time of crop/weed competition in lentil starts during the early establishment period of the crop and extends up to the early flowering stage (Rezene 1986).

Cultural Weed Control

Hand-weeding

Several manual weed control experiments were conducted across major food legume growing regions of Ethiopia. Most of them were in verification plots and a few were on-farm trials. Weeding practices studied were mainly weed removal by hand-pulling. Selected results for each region are summarized for faba bean, field pea and lentil in Tables 2, 3 and 4, respectively; the recommended times of hand-weeding are given in Table 5.

Table 2. Effect of selected hand-weeding on seed yield of faba bean.

Comparison	Location	Yield (t/ha) Unweeded check	Yield (t/ha) Hand-weeded	Yield increase (%)
Unweeded vs. 1 hand-weeding	Holetta	0.98	1.60	63.3
	Welemera	2.23	2.96	32.7
	Debre Zeit	1.81	1.96	8.3
	Welemera	2.09	2.58	23.4
	Sheno	2.33	2.95	26.6
	Kulumsa	0.55	0.75	36.4
	Sinana	1.77	2.65	49.7
Unweeded vs. 2 hand-weedings	Holetta	1.01	1.85	83.2
	Sheno	2.33	3.18	36.5
	Sheno	0.60	1.23	105.0
	Sinana	1.77	3.09	74.6
Unweeded vs. 3 hand-weedings	Holetta	1.01	1.71	69.3

Source: Rezene 1986; Adamu 1991, 1992; Chilot *et al.* 1991; Aleligne *et al.* 1992; Zewdu *et al.* 1993.

Table 3. Effect of selected hand-weeding on seed yield of field pea.

Comparison	Location	Yield (t/ha) Unweeded check	Hand-weeded	Yield increase (%)
Unweeded vs. 1 hand-weeding	Holetta	1.23	1.45	17.9
	Sinana	3.30	3.60	9.1
	Sinana	2.20	3.03	37.7
	Kulumsa	0.41	0.85	107.3
Unweeded vs. 2 hand-weedings	Holetta	1.23	1.08	-12.2
	Sinana	3.30	3.70	12.1
	Sinana	2.20	3.25	47.7
Unweeded vs. 3 hand-weedings	Holetta	1.23	0.87	-29.2

Source: Rezene 1986; Aleligne *et al.* 1992; Zewdu 1992b; Zewdu *et al.* 1993.

Table 4. Effect of selected hand-weeding on seed yield of lentil.

Comparison	Location	Yield (t/ha) Unweeded check	Hand-weeded	Yield increase (%)
Unweeded vs. 1 hand-weeding	Debre Zeit	1.90	3.20	68.4
	Debre Zeit	0.40	0.50	25.0
	Debre Zeit-LS	0.12	0.47	291.0
	Debre Zeit-BS	0.10	0.27	170.0
	Akaki	1.13	1.21	7.1
	Debre Zeit	1.23	1.47	19.5
Unweeded vs. 2 hand-weedings	Debre Zeit	1.90	3.90	105.0
	Debre Zeit	0.40	0.50	25.0
	Debre Zeit-LS	0.12	0.57	375.0
	Debre Zeit-BS	0.10	0.35	250.0
	Akaki	1.13	1.29	14.1
	Debre Zeit	1.23	1.35	9.8
Unweeded vs. 3 hand-weedings	Debre Zeit	1.90	3.30	73.6

LS = Light soil; BS = Black soil.
Source: Rezene 1986; Seid *et al.* 1992b, 1993c, 1993d; Sewalem *et al.* 1994.

Table 5. Critical period for weed competition and optimum hand-weeding frequency requirement.

Crop	Weed-free period required (weeks)†	Length of competition tolerated (weeks)	Optimum no. of hand-weedings
Faba bean	4	8	2
Field pea	4	6	1
Lentil	4	8	2
Chickpea	4	6	1

† After sowing.

Faba Bean

Sowing method × hand-weeding

Weedy check, one and two hand-weedings were compared under two planting methods (broadcasting and row planting). The initial observations at Kulumsa (Table 6) indicated that row planting by itself seems to raise yield of faba bean compared with broadcasting and the hand-weedings were more efficient in row-planted crops. Significant yield increases were obtained from one and two hand-weedings compared with the weedy check (CADU 1968, 1969, 1971). In a recent study at Holetta a yield advantage and superior crop vigor were noted on row-planted faba bean compared with broadcasting although yield differences were not significant. Major differences between sowing methods were observed, possibly due to the variable planting depth of the broadcast seeds. Of the weed control treatments, hand-weeding twice increased yield by 55 and 24%, respectively, over the unweeded check (Rezene 1991).

Sowing date × seeding rate × hand-weeding

Trials conducted on a pellic Vertisol at Sheno in 1989 and 1990 assessed seed yield in faba bean as affected by sowing date, seeding rate and frequency of hand-weeding. These experiments failed to show interactions between sowing date, seeding rate and frequency of hand-weeding in affecting seed yield of faba bean. In both years two hand-weedings gave significantly higher yields (0.60 and 0.86 t/ha) over the weedy check regardless of sowing date and seeding rate treatments (Adamu 1991, 1992).

Table 6. Effect of sowing method and weeding frequency on seed yield of faba bean, Kulumsa.

Sowing method and weeding frequency	Seed yield (t/ha) 1967	1968	1969	Mean
Broadcast				
Weedy check	0.22	0.55	0.30	0.36
Hand-weeding once	0.37	0.75	1.32	0.81
Hand-weeding twice	0.38	0.74	1.47	0.86
Row planted				
Weedy check	0.66	0.78	0.34	0.59
Hand-weeding once	0.99	0.84	1.36	1.06
Hand-weeding twice	1.03	0.89	1.69	1.20

Source: CADU 1968, 1969, 1971.

Cultivar × seeding rate × hand-weeding

This experiment was carried out in 1990 and 1991 at Sinana to generate information on suitable cultivar, optimum seeding rate and weeding frequency in faba bean (Zewdu 1992a; Zewdu *et al.* 1993). An interaction effect of cultivar × seeding rate and weeding × cultivar × seeding rate was detected in the 1991 trial season. Considering all factors, weeding twice and the highest seeding rate (260 kg/ha) with cultivar NC 58 gave the highest yield (3.7 t/ha) (Zewdu *et al.* 1993).

Field Pea

Cultivar × hand-weeding

This trial was carried out to determine the effect of frequency of weeding on two contrasting cultivars of field peas: Dubie (a selection from Ethiopian stock characterized by vigorous vegetative growth) and Prussian Blue (an introduction with short vines). There was a trend in seed yields to show an advantage with increased weeding frequencies. Dubie competed against weeds more efficiently than Prussian Blue (AAU 1975).

Cultivar × seeding rate × hand-weeding

This study was designed to determine the effect of cultivar, seeding rate and weeding frequencies on field pea yield under Sinana conditions for two consecutive years (1990 and 1991). No interaction effect was observed (44, 46). In 1991, one and two hand-weedings gave yield advantages of 0.83 and 1.05 t/ha (37.5 and 47.7%) over the weedy check (Zewdu *et al.* 1993).

Lentil

Seeding rate × weeding methods

The trial was carried out at Akaki on black clay soil to determine the effect of seeding rates and weeding methods on lentil yield in 1990 and 1991. In the first year, the interaction effect was significant in reducing the weed biomass but not in increasing seed yield. The highest yield was obtained from hand-weeding twice and a seeding rate of 90 kg/ha followed by 80 kg/ha. Lower seed yield was obtained from terbutryn which might be attributed to slight toxicity of the herbicide (Seid *et al.* 1993d). In the second year, neither weed management practices nor seeding rates affected seed yield and further studies were suggested to confirm the previous findings (Sewalem *et al.* 1994).

Pre-planting tillage × weeding methods

A clean seedbed is important to lessen post-planting weed pressure. A study at Debre Zeit on light soil in 1990 and 1991 indicated that conventional tillage (two plowings + one harrowing) did not have much effect in reducing dry matter accumulation of weeds when compared with minimum tillage (pre-planting application of glyphosate at 5.0 L/ha + harrowing) and zero tillage (only pre-planting application of glyphosate at 5.0 L/ha) irrespective of weed management treatments. However, lentil grain yield was the highest under a zero tillage system, with the lowest being in conventional tillage treatment which clearly reflected the effect of these treatments on weed biomass (Seid *et al.* 1992b, 1993c).

Mechanical Weeder

Weed control by using a wheel-hoe row weeder, developed by the Agricultural Implements Research and Improvement Center of IAR, was tried at Holetta on Nitosols. Treatments comprised all logical combinations of broadcast and row-seeded faba bean without weed control, with one and two hand-weedings, with broad-spectrum herbicidal treatment (terbutryn 2.0 kg a.i./ha pre-emergence) and with the row weeder + supplementary hand-weeding. Yield obtained on the row-weeded plots did not differ significantly from any of the weeding treatments. However, labor time for weeding differed dramatically. The row weeder saved 12.7 and 65.7 mandays/ha over the broadcast/hand-weeded and row-seeded/hand-weeded treatments, respectively (Rezene *et al.* 1991b).

Chemical Weed Control

Chemical weed control in CSFL is not developed in Ethiopia. Rezene (1986) reviewed potential herbicides identified before 1985 for weed control in faba bean, field pea, lentil and chickpea. Table 7 lists herbicides tested in CSFL during the period of 1968-92. In the testing process new chemicals were brought in, and the promising ones were advanced for further testing and verification.

Pre- and post-emergence herbicides applied to CSFL reduced significantly the time required for weeding without affecting crop stand or yield. Against annual broadleaved and grass weeds suitable pre-emergence herbicides were: terbutryn at 2.0 kg a.i./ha for faba bean, field pea and lentil; terbutryn + terbuthylazine at 2.0, terbutryn + metobromuron at 2.0, metolachlor + metobromuron at 5.0 and pendimethalin at 2.0 kg a.i./ha for faba bean; and prometryn at 2.0 kg a.i./ha for lentil. Against annual grass weeds fluazifop-butyl at 0.25 kg a.i./ha was effective as post-emergence application in faba bean and field pea.

Herbicides are expected to be the mainstay of a weed control system in the large-scale crop production of food legumes. Unlike in small cereals, herbicide use for weed control in food legumes by peasant farmers has not been developed. An on-farm verification of pre-emergence herbicides in wheat, barley and faba bean at Welemera showed that it is more economical to apply herbicides in wheat and barley and to hand-weed faba beans (Hailu *et al.* 1992). Herbicides for weed control in faba bean, field pea and lentil are listed in Table 8. Table 9 presents susceptibility of major weeds in food legumes to some of the recommended herbicides (Rezene 1993, 1994; Rezene *et al.* 1991a).

Table 7. Herbicides tested in CSFL in Ethiopia.

Herbicide		Crop tested†			
Common name	Trade name	FB	FP	LN	CP
Alachlor	Lasso (480 g/L EC)	x	x		
Atrazine	Gesaprim (500 FW)	x	x		
Barban	Carbyne	x	x		
Cyanazine	Bladex (800 g/L WP)	x	x		
Dinoseb acetate	Aretit 50% EC	x	x		
Fluazifop-buthyl	Fusilade	x	x		
Fluorodifen	Preforan (30 EC)	x	x		
Linuron	Afalon (50 WP)	x	x	x	
MCPB		x	x		
Metobromuron	Patoran (50 WP)	x	x	x	x
Metolachlor + metobromuron	Galex (500 EC)	x			
Pendimethalin	Stomp (500 g/L EC)	x	x		
Prometryn	Gesagard (500 FW)	x	x	x	
Simazine	Gesatop (50 WP)	x	x		
TCA	NATCA 47%				x
Terbutryn	Igran (500 FW)	x	x	x	
Tebutryn + metolachlor	Igran combi (400 FW)	x			
Terbutryn + terbuthylazine	Topogard (500 FW)	x	x	x	
2, 4-DB		x	x		

† FB = Faba bean, FP = Field pea, LN = Lentil, CP = Chickpea.
Source: CADU 1968, 1969, 1970, 1971; Rezene 1986, 1993, 1994; Rezene *et al.* 1991a.

Table 8. Herbicides recommended for use in CSFL production.

Herbicide	Rate (kg a.i./ha)	Crop†	Weed control spectrum‡
Terbutryn	2.0	FB, FP, LN	BLW, GW
Terbutryn + terbuthylazine	2.0	FB, FP	BLW, GW
Terbutryn + metolachlor	2.0	FB	BLW, GW
Metolachlor + metobromurom	5.0-6.0	FB	BLW, GW
Pendimethalin	1.5-2.0	FB	BLW, GW
Prometryn	2.0	LN	BLW, GW
Fluazifopbutyl	0.25	FB, FP	GW

† FB = Faba bean, FP = Field pea, LN = Lentil.
‡ BLW = Broadleaved weeds, GW = Grass weeds.

Table 9. Reaction† of major weeds of faba bean to some recommended herbicides.

Weed species	Herbicide‡				
	1	2	3	4	5
Polygonum nepalense	S	S	S	S	S
Guizotia scabra	MS	R	MS	MS	MS
Corrigiola capensis	S	S	S	S	S
Plantago lanceolata	MR	MR	S	MS	MR
Avena fatua	MS	MR	MS	MS	MS
Phalaris paradoxa	MS	MR	MS	MS	MS
Setaria pumila	MS	MR	S	S	MS

† S = susceptible; MS = moderately susceptible; MR = moderately resistant; R = resistant.
‡ 1 = Terbutryn; 2 = Terbutryn + terbuthylazine; 3 = Pendimethalin; 4 = Terbutryn + metolachlor; 5 = Metolachlor + metobromuron.
Source: Rezene 1993, 1994; Rezene *et al.* 1991a.

In chickpea two chemical weed control trials were carried out at Kulumsa during 1969 to 1970. The herbicides tested were: linuron, alachlor and dinoseb acetate. Alachlor at 2.4 and linuron at 1.0 kg a.i./ha were very promising. Linuron did not persist long enough to control the late-emerging weeds. Chickpea is less competitive to weeds and the conclusion from this trial was that a herbicide treatment in this crop must be supplemented by hand-weeding to control late-emerging weeds (CADU 1970, 1971; Rezene 1986).

Cost of Weed Control

Faba Bean

Faba bean has to be weeded within the busy labor period in major faba bean growing areas. Data on weeding labor requirements are highly variable and unreliable because of differences in labor productivity among individuals, variation in weeding requirements both between and within areas, and biases in measurement or estimation. Samples of data generated on labor and cost of hand-weeding at various locations are given in Table 10. Demonstration trials in various areas of Menagsha, and Ada zones (in Shewa), Arsi and west Gojam showed that weeding of faba bean accounted for 25.9, 23.1, 50.1% and 34.2% of the total labor cost of all farm operations at the respective locations (Adugna *et al.* 1991; Adugna and Bisrat 1992; Mekonen *et al.* 1992).

Table 10. Cost of hand-weeding in some faba bean growing areas.

Location	No. of hand-weedings	Cost†
Menagesha (1)	2	98.5
Menagesha (2)	2	160.0
Ada (1)	2	45.0
Ada (2)	2	180.0
Arsi	2	226.0
West Gojam (1)	1	72.2
West Gojam (2)	1	81.8

† Calculated as Birr/ha in 2 workdays.
Source: Adugna *et al.* 1991; Adugna and Bisrat 1992; Mekonen *et al.* 1992.

In an on-farm verification trial at Welemera a pre-emergence herbicide (terbutryn at 2.0 kg a.i/ha with and without hand-weeding) was compared with one hand-weeding (25-30 days after crop emergence) and farmers' practice (no weeding). Results (Table 11) indicated that hand-weeding at the recommended time gave higher yield and net benefit in faba bean (Hailu *et al.* 1992).

Table 11. Mean seed yield, net benefit and labor requirement for on-farm verification of weed control methods in faba bean, Welemera (1989/90).

Weed control treatment	Person-days/ha	Yield (t/ha)	Net benefit (Birr/ha)
Farmers' practice†	0	2.1	1675
HW × 1	51	2.6	1964
Terbutryn	1	2.4	1778
Terbutryn + HW × 1	25	2.6	1893

† No weeding.
Source: Hailu *et al.* 1992.

Lentil

An on-farm herbicide verification trial was carried out in 1991 at Ada, Lemi and Akaki areas by Debre Zeit Agricultural Research Center. Details of treatments and results are shown in Table 12. In general no significant yield differences were observed among treatments, at all locations. The mean seed yield and net benefit from farmers' practice were slightly higher than the remaining treatments. However, further studies were suggested to confirm these results (Workneh *et al.* 1993a).

Future Research Directions

There is a paucity of research information on weed management practices of field pea and chickpea compared with other food legumes. Thus, these crops should receive top priority or at least equal share in future weed research programs of CSFL.

Table 12. Mean seed yield, cost and net benefit for weed control methods in lentil at Ada, Lemi and Akaki areas, 1991.

Weed control treatment	Seed yield (t/ha)	Total cost (Birr/ha)†	Net benefit (Birr/ha)
Terbutryn (2.0 kg a.i./ha)	1.18	20.50	1.51
Terbutryn (2.0 kg a.i./ha) + 1×HW	1.22	236.05	1.46
Farmers' practice‡	1.24	155.50	1.53

† Variable cost of labor, sprayer and herbicide.
‡ One late hand-weeding.
Source: Workneh *et al.* 1993a.

Recent surveys indicated that *Cuscuta* spp. in faba bean and lentil and *Orobanche ramosa* in faba bean and field pea are present in some localities of Gojam and Shewa regions. Thus, targeted surveys on parasitic weeds which include identification of species, distribution and other relevant data associated with production losses need to be developed.

To alleviate the labor shortages for weeding operations by smallholder peasant farmers, mechanical weed control using row weeders (hand-operated or animal-drawn implements) needs to be developed for use on faba bean, lentil and chickpea.

On-farm verification studies should be conducted for the potential pre-emergence herbicides (pendimethalin, terbutryn + metolachlor and metobromuron + metolachlor) on fields representing different production areas, weed infestation levels and weed species distribution.

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Discussion

Ato Chilot Yirga
Ato Rezene said that farmers could not weed faba bean because of overlapping of cereal activities, and added that weeds of faba bean are used as animal feed. Doesn't this affect future strategy?

Ato Rezene
The use of weeds as animal feed is location specific. Although we are supposed to take all aspects into consideration, the important thing is the removal of weeds.

Ato Bekale
Row planting facilitates weeding and intercultural operation by wheel hoes. Was there a study conducted on how to row plant? It is difficult to do it by such methods as dibbling.

Ato Rezene
IRGC has developed some machines for seeding in rows and IAR will make a trial starting from next year.

Ato Dawit
Are these agronomic recommendations applicable to all cultivars?

Ato Rezene
The recommendation depends on the trials. In the on-farm trials, improved cultivars were always tested against the local check.

Ato Bekele
Farmers don't want to make use of the broad bed maker. They complain that it is a heavy implement. What is the reason?

Dr Tekalegn
Farmers use the broad bed maker during the wet season which makes its use difficult. They are supposed to use it during the dry season. If they use it properly in the dry season, it is recommendable; farmers and NGOs are ordering many of them.

Chapter 4
Soil Fertility and Microbiology

Fertilizer Response Trials on Highland Food Legumes

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Abstract

Faba bean (*Vicia faba* L.), field pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) are the dominant highland grain legumes of Ethiopia, but their yields are low under Ethiopian conditions. Fertilizer research on these crops is reviewed in this paper. Application of N on faba beans significantly increased grain yields. Similarly, application of P significantly increased faba bean grain yields in most trials. A highly significant increase in yield was obtained with the application of N and P fertilizers across the nation. There was no significant response to K application, whereas the combination of N, P and K increased faba bean grain yield by over 100%. Response to fertilizer application was greater by the improved cultivars. Moreover, it was clear that faba bean responded significantly when cropped after cereals and grain legumes but not after highland oilseeds. Therefore, it is quite important to fertilize faba bean to achieve high grain yields. Chickpea did not respond significantly to N and P application at Debre Zeit, Adet and Ginchi. Lentil failed to show an increase of yield due to N and P applications at Ginchi and Dembi. Response to N application implied that inoculating the crop with suitable strains of *Rhizobium* might be an alternative for obtaining increased crop production as well as ameliorating the soil. Field peas responded to N and P applications, in some places with a yield increase of over 61%, but there was no significant response to N and P fertilizer at Holetta. There is a need to work on the fertilizer needs of these crops in other production areas. Thorough investigations on the amount of N, P and K fertilizers, and on the use of alternate fertilizer sources such as rock phosphate, bone meal and mustard meal are needed.

Introduction

Next to cereals, grain legumes are the most important crops, playing a major role in the country's economy (Angaw 1992). However, yields of the grain legumes grown under traditional farming systems are generally low. Among the factors contributing to low grain yield is the poor soil fertility in the legume production zones. Therefore, in order to improve the yield of the major highland grain legumes of the nation, intensive research work was launched by the Institute of Agricultural Research (IAR) and the Debre Zeit Agricultural Research Center. Research included assessment of the nutrient status of different soils and investigations on different application rates of nitrogen (N), phosphorus (P), nitrogen and phosphorus (N-P) and nitrogen, phosphorus and potassium (N-P-K). The IAR experimental results are reviewed and discussed in this paper.

Faba Bean

Response to Nitrogen

Average grain yields of faba beans for 3 years (1970-72) showed that application of 90 kg N/ha significantly increased faba bean grain yields on both Nitosols and Vertisols at Holetta. Mean grain yield increased with an increase of N rates on both soil types (Table 1). Application of nitrogen is thus important for increasing faba bean yields.

Table 1. Effect of fertilizer rates on faba bean yields at Holetta, 1970-72.

Fertilizer level (kg/ha)	Grain yield (t/ha)		Increase (%) due to fertilizer	
	Nitosol	Vertisol	Nitosol	Vertisol
Nitrogen				
0	1.76	1.36		
30	1.80	1.83	2.3	34.6
60	1.98	1.64	8.0	20.6
90	2.05	2.03	16.5	49.3
Phosphorus (P_2O_5)				
0	1.83	1.51		
13	1.74	1.70	-9.5	12.6
26	1.95	1.90	6.6	25.8
40	2.07	1.90	13.1	25.8

Source: Desta 1988a.

Response to Phosphorus

Different rates of phosphorus (triple superphosphate, TSP) were applied in trials to assess the response of faba bean on Nitosols and Vertisols at Holetta. There was no significant response to P application under either soil type (Table 1).

Response to Nitrogen and Phosphorus

Nitrogen and phosphorus applied as urea and TSP were used in the need-for-inoculation assessment trials and the fertilizer rate trials on many sites in the faba bean growing regions. Faba bean CS 20DK was used for the experiment.

At Holetta and Bekoji, significantly higher yields of faba beans were obtained with the application of N-P fertilizers except for the lower rate of N (23 kg/ha). Mean grain yields of faba beans were highly significantly increased with the application of either 20 kg P_2O_5/ha alone or a combination of 23-20 kg N-P_2O_5/ha at both places and in both years (Table 2). Faba beans also responded to the highest dose of N application (46 kg/ha) on Nitosols at both locations.

Table 2. Effect of N and P fertilizer on grain yield of faba beans under Nitosol conditions.

Treatment (kg/ha)	Holetta			Bekoji			Mean yield (t/ha)
	1988	1989	Mean	1988	1989	Mean	
Control	1.95	1.11	1.53	3.60	5.02	4.31	2.92
23 N	1.76	1.24	1.50	3.36	5.18	4.27	2.89
46 N	2.09	1.38	1.71	4.22	4.79	4.50	3.11
23-20 N-P_2O_5	2.41	2.26	2.33	4.72	6.13	5.43	3.88
46-20 N-P_2O_5	2.31	2.18	2.25	4.30	6.25	5.28	3.77
20 P_2O_5	2.25	1.97	2.11	4.90	5.90	5.40	3.76

There was a general tendency for faba bean yields to increase with an increasing rate of N fertilizer and with a combination of both N and P fertilizers on Vertisols at Holetta and Sheno. Faba bean grain yields were generally higher in the Sheno area than at Holetta, which receives high rainfall, in both 1988 and 1989 crop seasons (Table 3).

Table 3. Effect of N and P fertilizer on grain yield of faba beans under Vertisol conditions (10% moisture).

Treatment (kg/ha)	Holetta			Sheno			Mean yield (t/ha)
	1988	1989	Mean	1988	1989	Mean	
Control	1.10	0.59	0.84	2.04	1.86	1.95	1.40
23 N	1.15	0.62	0.89	2.13	2.19	2.16	1.53
46 N	1.31	0.82	1.07	2.41	2.27	2.34	1.71
23-20 N-P_2O_5	1.59	0.85	1.22	2.27	2.22	2.25	1.74
46-20 N-P_2O_5	1.39	0.69	1.04	2.19	2.62	2.41	1.73
20 P_2O_5	1.79	0.65	1.22	2.02	2.00	2.01	1.62
Mean	1.39	0.70		2.18	2.19		

Similar trials were conducted at Debre Zeit (Dembi) and in the Goha Tsion area. Faba bean yields increased with the application of 40-20 kg N-P_2O_5/ha. Otherwise, response to fertilizers was rather erratic. Yields were very low in those areas because of moisture stress and disease pressure.

A similar trial was carried out in Wolaita region, Kokate area of the south highland as early as 1974, where it was found that the application of 23-46 kg N-P_2O_5/ha produced the best grain yield (2.58 t/ha) (Table 4). This was also a recommended rate for faba bean production under Kokate conditions (WADU 1977).

Table 4. Grain yields of faba bean in a fertilizer trial at Kokate.

N rate (kg/ha)	P_2O_5 rate (kg/ha)				Mean yield (t/ha)
	0	23	46	92	
0	1.33	1.66	1.64	2.01	1.66
23	2.23	2.07	2.58	2.02	2.22
46	1.08	1.53	1.62	2.12	1.59
92	1.23	1.69	1.74	2.14	
Mean	1.47	1.74	1.90	2.07	

Source: WADU 1977.

In the 1991/92 cropping season, the effects of N and P on faba bean in trials at different faba bean production areas were studied. There was no response to either N or P or to their interactions at both Kulumsa and Debre Zeit but a significant yield response to P application was shown under Sinana conditions. However, results showed that faba bean yield was highly significantly affected by the application of both N and P but not by their interactions. A yield advantage of 35.3, 40.6 and 59.2% over the control was obtained with the application of 23, 46 and 69 kg P_2O_5/ha, respectively (Table 5). Nitrogen applied at a rate of 18, 27 and 36 kg/ha significantly increased seed yield of faba bean under Holetta conditions (Table 5).

Table 5. Effect of N and P fertilizers on faba bean seed yields at Holetta, 1991.

N rate (kg/ha)	P_2O_5 rate (kg/ha)				Mean yield (t/ha)
	0	23	46	69	
0	1.77	2.25	2.36	2.47	2.21b†
9	2.20	2.47	2.56	2.19	2.19b
18	1.56	2.52	2.82	3.05	2.49ab
27	1.95	2.71	2.81	3.00	2.62a
36	2.07	2.34	2.83	3.06	2.57a
Mean	1.78c	2.40b	2.63ab	2.83a	

† Values followed by the same letter(s) are not significantly different from each other at 5% probability level according to DMRT.

Fertilizer demonstration trials were conducted in different agroecological zones of the country with two released cultivars, Lume Nazareth and Col-31/7. Fertilizer as urea and TSP was applied at rates of 18-46 kg N-P_2O_5/ha. Soils were sampled and analyzed for some important characteristics as shown in Table 6.

Faba bean seed yields were significantly increased by fertilizer applications in all sites. Grain yield of the local farmers' cultivars increased by over 16% across many locations except at Goha Tsion. This could probably be due to the high levels of soil N and P available to the crop (Table 6). On the other hand, the yield of the improved faba bean cultivar increased highly significantly with the application of 18-46 kg N-P_2O_5/ha across all locations under all circumstances. It was also clear that response to fertilizer application generally was much greater by the improved cultivars than it was by the local ones (Table 7). Faba bean grain yields were generally high during the period of 1981 to 1983 across all locations. This was very encouraging to the farmers as well as to the researchers of the nation.

Table 6. Some important characteristics of the soils of the different IAR/ADD sites used for fertilizer demonstration trials.

Location	Textural class	pH (H_2O)	N (%)	P_2O_5 (ppm)
Inewari	Clay	6.6	0.12	13.19
Bichena	Clay	5.75	0.12	13.70
Goha Tsion	Clay loam	5.07	0.32	28.12
Mota	Clay	4.85	0.16	6.48
Debre Tabor	Silty clay loam	4.85	0.19	76.64
Robe	Silty clay	5.63	0.16	15.62
Shambu	Clay	5.00	0.20	21.34

Source: Adugna and Hiruy 1988.

Table 7. Influence of fertilizer application (18 kg N + 46 kg P_2O_5/ha) on the seed yield (t/ha) of faba bean cultivars at different IAR/ADD sites, 1981-83.

	Unfertilized cultivar		Fertilized cultivar		Increase (%) due to fertilizer	
Location	Local	Improved	Local	Improved	Local	Improved
Inewari	3.13	2.67	3.83	4.19	22.0	57.0
Bichena	5.78	5.01	5.88	5.30	1.7	5.8
Goha Tsion	3.71	3.87	3.64	4.33	-2.0	11.9
Mota	2.78	3.06	3.44	4.22	23.7	37.9
Debre Tabor	2.89	3.13	3.35	3.58	15.9	14.4
Robe	1.71	2.46	2.19	3.04	28.1	23.6
Shambu	1.97	2.64	2.35	3.26	19.3	23.5

Source: Adugna and Hiruy 1988.

Response to Nitrogen, Phosphorus and Potassium

At Holetta, N-P-K fertilizer trials were conducted for 3 consecutive years. The N and P fertilizers increased faba bean grain yield significantly, but the response to potassium was not pronounced. However, application of N-P-K together increased faba bean yield by >100% over unfertilized treatments (Table 8). In the 3 years of the study, highest mean grain yields were achieved with the application of 120-26-40 kg N-P-K/ha.

Table 8. Mean grain yield of faba bean (t/ha) as affected by N, P and K fertilizers at Holetta, 1980-82.

Fertilizer treatment (kg/ha)	Year			Mean	Increase (%) due to fertilizer
	1980	1981	1982		
Control	1.04	0.38	2.42	1.28	
60 N		1.09	2.08	1.59	24.2
26 P	1.91	0.70	3.13	1.91	49.2
40 K	1.25	0.45	2.31	1.34	4.7
60-26-40 N-P-K		1.57	3.40	2.59	102.3
120-26-40 N-P-K	3.17	1.90	3.48	2.85	122.7

Source: Sahlemedhin and Desta 1988.

Another trial was conducted at Holetta to determine the best preceding crop and best rate of fertilizer for faba bean production under Holetta conditions. It was clear that faba bean grain yield showed greater increase with the application of N-P-K fertilizers when the crop was preceded by cereals or pulses (Table 9).

Response to some Animal Wastes and Fertilizer

A comparative effect of some animal wastes and 18-46 kg N-P_2O_5/ha on the yield of faba bean was conducted at Holetta. All the treatments gave a significantly higher grain yield than the control (Table 10). A yield advantage of 10-38% was obtained in the application of waste products of dead animals, which have remained unused in the country so far and can serve as an alternate source of fertilizer.

Table 9. Effect of fertilizer treatments on the grain yield of faba bean grown after different preceding crops at Holetta.

Fertilizer treatment (kg/ha)	Preceding crop†						Mean yield (t/ha)
	WH	BA	LI	RA	FP	FB	
Control	1.00	1.49	1.44	1.51	0.96	0.95	1.23
60 N	1.55	1.54	1.66	1.90	1.25	1.33	1.54
60-26 N-P	1.95	2.51	2.14	1.67	2.58	2.30	2.20
60-26-25 N-P-K	1.94	2.39	1.73	1.87	2.76	2.12	2.12
60-25 N-K	1.61	1.75	1.62	2.10	1.42	1.58	1.68
Mean	1.61	1.92	1.72	1.80	1.79	1.66	

† WH = wheat, BA = barley, LI = linseed, RA = rapeseed, FP = field pea, FB = faba bean.

Source: Desta and Angaw 1986.

Table 10. Effect of different sources of fertilizer on grain yield of faba bean.

Treatment	Yield (t/ha)
Control	1.73
Bone + hoof	2.11
Bone + blood	1.91
Mixed	2.39
N-P	2.37
LSD 5%	0.36
CV %	9.00

Source: Asnakew 1986.

Field Pea

Application of 18-46 kg N-P_2O_5/ha significantly increased grain yield of field pea under different agroecological conditions of Ethiopia. The response of both local and improved cultivars of field pea was very high to fertilizers at many locations. Unlike many field crops, the response of local field pea cultivars to N-P was much higher than that of the improved cultivars (FP-Nur-78 and Goba-7) at many locations (Table 11). In the Shambu area, yields of farmers' cultivars were 61% greater with N-P fertilizer application; the yield of improved cultivars increased by 9-57% with N-P application at all locations.

Table 11. Influence of fertilizer on the seed yield (t/ha) of local and improved field peas at different IAR/ADD sites, 1981-83.

	Unfertilized		Fertilized		Increase (%) due to fertilizer	
Location	Local	Improved	Local	Improved	Local	Improved
Bichena	2.78	3.37	4.01	4.26	4.42	2.64
Goha Tsion	3.99	3.25	3.23	3.68	1.90	1.32
Mota	2.56	3.28	3.33	4.26	3.01	2.79
Debre Tabor	1.45	1.06	1.63	1.16	1.24	0.94
Robe	1.84	1.79	2.20	2.25	1.96	2.57
Shambu	1.72	1.55	2.77	2.4	6.10	5.68

A N-P fertilizer rate trial on field pea conducted at Indibir showed a highly significant response (Table 12). Highest field pea grain yields were obtained with the highest N-P rates.

Table 12. Yield of field pea as affected by N-P fertilizer at Indibir, 1980/81.

	N level (kg/ha)			Mean yield (kg/ha)
P_2O_5 level (kg/ha)	0	23	46	
0	150	370	160	230
46	440	500	760	570
69	580	610	870	690
92	640	810	940	800
Mean	450	570	690	
LSD (5%)		270		
CV (%)	1	50	1	

Source: IAR 1984.

Three years of data from N response trials conducted on Holetta Nitosols and Vertisols showed no apparent response to N application. Field pea grain yields were generally higher on Nitosols than on Vertisols (Table 13). Similarly, there was no significant response of field peas to P fertilizer applications on both soil types (Table 14).

Table 13. The mean effects of N fertilizer on the yield of field pea at Holetta, 1970-72.

Fertilizer level (kg/ha)	Year			Mean yield (t/ha)
	1970	1971	1972	
Nitosol				
0	1.18	2.11	2.36	1.90
30	2.01	2.30	2.00	2.10
60	1.44	2.36	2.51	2.10
90	1.33	2.24	2.41	1.99
Mean	1.49	2.25	2.32	
Vertisol				
0	1.13	1.18	1.96	1.42
30	1.08	1.30	1.89	1.42
60	1.02	1.58	1.89	1.50
90	1.34	1.44	1.67	1.48
Mean	1.14	1.38	1.85	

Source: Desta 1988a.

Chickpea

Chickpea is one of the dominant crops grown on Vertisols of Ethiopia. It is mostly grown at the end of the rainy season and utilizes the residual moisture of the Vertisols. Highest chickpea yields were obtained with the application of 26 kg P/ha in the Debre Zeit area. Yields were 1.91, 1.47, 2.12 and 1.93 t/ha at P_2O_5 rates of 0, 13, 26 and 40 kg/ha (Desta 1988b). Chickpea that did not receive P also produced high grain yields, but chickpea receiving the 26 kg P/ha yielded about 11% more than the control.

Table 14. The mean effects of P fertilizer (P_2O_5) on the grain yield of field pea at Holetta, 1970-72.

Fertilizer level (kg/ha)	Year			Mean yield (t/ha)
	1970	1971	1972	
Nitosol				
0	1.74	2.17	1.93	1.95
30	1.53	2.30	1.88	1.90
60	1.75	2.24	2.33	2.11
90	1.20	2.35	2.61	2.05
Mean	1.56	2.27	2.19	
Vertisol				
0	0.84	1.02	1.86	1.24
30	1.08	1.51	1.90	1.50
60	1.13	1.71	1.92	1.59
90	1.51	1.25	1.73	1.50
Mean	1.14	1.37	1.85	

Source: Desta 1988a.

Response to N and P

A trial to study the combined effect of N (0, 23, 60 and 120 kg/ha) and P_2O_5 (0 and 46 kg/ha) on the yield of chickpea was conducted at Adet (Asgelil and Gebreselasie 1993). Results indicated no significant grain yield difference due to fertilizer application.

Drainage Trials

From 1975 to 1977 different drainage systems (camber beds, open trenches, and subsurface trenches filled with wooden poles and branches at 4, 6 and 8-m intervals) were compared using chickpea and other crops receiving 0 and 27-30 N-P kg/ha fertilizers.

The research site at Ginchi (2200 m asl) receives about 1080 mm rainfall annually of which about 65% falls between June and September. Therefore, it was of paramount importance to drain excess moisture in order to attain a maximum crop yield. Improvement of drainage had a significant effect on the grain yield of chickpea, increasing it by about 70% with the use of subsurface drainage system compared with yields from undrained (control) plots. Fertilizer application made little impact on the yield of chickpea under flat land conditions but its effect was improved when it was coupled with drainage.

A trial on influence of P application and methods of seedbed preparation on chickpea yield on Vertisols was conducted at Debre Zeit, Dembi and Akaki. Results showed that planting on broad bed and furrows gave significantly higher yields compared with planting on flat seedbed at all locations; there was no significant response to P applications at all locations (Miressa *et al.* 1993a).

Lentil

Lentils are normally produced on hillside areas and low fertile soils in Ethiopia. Fertilizer trials using cultivar NEL-358 were conducted at Ginchi and Dembi. No apparent lentil yield difference was obtained with N-P fertilizer application at Dembi (Table 15). Lack of response to fertilizers could be due to high soil fertility at Dembi (Angaw and Desta 1989). The Ginchi trial showed a linear yield increment due to N fertilization.

Table 15. Lentil response to N and P (P_2O_5) fertilizers at two locations in Ethiopia.

	Grain yield (t/ha)	
Treatment (kg/ha)	Dembi	Ginchi
Control	1.46	1.81
23 N	1.73	1.87
46 N	1.73	2.04
20 P	1.64	1.98
23-20 N-P	1.77	2.11
46-20 N-P	1.78	2.39

Source: Angaw and Desta 1990.

In trials conducted around Debre Zeit, lentil showed no response to P applications but planting lentil in Vertisols on broad bed and furrows resulted in a highly significant yield increase at Akaki. Lentil straw yield increased significantly with increasing rates of P in the same area (Miressa *et al.* 1993b).

Future Research Directions

Fertilizers affect the root development and biomass production of plants. This could have an effect on the nitrogen-fixing capability of legumes. Hence, quantification of the effect of fertilizer on nitrogen fixation of legumes is essential and deserves attention.

The Ethiopian highland plateau receives high rainfall (900-1100 mm annually) and as a result the soils are predominantly acidic. Acid soils could adversely affect establishment of crops, the growth and production of crops, and the survival of agriculturally important and beneficial soil microorganisms such as *Rhizobium*. Nitrogen fixation could be adversely affected. Therefore, studying the effect of liming on the performance of legumes on acid soils could be of great importance.

Acid tolerance of crops varies greatly. It is known that there is a difference among cultivars of crop species in their degree of tolerance of acidity. Legumes with some degree of acid tolerance are an important aspect of research; breeding work on acid soil tolerance is needed.

Limited work on the use of bone meal, hoof and blood meal has shown promising results for faba bean yields. These products could be used as alternative sources of fertilizer in the absence of industrially produced fertilizers. Therefore, more work on the use of bone, hoof, blood and mustard meal and other substances is required on different highland grain legumes.

Research on soil fertility was mostly concentrated on N, P and N-P applications. Limited work with N-P-K has shown grain yield increases of more than 100%. Micronutrients are essential to plant growth and good nitrogen fixation, but no work has been done with them in Ethiopia. It is important to study the effect of micronutrients on the performance and nitrogen-fixation rates of legumes.

Acknowledgements

We sincerely acknowledge the contribution of Dr Desta Beyene and other researchers of IAR, who have contributed to research in the area of soil fertility.

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Soil Microbiology Research

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Abstract

Of the cool-season food legumes grown in Ethiopia, only faba bean and chickpea have received some attention while few studies on rhizobiology have been made on the rest (field pea, lentil, lathyrus). From the limited soil microbiology research studies, it was found that faba bean cultivars responded to inoculation with appropriate *Rhizobium* strains. Under Ethiopian conditions, *Rhizobium* strain no. 18 gave good results in terms of nitrogen fixation, even under waterlogged conditions. The emphasis in future research should be on identifying host-strain specificity, evaluating rhizobial strains and strengthening *Rhizobium* research capacities in Ethiopia.

Introduction

Legumes are important sources of protein for humans and animals. They play a key role in maintaining the productivity of soils, particularly through biological nitrogen fixation. They also provide nutritionally rich crop residues for animal feed. Farmers have understood the benefit of growing a succeeding cereal crop after legumes and have been practising crop rotation for many years.

With increasing costs of chemical fertilizers and farmers' inability to purchase them, the need to exploit inexpensive means of soil fertility maintenance such as biological nitrogen fixation is becoming important.

In the past, only limited research has been conducted in the area of soil microbiology, specifically on rhizobiology. Most of the work was done by the Institute of Agricultural Research (IAR), beginning in 1982 at Nazret Research Center. In 1986, the soil microbiology laboratory was moved to Holetta Research Center, where work has been conducted on the rhizobiology of highland pulses.

The major areas of research conducted so far include nodule collection and characterization, isolation and identification of *Rhizobium* strains, and investigations on inoculation needs of pulse crops.

Of the major pulse crops most rhizobiology work has been conducted on faba bean (probably owing to its being the dominant legume crop in the country), followed by chickpea. Work on other legume crops (field pea, lentil and lathyrus) has been minimal.

Soil Characteristics

Food legumes are grown on a wide range of soils, but the common ones are those predominantly occupying large hectarages in the country. These are Nitosols, Vertisols and Cambisols; they have variable characteristics in terms of drainage and nutrient status, but some are similar in texture (Tables 1 and 2). Except for a few locations such as Dukum, Oude, Gondi and Syrbanagodetti, which have high available phosphorus, the majority are deficient in N and P. This is in agreement with the fertility conditions of most Ethiopian soils (Tekalign and Haque 1987). The soils are in the acidic range (Tables 1 and 2).

Rhizobial Studies

Faba Bean

Nodule collection and characterization

Surveys and collection of nodules from the roots of faba bean from different locations were made. From visual observation of nodulation patterns (Table 3) it was found that the average number of nodules per plant for most sites was generally greater than 15 with the lowest nodule number (<5) observed at Holetta. Nodules at most sites were medium in size (2-10 mm) except for Geba-Guba and Gondi where they were greater than 10 mm. Nodulation scores were correlated with yield (Desta and Angaw 1987), but only the correlation coefficient between yield and nodule number was significant.

Of the thousands of nodules collected, 108 isolates of *Rhizobium leguminosarum* were identified (Desta and Angaw 1987). Selection work for faba bean *Rhizobium* strains so far showed that 23 faba bean strains were highly superior. A few of these strains were promoted for field inoculation.

Table 1. Characteristics of soils at different locations used in faba bean nodulation and isolation studies.

Location	pH (1:1 H_2O)	Organic C (%)	Total N (%)	Available P (Olsen) (ppm)
Dukum	6.3	2.6	0.12	277
Kurkura	6.3	2.0	0.14	21
Kajima	6.4	1.2	0.08	31
Syrbanagodetti	6.1	1.6	0.12	128
Selae	5.7	2.1	0.08	12
Deyu Genguda	5.5	1.8	0.17	31
Ali-Doro	5.1	2.5	0.21	33
Goha Tsion	4.7	1.9	0.62	14
Geba-Guba	5.0	1.2	0.08	30
Ula-Emu	6.3	1.6	0.14	54
Kassim	5.5	2.3	0.21	3
Teltelae	5.4	2.2	0.21	19
Oude	6.0	1.4	0.11	137
Gondi	6.0	1.4	0.11	136
Holetta	5.4	1.6	0.16	69
Sheno	6.2	2.4	0.32	186
Bekoji	5.2	1.8	0.34	88

Source: Desta and Angaw 1986.

Assessment of inoculation needs

A number of experiments have been carried out at different locations to establish whether there was a need for rhizobial inoculation by studying the effects of N and P fertilizer application (singly or in combination) on the nodulation and yield of faba bean cultivar CS 20DK (Desta and Angaw 1988b).

Table 2. General characteristics of different locations used in inoculation need studies.

	Locations					
	Holetta					
	Red soil	Black soil	Dembi	Sheno	Goha Tsion	Bekoji
Altitude (m)	2400	2400	1800	2800	2500	2700
Rainfall (mm)	1100	1100	1300	1200	800	1000
Soil type	Nitosol	Vertisol	Cambisol	Vertisol	Nitosol	Nitosol
Soil texture	Clay loam	Clay loam	Clay loam	Clay	Clay loam	Clay loam
pH (1:1 H_2O)	5.4	5.2	6.0	6.2	5.1	5.2
Organic C (%)	1.63	2.7	2.3	2.4	2.1	1.8
Total N (%)	0.16	0.18	0.14	0.32	0.20	0.34
Available P (ppm) (Bray II)	11.3	7.2	98.0	44.9	45.6	12.8
Exchangeable cations (meq/100 g)						
K	1.7	1.9	3.3	1.9	1.0	1.0
Ca	8.6	23.2	12.4	14.0	15.6	8.8
Mg	4.0	7.9	3.7	5.7	3.9	1.6
Al	0.10	0.08	0.02	0.09	0.24	0.09
CEC (meq/100 g)	22.6	41.0	34.8	29.9	21.9	45.4
Extractable Mo (ppm)	4.5	10.0	1.5	7.0	9.5	5.5
Water-soluble B (ppm)	2.9	2.5	2.0	0.9	2.4	5.5

Source: Desta and Angaw 1986.

Yields varied among locations but yield differences were significant only at Holetta (Vertisol), Goha Tsion and Bekoji. There was a tendency for faba bean yield to increase with an increase in N and P fertilizer except at Dembi and Goha Tsion. Further examination of the yield data in Table 4 shows higher yield for the control treatment at Sheno and Bekoji, which is probably due to high soil N contents. Rust incidence and moisture stress have negatively affected faba bean yield at Dembi.

Table 3. Average number, size, color and distribution of nodules per faba bean plant in different locations of the major faba bean growing areas of Ethiopia.

Location	Grain yield (t/ha)	Nodulation score			
		Number†	Size‡	Color§	Position¶
Dukum	2.72	4	2	4	2
Kurkura	1.91	3	3	4	3
Kajima	1.20	3	2	3	3
Syrbanagodetti	1.78	4	2	4	3
Selae	0.97	2	3	2	3
Deyu Geneguda	0.13	2	3	3	2
Ali-Doro	0.83	2	3	3	4
Goha Tsion	1.53	2	2	1	3
Geba-Guba	1.53	3	4	2	3
Ula-Emu	1.03	3	3	3	2
Kassim	0.58	3	2	4	3
Teltelae	0.43	3	2	4	3
Holetta	11.3	1	2	4	4
Sheno	5.4	2	1	3	2
Oude	2.79	4	2	4	2
Gondi	3.25	4	4	4	2
Bekoji	2.58	3	1	4	3

† On 0-4 scale where 0 = no nodules/plant and 4 = more than 30 nodules/plant.
‡ On a 1-4 scale where 1 = 0-2 mm nodule size and 4 = more than 10 mm.
§ On a 1-4 scale where 1 = white nodule and 4 = deep red nodule (reflecting high leghaemoglobin content).
¶ On a 1-4 scale where 1 = nodule on the top part of the main root and 4 = nodules on lateral or secondary roots.
Source: Desta and Angaw 1986.

Table 4. Summary of faba bean grain yields in inoculation need trials conducted across different locations, 1987.

Treatment (kg/ha)	Yield (t/ha)						
		Holetta					
	Dembi	Nitosol	Vertisol	Sheno	Goha Tsion	Bekoji	Mean
Control	0.75	1.95	1.10	2.04	1.08	3.60	1.65
23 N	0.67	1.76	1.15	2.13	0.90	3.36	1.66
46 N	0.72	2.09	1.31	2.41	1.02	4.22	1.96
23-20 N-P	0.74	2.41	1.60	2.27	1.36	4.72	2.18
46-20 N-P	0.77	2.32	1.39	2.19	1.32	4.30	2.05
20 P	0.69	2.25	1.79	2.02	1.36	4.90	2.17
Mean	0.72	2.13	1.39	2.18	1.39	4.18	
LSD (5%)	NS	NS	2.3	NS	0.16	0.97	
SE ±	0.54	2.5	0.8	2.5	0.54	3.2	
CV (%)	14.9	23.7	11.1	23.0	9.0	15.4	

Source: Desta and Angaw 1988a.

The highest mean nodule number was obtained at Holetta on both soil types whereas the lowest scores were for Bekoji and Goha Tsion. It appeared that size and the leghaemoglobin content of nodules decreased with the application of N.

Studies conducted in 1989 at Holetta on Nitosols showed that a high number of nodules per plant was scored when faba bean was fertilized with P-K followed by N-P-K fertilizers. Nodule size and activity (based on color) were suppressed with 100 kg N/ha. However, both grain and dry matter yields were significantly increased by the applications of N, P-K and N-P-K (25, 25 and 68%, respectively). Hence, since a positive response was achieved with N application, rhizobial inoculation may be justified for increased faba bean yield at Holetta (Nitosol).

Similar studies were conducted at Adet Research Center during the 1990 and 1992 cropping seasons. Results of the 1990 cropping season indicated that there were significant yield differences among the treatments. The highest grain yield was 3.2 t/ha (Table 5). Similar results were obtained from the 1992 growing season data. The increase in yield with the application of higher rates of N and P fertilizers justifies the need for faba bean inoculation with the appropriate *Rhizobium* strains for increased yield under Adet conditions.

Table 5. Effects of N and P fertilizers on the yield and nodulation pattern of faba bean at Adet, 1990.

Treatment (kg/ha)	Nodule score†				Yield (t/ha)
	No.	Size	Color	Position	
Control	4.0	2.2	3.0	3.0	1.3
23 N	4.0	2.3	2.5	3.0	1.7
120 N	3.6	2.0	3.5	3.0	2.2
20 N	4.0	2.2	2.2	3.0	2.2
23-20 N-P	4.0	2.3	2.5	4.0	2.5
120-20 N-P	4.0	2.0	3.0	3.0	3.2
LSD (5%)					0.3
SE (±)					0.1
CV (%)					8.6

† See Table 3 for scale.
Source: IAR 1990.

Inoculation response studies

The purpose of these studies was to evaluate the effectiveness of native and exotic *Rhizobium* strains on nodulation and grain yield of faba bean. Out of 57 native *Rhizobium* isolates evaluated for their effectiveness in 1988, isolate numbers 18, 51 and 64 were tested with introduced strains and N fertilizer.

In the 1989 season *Rhizobium* inoculation increased nodulation 6- to 7-fold on Holetta Nitosol whereas dry matter and grain yield increased by 67-112% and 32-45%, respectively (Table 6). However, differences were only significant for isolate number 18. When the same isolates were evaluated with P fertilizer, grain yield and dry matter were increased 4- to 5-fold.

Table 6. Effect of *Rhizobium* strains and N and P fertilizers on nodulation, plant height and yield of faba bean at Holetta, 1989.

Treatment	Nodule score† No.	Size	Position	Color	Plant height (cm)	Yield (t/ha) Dry matter	Grain
Control	0.5	1.6	2.5	2.2	84	1.34	0.44
20 kg P/ha	1.6	2.2	1.7	2.9	103	3.14	0.74
120 kg N/ha	0.7	1.3	1.5	1.8	91	3.94	0.67
120-20 kg N-P/ha	1.5	1.8	0.9	2.4	128	6.12	1.40
Isolate 18	3.8	1.2	1.0	4.0	94	2.85	0.64
Isolate 51	3.8	1.0	1.0	4.0	87	2.24	0.54
Isolate 64	3.8	1.6	1.0	4.0	90	2.59	0.61
Multistrains	3.9	1.4	1.0	4.0	90	2.35	0.58
LSD (5%)					9	0.15	0.20
SE (±)					3.0	1.5	1.0
CV (%)					6.2	9.9	19.5

† See Table 3 for score.
Source: IAR 1990.

Further studies conducted at Holetta and Dembi (IAR 1990) proved the beneficial role of inoculation and the enhancement of rhizobial activity with P applications. In subsequent experiments (Balesh and Asnakew 1993a, 1993b) *Rhizobium* strain 18 increased dry matter yield of a wide range of faba bean cultivars. Atmospheric N_2 fixation also increased as a result of inoculation with this particular strain. Moreover, it was proved that this strain remained active and enhanced nitrogen fixation of faba bean even under waterlogged conditions (Angaw 1992).

Faba Bean International Inoculation Response Trials coordinated by ICARDA were conducted to evaluate yield response of faba bean to inoculation with known superior *Rhizobium* strains. Three strains (414, 420, 481) and N-P-K fertilizer were evaluated at Holetta and Dembi in 1989 and 1990 cropping seasons.

In the first season, the highest response in grain yield, dry matter and plant height was obtained with the application of N-P-K and P-K (Table 7) at Holetta. There were significant yield differences among the treatments and inoculation of faba bean with various *Rhizobium* strains in addition to P-K increased dry matter and grain yield significantly over the control.

Table 7. Effects of *Rhizobium* strains and fertilizers on plant height, dry matter, grain yield and nodulation of faba bean at Holetta, 1989.

Treatment (N-P-K kg/ha)	Plant height (cm)	Yield (t/ha)		Nodule score†			
		Dry matter	Seed	No.	Size	Position	Color
Control (not inoculated)	87	2.13	0.89	0.8	2.3	2.3	2.7
120-35.2-48	144	5.89	2.46	1.3	2.2	2.5	3.7
0-35.2-48	128	5.12	2.18	1.3	2.3	2.6	3.6
Strain 414 (0-35.2-48)	120	4.45	1.56	2.0	2.4	1.0	4.0
Strain 420 (0-35.2-48)	115	3.51	1.53	2.8	1.1	1.0	3.8
Strain 481 (0-35.2-48)	115	3.70	1.74	3.9	2.8	1.0	4.0
LSD (5%)	7	0.76	0.47				
SE (±)	2.3	0.25	0.22				
CV (%)	3.9	1.22	1.81				

† See Table 3 for score.
Source: IAR 1989.

The second year (1990/91) results from Holetta and Dembi showed that nodule number, size and visual leghaemoglobin content score were high when faba bean was inoculated with strains 414, 420 and 481 in soils applied with P and K fertilizers (IAR 1990). Nodulation was poor when N-P-K was applied, which may be due to the suppression effect of N fertilizer. At Holetta, application of N-P-K gave the highest grain and dry matter yields while at Dembi application of P-K gave the maximum grain and dry matter yields. In terms of nodule characteristics all inoculants were best at Holetta while at Dembi strain 414 was best, followed by the other two strains.

In a recent nodulation study of some Ethiopian *Rhizobium* strains of faba bean under greenhouse conditions in the UK, Angaw (1992) reported that of the four selected faba bean *Rhizobium* strains (18, 64, 107 and 123) used to inoculate cultivar Fava bean, strains 18, 64 and 123 showed better fixation of atmospheric nitrogen. Increased dry matter yield of 21.6% was obtained by strains 18 and 64 over the control although the effects were not significantly different from the locally available soil rhizobia of the Rowland soil series in UK. It was concluded that the local *Rhizobium* strains were as efficient in atmospheric nitrogen fixation as those *Rhizobium* strains used for inoculation, but still either of *Rhizobium* strains 18 and 64 could be used for inoculating faba bean cv. Fava bean.

Chickpea

Nodule collection and characterization

In 1989, chickpea nodules were collected from various parts of the country and more than 128 *Rhizobium* isolates were preserved as culture collections to select the most efficient N_2 fixers. Pure colonies of *Rhizobium* isolated from the nodules were then transferred into slanted culture vials and preserved in a refrigerator.

Thirty-three isolates from the chickpea *Rhizobium* collection were tested in big test tubes out of which 23 isolates were found to be effective in biological N_2 fixation based on nodulation, color and accumulation of biomass. These isolates were again tested using hydroponic cups and the results (Table 8) showed that 11 isolates were superior. In 1991, a total of 12 isolations and 20 selections of the best chickpea *Rhizobium* strains were made. Two isolates of chickpea were found to be superior and were promoted to an intact soil core study.

A study also was conducted at Alemaya to assess the nodulation capacity of chickpea cultivars grown on Vertisols. Results (Table 9) showed that statistically significant differences occurred among chickpea cultivars on nodule numbers only. This suggests the need for further studies on the effectivity of the nodules.

Assessment of inoculation needs

Studies were conducted at Adet and Wereta to assess the nodulation pattern of chickpea and determine whether there is a need for inoculation with *Rhizobium* strains through the application of N and P fertilizers, singly or in combinations (Asgelil 1992).

Results showed that there were no significant yield differences among the treatments at both locations. However, the highest dry matter yields (5.95 t/ha at Adet and 5.29 t/ha at Wereta) and grain yields (3.62 t/ha at Adet and 2.90 t/ha at Wereta) were obtained with the application of 120 kg N and 20 kg P/ha at both locations. The lack of significant response to fertilizers may be due to the inherent high soil fertility status of the experimental sites.

Table 8. Effects of *Rhizobium* isolates on mean dry matter yield and nodulation of chickpea cultivar K 850-3/27 × F 378 in hydroponic cups under greenhouse conditions at Holetta, 1989.

Treatment (isolate no.)	DM yield (g/plant)	Nodulation	Treatment (isolate no.)	DM yield (g/plant)	Nodulation
Control	1.1	Poor	Control	1.8	Poor
321	1.5	Good	410	2.4	Excellent
334	1.3	Good	319	2.1	Excellent
344	2.4	Excellent	358	1.9	Excellent
347	1.1	Excellent	354	2.8	Good
357	2.0	Excellent	359	2.3	Excellent
367	2.2	Excellent	335	2.1	Excellent
368	2.6	Excellent	385	2.1	Very good
374	1.5	Very good	388	2.4	Very good
403	0.9	Very good	323	4.2	Excellent
406	0.8	Very good	333	1.9	Good
432	1.6	Very good	339	1.9	Good

Source: IAR 1989.

In general, inoculation need studies on chickpea have been minimal and more studies are required at many locations along this line.

Inoculation response studies

A study was conducted on the evaluation of the effectiveness of inoculation with exotic and efficient *Rhizobium* strains under field conditions at Ginchi using chickpea cultivar K 850-3/27F × F 378 (IAR 1989). The treatments were N-P-K, P-K, N fertilizer and ICARDA's chickpea strains 31, 36 and 39. Nodule number, size, position and activity were good for all treatments except for 120 kg N/ha. The highest grain yield of 3.71 t/ha was obtained with the application of N-P-K fertilizer followed by 3.38 t/ha obtained from only P and K fertilizers, but none were significantly higher from yield obtained from the control.

Table 9. Nodulation status of chickpea cultivars grown on Vertisol at Alemaya, 1988/89.

Cultivar	No. nodules/plant	Volume (ml) of nodules/6 plants
82303	5.75	1.20
Mariye	12.30	2.86
ICC-6800	14.10	3.55
DZ-10-11	7.80	3.37
ENT-46	12.00	1.30
7-D-A	9.00	2.82
ICCL-84229	12.00	1.82
JG-62 × Radhy	14.30	2.97
Dubie	8.50	2.25
H-54-10	11.00	4.65
Mean	10.70	2.66
LSD (1%)	2.12	NS

Results of International Inoculation Response Trials conducted at Ginchi showed that both dry matter and grain yields were very low due to moisture shortage during pod formation (Balesh and Asnakew 1993c). Treatment effects were not significant.

Lentil

Nodule collection and characterization

Nodules were collected from various agroecological zones in the country to identify the most effective *Rhizobium* isolates. From the 13 isolates of the culture collections, 11 were evaluated for plant infection test in big test tubes and 6 were found to be effective in nodulating lentil seedlings (Cultivar NEL 358). The six isolates were again evaluated further using hydroponic cups and only three lentil *Rhizobium* isolates (308, 545 and 546) were promoted for evaluation using soil core tests and later under field conditions. Evaluation of the three isolates continued in 1991/92 and the same were found to be superior.

Assessment of inoculation needs

A study on the need for *Rhizobium* inoculation in lentil was carried in 1989 at two locations (Ginchi and Dembi). Results showed no significant yield differences among the treatments because of fertilizer application. There was no good nodulation at either locations, which may be due to local soil factors (IAR 1989).

Similarly, results of an international inoculation response trial on lentil indicated that there were no significant differences among the treatments (IAR 1991).

More studies are needed at representative locations to determine the need for lentil inoculation.

Field Pea

Although the crop is one of the major highland grain legumes cultivated by a large portion of the farming community, studies on its biological N_2 fixation behavior and inoculation needs have been almost lacking. Only recently were nodules collected from farmers' fields at some locations. Among 34 isolates of field pea *Rhizobium*, 9 were tested for nodulation and effectiveness, out of which only three isolates (coded 285, 286 and 291) were found to be superior.

Emphasis needs to be given in the future on the identification of effective field pea *Rhizobium* strains for maximum crop production.

Grasspea

Grasspea is mostly grown and consumed by low-income farmers who generally lack a source of protein in their diet. The crop's adaptability to adverse agricultural conditions such as waterlogging coupled with its potential for providing protein make it ideal for planting in adverse conditions by farmers (IAR 1991).

Preliminary investigation on the nodulation pattern of grasspea was carried out in the northwestern region of Ethiopia where nodules were collected from Bichena, Mota, Wereta and Yilmana Densa areas.

Results (IAR 1991) have shown that the nodule formation was very poor indicating that local strains of bacteria were ineffective in fixing atmospheric N. However, this is only a preliminary finding and more work is needed to arrive at conclusive results.

Factors Affecting N_2 Fixation in Legumes

Biological N_2 fixation in legumes is influenced by a range of factors which act inseparably. These are environmental (temperature, moisture, aeration), soil chemical (salinity and alkalinity, soil acidity, soil fertility status, pollution) and biological factors (host plant-*Rhizobium* specificity, antagonistic or synergistic effects by other microorganisms).

However, studies made on the influence of these factors on biological N_2 fixation in legumes in Ethiopia are quite minimal, and the only documented account is that reported by Angaw (1992).

Host × Strain Interaction

The genus *Rhizobium* is host specific and the species of *R. leguminosarum* does not infect every cool-season legume. The degree of infectivity and effectivity with strains of *Rhizobium* is also variable on different cultivars of a particular crop.

In an attempt to identify the best compatible Ethiopian rhizobial strains with the available faba bean cultivars, Angaw (1992) tested the response of six faba bean cultivars (Alfred, Minica, Albatross, Fava bean, Barker and Tigo) to inoculation with *Rhizobium* strains 18, 50, 64, 107 and 123 under controlled conditions. He found highly significant differences in shoot dry matter production of the six faba bean cultivars inoculated by six different strains of *Rhizobium leguminosarum* biovar *viciae*, but there was no strain × cultivar interaction for N_2 fixation. It was also found that the cultivar Tigo and the very large-seeded Fava bean responded more to inoculation followed by Minica and Barker. He concluded that *Rhizobium* strain 18 was, in general, superior to other strains used. The second-best strain was 107, followed by strain 64.

Waterlogging

Faba bean is a cool-season, highland crop in Ethiopia. As Vertisols remain waterlogged during the months of July and August, crops may suffer from poor aeration and nutrient deficiency.

A study was made by Angaw (1992) to investigate the effects of waterlogging on the effectiveness of *Rhizobium* inoculation on faba bean under greenhouse conditions. *Rhizobium* strain 18 was used to inoculate faba bean cultivar Barker.

When plants were waterlogged for 38 days, there was no significant yield difference obtained with either inoculation or N application (Table 10). Neither plant height nor nodule number was significantly affected by 38 days of waterlogging. Inoculation increased the number of nodules per plant (Table 10).

Similarly, inoculation with *Rhizobium* strain 18 increased total nitrogen yield of faba bean cv. Barker. The inoculum increased fixed nitrogen yield by 0.40 t/ha over the control. Although there was a general decreasing tendency in total amounts of fixed nitrogen under waterlogged conditions, strain no. 18 still remained superior to the native soil rhizobia.

Time of Inoculation

Inoculants are normally applied at planting time. The carrier often used is peat, which may be too acidic for good rhizobia development. Therefore, peat carriers are adjusted to neutral pH by addition of lime. Seeds coated with inoculant are held for weeks before they form nodules on the plant. As a result, the rhizobia are exposed to several adverse environmental factors. If freshly grown rhizobial culture is applied to a growing plant, efficiency might be better, provided root nodule sites are not occupied by ineffective soil rhizobia (Angaw 1992).

In an attempt to determine the appropriate time of inoculating faba beans, an experiment was conducted (Angaw 1992) using faba bean cv. Barker, *Rhizobium* strain 18 and three stages of inoculation (0, 15 and 22 days after planting).

Total dry matter yield and plant height were higher when plants were inoculated at planting time (Table 11). Similarly, nodule number per plant was highest for plants inoculated at planting time. Inoculation significantly increased the amount of nitrogen fixed, regardless of time of inoculant application (data not shown). However, Angaw (1992) stresses that inoculant application at the time of planting remains important in terms of dry matter yield production and nitrogen accumulation.

Table 10. Mean faba bean dry matter yields, plant height and number of nodules as affected by difference treatments when subjected to 38 days of waterlogging.

Treatment	DM yield (g/plant)			
	Shoot	Root	Plant height (cm)	No. nodules/ plant
Control (uninoculated)	3.2	2.6	52.3	77.5
Inoculated (*Rhizobium* strain 18)	3.5	2.8	57.8	85.5
N application†	3.8	2.2	62.5	65.5

† Application of 92.3 mg N/pot (equivalent to 120 kg N/ha).
Source: Angaw 1992.

Table 11. Faba bean dry matter yield (shoot, root and total) and plant height as affected by time of *Rhizobium* inoculant application in sand culture.

Treatment	Average no. nodules/ plant	DM yield (g/plant)			Plant height (cm)
		Shoot	Root	Total	
Control (uninoculated)	55.7	0.91	0.42	1.33	32.0
Inoculated					
at sowing	236.7	2.20	1.12	3.32	47.3
15 DAS†	89.3	0.85	0.37	1.21	36.3
22 DAS	65.7	0.92	0.44	1.36	36.6
SED	45.0	0.18	0.18	0.30	7.2

† DAS = days after sowing.

Future Research Needs

From the foregoing review, it is evident that our knowledge of the rhizobiology of cool-season food legumes in Ethiopia is quite limited, owing to the small research emphasis given to them so far. Therefore, efforts must be stepped up in order to strengthen the research and exploit the potential of biological nitrogen fixation of legumes. In this regard, the following are some of the priority areas of research to be considered in the near future.

Host-strain Specificity

It is known that different species of legumes have different capabilities of N_2 fixation, meaning that certain legumes fix higher amounts of atmospheric nitrogen than others depending on the efficiency of their associative rhizobial strain. Therefore, identification of the right host-strain combination is of paramount importance.

Characterization and Evaluation of Isolates

Emphasis should be given to the assessment of nodulation of legumes and characterization of the isolates in terms of infectivity and effectiveness. Screening of isolates (both local and exotic) must be given due attention.

Understanding of Factors affecting Nodulation

A wide range of environmental and soil factors can affect nodulation and rhizobial activity. Studies should involve the investigation of the importance of these factors and means of enhancing rhizobial activity. Identification of rhizobial strains that have the capability of withstanding harsh conditions is important.

Capability Building

Efforts must be made to strengthen rhizobiology research in the country. Development of such laboratories along with trained manpower are prerequisites for effective rhizobial inoculant production in the future.

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Discussion

Dr Solh

Response to nitrogen should be considered with reservations. We should emphasize more the rhizobiology rather than fertilizer application.

Dr Saxena

The whole scenario of fertilizer and rhizobiology should be linked together rather than discussing them separately.

Dr Eylachew
Earlier presenters said there is no response of fertilizer noticed in legumes which is contrary to the findings of the present paper where response to N as well as P has been shown.

Ato Angaw
Responses are different for different locations. A lot of data were collected through network group work and it clearly showed that most locations responded to N, mainly because of poor nodulation. Moreover, acidic soils will require P application and would show response.

Dr Saxena
If response to N or P or rhizobial inoculation is appreciable, it may be concluded that the system is not working properly. For example, fields with low pH (acidic) require liming for P to become available. Therefore, before recommending fertilizer the full background information needs to be collected and interpretations made in light of that. Emphasis should go more to the farmers' field situations.

Dr Geletu
Soil analysis around Debre Zeit station showed that P is very high in these soils.

Dr Tekalegn
I don't agree, in fact P levels are low not only around Debre Zeit but also at Akaki.

Dr Geletu
For conducting *Rhizobium* studies more genotypes should be selected. Conclusions derived from one genotype may not be valid.

Dr Tekalegn
We tested six genotypes with a *Rhizobium* strain and could get response only in one or two.

Dr Saxena
The fact that P requirement for chickpea is very low (2 ppm available) compared with other legumes (5 ppm) is the reason why responses have not been noticed in this crop. With regard to fertilizer and inoculation there should be clear-cut recommendations, future directions, priority areas, etc. Moreover, farmers' fields should only receive our attention for such work.

Chapter 5
Crop Protection

Diseases of Lathyrus in Ethiopia

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Abstract

Five diseases of lathyrus were initially recorded in Ethiopia. More recent surveys and identifications both locally and abroad increased the list to more than eight diseases. Of these, rust and wilt/root rot of lathyrus frequently and widely occur in Ethiopia. However, little work has been done on these diseases and therefore information is scant on their distribution and economic losses. Research programs are needed to establish the relative importance of diseases on lathyrus.

Introduction

Among cool-season food legumes grown in Ethiopia, grasspea (*Lathyrus sativus* L.) is considered a minor crop. Therefore, research emphasis has not been given to this crop as much as to faba bean, field pea, chickpea and lentil. Information on lathyrus has been acquired in fragments or during general assessments of the situation with other crops.

Lathyrus Diseases

The general impression is that among the food legumes grown in Ethiopia, lathyrus has the fewest disease problems. Lathyrus crops are mostly sown at the border of other crops such as tef, wheat and chickpea late in September. They are grown under residual moisture in black clay soils. Under these circumstances, only root rot/wilt appears, in low intensity, wherever the crop is grown. However, it is widely distributed throughout the country.

Six pathogens were previously recorded on lathyrus in Ethiopia (Stewart and Dagnachew 1967; Habtu and Dereje 1986). However, five additional pathogens were found to cause diseases on this crop (Table 1): *Ascochyta* sp. (Holetta Agricultural Research Center (HRC), Herbarium No. 5644), *Rhizoctonia* sp. (HRC 3734), *Fusarium* sp. (HRC 5614), *Macrophomina phaseolina* (HRC

5614) and *Uromyces viciae-fabae* (HRC 3735). The last was sent to the Commonwealth Mycological Institute (CMI) for confirmation, and although the telial state would have been useful, the CMI still identified it as *U. viciae-fabae* (CMI Herbarium No. 225614). *Uromyces viciae-fabae* is difficult to distinguish from *Uromyces pisi* (DC) Otth. in the uredial state when both these pathogens infect lathyrus (CMI, unpublished data).

Table 1. Lathyrus diseases identified in Ethiopia.

Pathogen	Disease	Reference
Ascochyta sp.	Stem lesion	HRC 3644†
Bean Mosaic Virus	Mosaic disease	IAR 1986
Cladosporium sp.		Stewart and Dagnachew 1967
Erysiphe poligoni DC.	Powdery mildew	IAR 1986
Fusarium sp.	Root rot	HRC 5614†
Macrophomina phaseolina (Tassi.) Goid.	Root rot	HRC 5614†
Glomerella cingulata	Blossom blight	Stewart and Dagnachew 1967
Rhizoctonia solani Kuhn	Root rot	HRC 3734†, IAR 1986
Uromyces viciae-fabae (Pers.) Schr.	Rust	CMI 225614†

† Sample numbers of plant diseases at Holetta Agricultural Research Center (HRC) and the Commonwealth Mycological Institute (CMI).

Future Research Priorities

A survey must be done for the major growing regions and quantitative data should be collected in order to decide on research priorities. Loss assessments should be considered for the major diseases already known.

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Field Pea Diseases in Ethiopia

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Abstract

Many diseases affect field pea production in Ethiopia. The most important in the main field pea growing regions are: powdery mildew caused by *Erysiphe polygoni* DC; leaf, stem and pod spots/blight caused by *Ascochyta pisi*, *A. pinodes* (*Mycosphaerella pinodes*); blotch caused by *Septoria pisi*; stem lesions caused by *Phoma medicagini* or *P. minutella*, and downy mildew caused by *Peronospora pisi*. The last disease is important only in a few restricted areas of Bale. However, other diseases, those caused by viruses, nematodes and bacteria, are not yet well documented. Foliar diseases such as powdery mildew and spots/blight were a severe threat to this crop in different regions in certain years, while root rot, blotch and viruses caused less serious damage. In this paper, we briefly summarize the most important information on diseases of field pea in Ethiopia with special reference to survey and identification, control measures and future research directions.

Introduction

Field pea (*Pisum sativum*) is a major contributor to the economy of Ethiopia (Amare and Beniwal 1988; Asfaw 1979). Diseases are among the important constraints limiting production of this food legume (Amare and Beniwal 1988; Habtu and Dereje 1986).

Information available on field pea pathology up to 1984 was reviewed by Habtu and Dereje (1986), but in this paper we present a summary of more recent advances. Survey and identification, specific diseases and future research direction are included. In the specific diseases section, available information on symptoms, yield losses and control measures are summarized for the most important diseases: powdery mildew, Fusarium root rot and the "spot/blight complex."

Survey and Identification

A number of pathogens causing diseases on field pea have been recorded in Ethiopia (Table 1). Fifteen fungi, one bacterium, four nematodes, and two viruses have been identified from diseased field pea plants (Stewart and Dagnachew 1967; Bos 1974; O'Banen 1975; Habtu and Dereje 1986). Many of these pathogens were identified after the first publication by Stewart and Dagnachew (1967), the "Index of Plant Diseases in Ethiopia."

Table 1. Pathogens causing diseases of field pea in Ethiopia.

Pathogen	Disease	Reference
Ascochyta pisi	Leaf/pod spot	Stewart and Dagnachew 1967
A. phaseolorum	Leaf spot/blight	HRC 669, CMI 215709†
Cochliobolus bicolor	Collar discoloration	HRC 3656, CMI 241897
Colletotrichum pisi	Spot	HRC 4022
Erysiphe polygoni	Powdery mildew	Stewart and Dagnachew 1967
Oidium sp. (imperfect stage)		Stewart and Dagnachew 1967
Fusarium solani	Fusarium root rot	HRC 5709
Helycotylenchus sp.	On roots	HRC 1481
Mycosphaerella pinodes Berk. & Block	Spot/blight	HRC 230, CMI 215676c
Pea Leaf Roll Virus	Leaf roll	HRC 3437
Pea Mosaic Virus (?)	Mosaic	Stewart and Dagnachew 1967
Peronospora viciae	Downy mildew	HRC 3557, CMI 225591b
Phoma minutella or *P. medicaginis* (Jones) Boerema	Stem lesion	HRC 230, CMI 215676
Pratylenchus sp.	Root lesion	HRC 1481
Pseudomonas pisi	Leaf spot	HRC 5150
Rhizoctonia solani Kuhn	Root rot	HRC 5709
Sclerotium rolfsii	Collar rot	HRC 1094
Septoria pisi West	Blotch	HRC 226, CMI 241837
Tylenchorhynchus sp.	On roots	HRC 1501
Tylenchus sp.	Root lesion	O'Banen 1975
Uromyces pisi	Rust	Stewart and Dagnachew 1967

† Sample numbers of Holetta Agricultural Research Center (HRC) and the Commonwealth Mycological Institute (CMI).

Nematode diseases were found in restricted areas of Sheno and Jima (O'Banen 1975) but the distribution of viral and bacterial diseases has not yet been documented. However, fungal diseases, especially foliar, are prevalent everywhere the crop is grown. Leaf, stem and pod spots, powdery mildew, and Fusarium root rot are major diseases of field pea in the main production areas of Shewa, Gojam, Arsi and Gonder in Ethiopia (IAR 1985a, 1985b, 1986, 1987, 1988, 1989) while powdery mildew, downy mildew, *Ascochyta* and stem rot were reported as major diseases in the Bale highlands (Dereje *et al.* 1991). This observation at Bale needs to be confirmed with pathogenicity tests, as the report gives new occurrences of some pathogens of field pea in Ethiopia.

Although powdery mildew and Fusarium root rot are easy to diagnose, the spot and blight diseases are not easily identified under field conditions. They are caused by several pathogens (Habtu and Dereje 1986) that form a complex of diseases which is usually called "spot/blight complex" of field pea. There is always higher spotting than blight or blotch. The disease is caused by fungi: *A. pisi*, *A. phaseolorum*, *Cochliobolus bicolor*, *Mycosphaerella pinodes*, *Phoma medicaginis* and *P. minetula* (Habtu and Dereje 1986; Dereje *et al.* 1991). Since these diseases occur together, symptoms overlap and are difficult to diagnose. Many of them produce brown discoloration on leaves, stems and pods; light yellow spots on leaves and then dark brown discoloration on all plant parts. Details of each important disease are given in the following sections.

Specific Diseases

Powdery Mildew

Occurrence and severity

Powdery mildew disease of field pea is caused by *Erysiphe polygoni* D.C. (*Oidium* sp. is the imperfect stage of the fungus) which is mostly severe in dry areas (IAR 1985a). It is a troublesome disease where days are warm/hot and dry, and nights are cool enough to form dew. This disease is less destructive in areas of high rainfall which can be deleterious to spore survival and cause removal of spores from host tissue. Late-sown fields and off-season crops in the highland areas of Ethiopia were severely destroyed by powdery mildew (Dereje, unpublished data). There are reports that powdery mildew devastated field pea crops at Adet, Dembi, Debre Zeit, Kulumsa, Bako, Alemaya and Melkasa (IAR 1985a, 1986, 1987, 1988). In these places, dry weather in the day and cool temperatures in the night favored development of the disease.

The pathogen has a hyperparasite fungus, *Ciccnobolus cesatii* (De Bary), which lives on *E. polygoni* (Stewart and Dagnachew 1967). This has great importance for the biological control of powdery mildew of field pea in the future.

Yield losses

An experiment was carried out from 1982 to 1984 at Melkasa and Debre Zeit, where powdery mildew occurrence was severe every year, to determine the yield losses that can be caused by this disease in field pea crops (IAR 1985a, 1985b, 1986). The fungicides Thiophanate-methyl and Topsin-M, which were thought to be effective in controlling powdery mildew, were sprayed at intervals of 7, 14 and 21 days starting with the onset of the disease. This was programmed to create a gradiant of powdery mildew infection (IAR 1985a, 1985b). Neither fungicide checked the disease completely. However, the disease gradient created was accompanied by a gradient of seed yield (Table 2). An overall mean yield loss of 37.7% was found due to powdery mildew under severe disease in experimental fields. If complete control was assured, the yield increase due to controlling powdery mildew would be much higher than what was reported from this work.

Table 2. Disease score and yield increase (%) of field pea due to control of powdery mildew with spraying of fungicides Topsin-M or Thiophanate-methyl.

Spray interval (days)	1982		1983		1984		Mean	
	Dis.†	Incr.†	Dis.	Incr.	Dis.	Incr.	Dis.	Incr.
7	0.3	44	1.8	86	2.6	17	1.6	49
14	0.5	33	2.8	57	3.2	15	2.2	35
21	0.4	22	2.5	43	3.5	23	2.1	29
Unsprayed	0.5	0	3.8	0	3.8	0	2.7	0

† Dis = Powdery mildew score on 0-5 rating scale, with 0 = no disease, 5 = heavy disease infestation; Incr. = Percent increase of seed yield over the unsprayed control.
Source: IAR 1985a, 1985b, 1986.

Control measures

Host resistance to powdery mildew. This is one of the most widely used control measures for powdery mildew of field pea in many places of the world and was especially effective in the USA (Hagedorn 1985). Screening work was done in Ethiopia to develop a resistant cultivar. The screening was performed under natural infection in the field at Ambo, Debre Zeit, Dembi and Kulumsa (IAR, unpublished data). Evaluation was done for disease severity and good plants were selected as a bulk or single plants. Thus, many lines and plants were selected for their resistance to powdery mildew: Coll. 52178, Coll. 28178, PGRC/E 032087, PGRC/E 032761, PGRC/E 032808, PGRC/E 032105 and PGRC/E 032750 (IAR 1984a, 1984b, 1985a, 1985b, 1986, 1987, 1988, 1989).

Chemical control. Not much work was done on chemical control. However, Topsin-M and Thiophanate-methyl were used for powdery mildew control (IAR 1985a, 1985b), although there was no information on how they were selected for use. By using these fungicides, the severity of powdery mildew was decreased to 2.6, 3.2 and 3.5 in a 0-5 rating scale which was 68, 84 and 92% of the unprotected check, respectively (IAR 1985a, 1985, 1986). This suggests that these chemicals can be used to control this disease.

Fusarium Root Rot

Distribution and incidence

Fusarium root rot of field pea is caused by *Fusarium solani* (Mart.) Appel and Wr., and has often been serious when field pea is grown in Vertisols in Ethiopia. Severe infections were recorded in Ambo, Inewari, Ginchi, Bichena and Dembi areas (Tesfaye 1985, 1988; Tesfaye and Gordenko 1986a, 1986b) and it was strongly associated with waterlogged conditions (Tesfaye and Dereje, unpublished data).

Fusarium solani usually infects at the cotyledon attachment area, epicotyl and hypocotyl (Hagedorn 1985). Initial symptoms are brown streaks at the main root and subsidiary roots where black discoloration remains at the soil level. As the season advances and infection progresses, all the root will become black and disintegrated. Leaves are yellow initially and turn brown to dark in color and finally the plant collapses. Infected plants are usually stunted with severe necrosis on the aboveground parts.

There is no quantitative information on the incidence of Fusarium root rot. However, observations showed that severe infection could reach up to 70% mortality of field pea at Ginchi experiment station, Inewari and Bichena (IAR, unpublished data).

Host resistance
Many field pea accessions have been evaluated for root rot resistance at Ambo under high inoculum level in a sick plot (Table 3) since 1986 (Tesfaye and Gordenko 1986a, 1986b; Tesfaye 1988; Tesfaye and Muluneh 1988a; SPL 1986, 1988). The screening was done following the method used for faba bean. Nursery management was the same so that uniformity and high root rot infection were ensured in the test plots. Selections were done by assessing the plants in the nursery and confirming the tests with a blotter method in the laboratory (Tesfaye 1988).

In 1986, PGRC/E 32816, PGRC/E 32783 and P 682801 were severely damaged with a mean incidence of 27.8% (Tesfaye 1988). However, in 1988, among 55 field pea lines tested at Ambo and Ginchi, Pis-48/77, 1677/77, Coll 101/77 192/77 and 205/77 G22854-3G × Prublue and PGRC/E 032740 showed moderate resistance, 0.2-3.5 score in a 1-9 rating scale (Tesfaye 1988).

In the same season at Ginchi, Pis 48/77, 173/77, 384/77, 1677/77 and Coll 157/77 showed a moderately resistant reaction with less than 10% infection.

Subsequent refining of the screening work provided five outstanding field pea accessions resistant to Fusarium root rot: Pis 48/77, Pis 173/77, Pis 1677/77, PGRC/E 032781 and PGRC/E 032801. They are useful materials to be used to develop resistant cultivars through hybridization or testing under wide ecological conditions so that they reach all the farmers in field pea growing regions of the country.

Table 3. Field pea accessions and lines screened for root rot resistance in Ethiopia.

Testing year	Screened (tested)	Selected
1986	20	0
1987	30	0
1988	51	11
1989	20	7
1990	30	19
1991	168	0
1992	35	0

Source: Gordenko *et al.* 1985, 1986; Tesfaye and Gordenko 1986a; Tesfaye 1988; Tesfaye and Muluneh 1988b.

Chemical control

At Ambo, a seed treatment experiment was carried out to control root rot diseases (SPL 1986). Seed was treated (dressed) with Campogram (2 g), Rezolax (3 g), Brassicol (0.55 g), Ferax (2 g), or Agrosan Heptachlor (3 g/kg seed). This seed treatment resulted in an average of 14% higher grain yield over the untreated control. Fernasan-D and Agrosan Heptachlor gave the lowest mortality (11% and 9%, respectively). However, it is worth noting that Agrosan and Fernasa-D are banned fungicides because of their hazard to human health and the environment.

Many workers, including us, do not favor seed treatments against root rot diseases except for the seedling rots because fungicides may not persist in the soil long enough to protect the plant from later infections at later stages of the crop.

Spot and Blight Diseases

Causal organisms and symptoms

Several pathogens are involved in causing spot and blight diseases of field pea in Ethiopia. These include *M. pinodes*, *A. pisi*, *S. pisi* and *P. medicaginis* (Habtu and Dereje 1986; Stewart and Dagnachew 1967). These pathogens have some distinct features (symptoms) which help in identification. Proper identification is a prerequisite to successful control of a disease (Hagedorn 1985).

Mycosphaerella pinodes (*Ascochyta pinodes*). This pathogen infects leaf, stem and pod tissues. It starts as small, dark, irregular flecks on leaves, stems and pods. Often lesions enlarge under favorable conditions. Pycnidia are formed on lesions, especially on the leaves and less so on the stems and pods. Stem lesions usually become elongated and wider streaks often coalesce to completely girdle the stem. Stem infection usually is confused with the infection of *P. medicaginis*. Unless isolated it can not be readily identified (Hagedorn 1985).

The spot caused by *M. pinodes* is the most widely distributed disease in Ethiopia. It is found in severe forms in Holetta, Kulumsa, Adet, Ambo and Sheno (IAR, unpublished data). In fact it occurs everywhere that field pea is grown. Most instances of spot disease, which resembles dirt on field pea, are the dark spot caused by *M. pinodes* (Dereje, pers. comm.). Previously it was believed that *A. pisi* was the most important pathogen in Ethiopia, but more recently it was found that *M. pinodes* is far more important and significant (IAR, unpublished data).

***Phoma medicaginis* and *P. minutella*.** This pathogen usually infects the lower part of the stem, especially at and below the soil levels. It causes brown, dark brown and even dark lesions on the stem. Pycnidia develop at the latter stage of the crop development.

This disease is difficult to recognize because, as the field pea plant matures, the basal stem crawls on the ground and on contact with the soil it resembles a stem maturing (drying) or dirt on the stem.

This disease is found all over the country where field pea is grown. It seems, at present, that it is the second most important disease among those causing spot/blight complex of field pea.

***Ascochyta pisi*.** This pathogen causes spot on leaves, stems and pods (Hagedorn 1985) of field pea. Lesions are slightly sunken, tan colored, and sharply delineated by a distinct dark border. Spots are circular on leaves and pods but elongated on the stems, usually having numerous pycnidia on the lesions (Hagedorn 1985).

This disease is of minor importance as no severe damage has been observed anywhere in the country.

***Septoria pisi*.** This pathogen of field pea causes blotch on the foliage (Hagedorn 1985). There is a definite margin between the diseased and healthy parts of the tissue. Diseased areas on the pea foliage are of indefinite size and shape, first yellow and then straw-colored. Several blotches can coalesce to cover the entire tissue and at this stage pycnidia develop all over the infected parts.

This disease was found to be severe at Ambo, Adet, Dembi and Kulumsa (Habtu and Dereje 1986; Bekele and Hailu 1992). However, there were many reports from other parts of the country (Habtu and Dereje 1986; IAR 1985a, 1985b). This disease is the third most important disease of field pea in Ethiopia, among the spot/blight complex of field pea.

Host resistance

Many field pea accessions were screened for resistance to foliar diseases in general, and no distinction has been made so far between the diseases. The results obtained are briefly summarized as follows.

In the 1984/85 cropping season, 66 field pea accessions were evaluated at three locations (Ambo, Holetta and Kulumsa) for *Ascochyta* resistance (IAR 1987, 1988; Gordenko *et al.* 1985, 1986). As a result, three best lines were selected (PGRC/E 032101, PGRC/E 032473 and PGRC/E 032465), which showed resistance at the three locations. PGRC/E 032808 and PGRC/E 032739 were most susceptible.

In the 1985/86 cropping season, 76 accessions were evaluated at four locations (Ambo, Dembi, Holetta and Kulumsa). Ten entries were moderately resistant and three (PGRC/E 032101, PGRC/E 032473 and PGRC/E 032465) were resistant across locations (IAR 1987, 1989).

In the 1989 season, 97 accessions were evaluated at Adet (Bekele and Hailu 1992). One resistant and 12 moderately resistant accessions were identified. The results of this experiment seem more reliable, since artificial inoculation was involved.

In the 1991 cropping season, 397 accessions were evaluated, again at Adet (Bekele and Hailu 1992). According to this result, none of the test accessions was free of *Ascochyta* infection. However, 13 accessions had a moderately resistant reaction. These were all PGRC/E accessions: 32014, 32168, 32173, 32214, 32227, 32281, 32394, 32397, 32538, 32541, 32569 and 32680. Line PGRC/E 032696 was resistant.

Future Research Directions

Surveys should concentrate on quantitative observations in order to map the distribution of major field pea diseases in the country. Determination of the relative importance of spot/blight fungi is more urgent. Virus diseases should receive attention, as they are potentially dangerous.

Fungicide screening, loss assessment of the spot/blight diseases, epidemiology and biology of major pathogens need to be studied.

Studies on control measures need to consider the components of integrated disease management, including cultural practices.

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Faba Bean Diseases in Ethiopia

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Abstract

Faba bean (*Vicia faba* L.) is the most important grain legume grown in Ethiopia and diseases are among the major constraints to production. More than 17 pathogens have been reported so far on faba bean from different parts of the country. Diseases that are economically most important in the major faba bean growing regions, including chocolate spot (*Botrytis fabae* Sard.), rust (*Uromyces viciae-fabae* (Pers.) Schr.) and black root rot (*Fusarium solani* (Mart.) Appel and Wr., are the most prevalent. Many research programs are underway on the control aspects of these diseases and the results are discussed in this paper. Other diseases are less significant, although viruses and Ascochyta blight are potentially important. Brief accounts on the most important diseases are given with special reference to yield losses, epidemiology and control measures. Future research directions are also highlighted.

Introduction

Faba bean (*Vicia faba* L.) is one of the most important food legumes grown in Ethiopia (Asfaw 1985) and diseases are among the major constraints to its production (Amare and Beniwal 1988; Amare 1990). Information on diseases of faba bean in Ethiopia before 1985 was reviewed by Habtu and Dereje (1986). However, in this paper we present more recent information as well as important research results from the past. Basic and applied research results are compiled in several sections including survey and identification, specific diseases and future research directions. In the specific disease sections, yield losses, epidemiology and control are presented for the major diseases (chocolate spot, rust and black root rot). As information was meager, other diseases are not discussed.

Survey and Identification

Extensive surveys were made during the past 10 years to assess disease situations in faba bean in the central and northwest highlands of Ethiopia (Dereje and Beniwal 1987, 1988a). Disease samples were collected and identifications were done from laboratory examinations or greenhouse tests. Identification was done with the confirmation of the Commonwealth Mycological Institute (CMI) at Kew, UK. Table 1 presents an updated list of faba bean diseases in Ethiopia.

Table 1. Pathogens causing diseases of faba bean in Ethiopia.

Pathogen	Disease
Alternaria tenuis Auct.	Black spot
Ascochyta fabae Speg.	Ascochyta blight
Botrytis fabae Sard.	Chocolate spot
Cercospora zonata Winter	Zonate leaf spot
Erysiphe polygoni DC.	Powdery mildew
Fusarium avenaceum (Cord. ex Fr.) Sacc.	Foot rot
Fusarium solani (Mart.) Appel and Wr.	Black root rot
Macrophomina phaseolina (Tassi.) Goid.	Dry root rot
Pratylenchus sp.	Root lesion
Rhizoctonia solani Kuhn	Root rot
Sclerotium rolfsii Sacc.	Collar rot
Trychothecium sp.	Orange leaf spot
Tylenchus sp.	Root lesion
Tyrenchorhynchus sp.	On roots
Uromyces viciae-fabae (Pres.) Schr.	Rust
Bean Leaf Roll Virus	Leaf roll
Mycoplasma-like organisms	Phyllody

Source: Stewart and Dagnachew 1967; Habtu and Dereje 1986; Dereje *et al.* 1988, 1993; Gordenko and Tesfaye 1985.

According to the results of these surveys, chocolate spot (*Botrytis fabae*) was the most important disease of faba bean, followed by rust (*Uromyces viciae-fabae*) and black root rot (*Fusarium solani*) (Dereje *et al.* 1988).

Chocolate spot was widely prevalent in all the faba bean growing regions of Ethiopia but in severe forms in the major production zones (1950-2400 m asl) such as Holetta, Debre Zeit, Ambo, Gondi, Kulumsa, Adet, Bekoji, Debre Birhan, Selale, Bichena, Debre Tabor, Debark and Sinana (Dereje *et al.* 1988, 1991 . Rust is widely prevalent in lower-altitude areas (<2000 m asl) such as Debre Zeit, Dembi, Gondi, Melkasa, Kulumsa, Bure, Adet, Bako, Inewari and Ambo, and occurs at low incidences at high altitudes (>2400 m asl) such as Holetta, Bekoji and Sheno. In these highland areas, rust occurs late in the season when the rain has stopped and hence has less economic importance there (IAR 1984a, 1984b).

Black root rot is widely prevalent only in the Vertisol culture of faba bean where it is mainly associated with waterlogging. Severe incidence was reported from Ambo, Holetta, Inewari, Selale, Bichena and Ginchi (SPL 1985; Dereje *et al.* 1988). Among other diseases, the potentially important ones are Ascochyta blight and viruses because they can devastate the whole crop in a short time and their immediate control may be difficult. The other diseases are less severe in the major growing areas. In the following sections some features are discussed and brief accounts given for chocolate spot, rust and black root rot.

Specific Diseases

Chocolate Spot

Yield losses

The yield losses caused by chocolate spot (*Botrytis fabae* Sard.) were determined in three types of replicated experiments conducted at Holetta during 1985 to 1991 cropping seasons. In the first trial, foliar sprays of chlorothalonil (2.5 kg/ha) at different intervals were applied on cv. CS 20DK to protect plants from chocolate spot infection and ensure a gradient of disease severity. Consequently, when mean infection of chocolate spot was 2.8 and 6.7, in a 1-9 scoring scale, on sprayed and unsprayed plots, respectively, the mean yield difference was 34.1% (IAR 1986; Dereje and Beniwal 1988b).

In the second trial, among six cultivars grown under disease-free and high disease pressure, the highest yield loss (61.2%) was obtained from PGRC/E 27113 and the lowest (38.7%) from PGRC/E 32314. Both cultivars are landraces. Mean infection was 7.6 and 7.8 scores for the two cultivars, respectively (Dereje and Beniwal 1988b; IAR 1989).

In the third trial, faba bean cultivars were grown under similar conditions, disease-free and diseased, at Dembi, Holetta and Kulumsa but at three sowing dates: early, intermediate and late for the respective locations. Mean yield loss was highest at Holetta (Table 2). When sowing dates were considered, mean yield loss was higher in the early date (Dereje 1993; Dereje *et al.* 1993a). Results showed that management of chocolate spot in faba bean crops seems economically justified.

Table 2. Mean yield of faba bean on diseased and disease-free plots and percent yield losses caused by chocolate spot on three sowing dates and at three locations.

Location	Sowing date	Yield (t/ha)		% yield loss due to disease
		Disease-free plot	Diseased plot	
Dembi	15 June	2.80	2.02	27.9
	25 June	2.05	1.76	14.1
	5 July	1.42	1.08	23.9
Holetta	15 June	2.81	1.71	39.3
	25 June	2.27	1.68	26.0
	5 July	1.86	1.30	30.1
Kulumsa	22 June	4.11	3.36	18.2
	2 July	3.15	2.98	5.4
	12 July	2.18	1.75	19.7

Source: Dereje 1993; Dereje *et al.* 1993a.

Epidemiology

Generally, *B. fabae* survives between two seasons on crop residues as mycelia, conidia or sclerotia (Harrison 1988). Dereje (unpublished) has found that this pathogen survives for more than two seasons outdoors on crop residues buried in soil, especially in infected leaves and stems. Most of the sclerotia embedded in the walls of dead faba bean stems survived while very few of the infected leaves and free sclerotia collected from media survived for long. Pieces of crop debris remaining from the previous year's harvest seem to be the main sources of primary inoculum for the next season crops. Detailed studies in this respect are in progress at Holetta.

Detailed analysis of chocolate spot epidemics by Dereje *et al.* (1993a) showed that this disease often started in mid-July at Dembi, Holetta and Kulumsa and progressed quickly in early September. It developed faster when conditions were favorable from the end of August to early September.

Under conducive environmental conditions, the rate of chocolate spot infection reached up to 0.54 unit of disease per day, which is a fast development rate. Disease onset was influenced by sowing date and locations. Generally, delaying the sowing date also delayed the disease onset and eventually the epidemic onset (Dereje 1993; Dereje *et al.* 1993a). In the last 3 years, the disease started earlier at Kulumsa than at Dembi or Holetta, which indicates that location may also influence the occurrence of chocolate spot in faba bean.

When weather records were analyzed, it was found that chocolate spot development increased faster when there was frequent rain, high morning RH, long periods of near-saturation humidity and optimum temperatures (10-23°C) (Dereje 1993).

Control measures

Cultural control. Several cultural practices can be applied to chocolate spot disease in faba bean (Harrison 1988), mainly through reduction of the inoculum level. Since this pathogen survives in crop debris, management of crop residues has paramount importance in its control. At Holetta when crop debris from the previous year was placed in faba bean plots in early August, severe chocolate spot developed in these plots in the stubble (Dereje, unpublished). This confirms that crop residues serve as sources of primary inoculum in the next crop. Cultural control, therefore, needs to concentrate on reducing the amount of crop residues remaining in the field.

Crop rotation and burning of crop residues may help to reduce the inoculum level (Dagnachew 1967) but no research has yet been done on either in Ethiopia. Despite a general recommendation on crop rotation and hygiene for chocolate spot control, no supporting evidence for it has been produced (Harrison 1988).

Recently, sowing date was studied in relation to chocolate spot development (Dereje 1993) where chocolate spot onset was delayed by delaying the sowing date. This can be used as a component in planning integrated control measures in the future.

Crop mixture (faba bean + field pea seeded together) showed some effects on the rate and severity of chocolate spot development (Dereje, unpublished). Amare Ghizaw (IAR, pers. comm.) also observed that different ratios of faba bean to field pea showed different levels of chocolate spot intensity at Holetta. Detailed studies are now in progress at Holetta.

Chemical control. Many fungicides, both systemic and protectant, were tested for control of chocolate spot in the past (Habtu 1986; IAR 1986, 1989). Among the fungicides tested (Table 3), chlorothalonil, benomyl and benomyl + mancozeb were effective against chocolate spot (IAR 1985b). Chlorothalonil (both Bravo 500 and Daconil) completely protected faba bean plants from infection when applied at weekly intervals, but extended intervals after 15 days were less effective even with the most effective fungicide (IAR 1985b). The rest were less effective at any spray intervals. Tilt was toxic to faba bean where the crop was burnt with black fire blight or general death. No pods developed in these treatments and it was not known if the cause was the rate of application or the active ingredient itself.

Spray intervals were usually dependent on the condition of the disease, fungicide and/or the weather. In this respect, chocolate spot developed quickly when favored by frequent rain and high morning RH (Dereje 1993). Fungicides which are persistent in character and have a good formulation that is not washed off by rain are preferred.

Results of previous experiments showed that spray intervals less than 15 days were effective but those after 21 days were not (IAR, unpublished). Hence, depending on the weather and disease conditions, sprays can be applied every 15 days, but spraying should be started only when infection of the disease at the lowest one-third of the plant has occurred (Dereje, unpublished).

Since faba bean is a low-price crop, application of fungicides may not justify the economics of chocolate spot control. Therefore, fungicides can only be applied in a high-risk situation. Benomyl application should be the last option since resistant strains can develop in *B. fabae* (Harrison 1988).

Host resistance

Since the 1984 cropping season, extensive work has been done on host resistance (Dereje and Beniwal 1986; Dereje *et al.* 1987, 1988, 1993b; Habtu and Dereje 1986). *Botrytis fabae* is a difficult fungus to manipulate (Dereje 1986a; Hanounik 1986; Harrison 1988). Propagation, isolation and culturing methods were thoroughly studied and a practical procedure was developed at Holetta (IAR 1987).

Table 3. Fungicides tested against chocolate spot disease in faba bean.

Fungicide	Formulation	Application rate (/L)
Haitin 60	†	†
Captafol	WP	†
Captafon	WP	†
Chlorothalonil	ES	3.3 ml
Chlorothalonil	WP	2.5 g
Benomyl	WP	2.5 g
Tilt	ES	†
Kocide	WP	†
Captan	WP	†
Saprol	WP	1.5 g
Aspar	WP	2.0 g
Topsin	WP	1.4 g
Vingram Blue	WP	4.0 g
Euparen	WP	2.5 g
Bayleton	WP	3.3 g
Calexin	ES	5.0 ml
Mancozeb	WP	5.0 g
Benomyl + Mancozeb	Mixture	2.5 + 5.0 g

† Not known.
Source: Habtu 1986; IAR 1984a, 1984b, 1985a, 1985b, 1986, 1989.

Mass spore production also was difficult because *B. fabae* requires sophisticated laboratory facilities (Dereje 1986a; Hanounik 1986). Therefore, extensive studies were carried out to improve sporulation under artificial conditions. As a result, a simple, inexpensive and suitable method of mass spore production was developed to support the screening work under field conditions and facilitate further research on this fungus (Beniwal and Dereje 1988). This method is now used in many laboratories. Furthermore, an inoculation method was developed and perfected to ensure uniform disease pressure in disease nurseries.

After these supporting procedures were developed, a screening strategy was set up to achieve consistent nursery management. In the following sections, these procedures and the results obtained from screening methodologies are presented.

Isolation and culturing of *B. fabae*. Lesions of chocolate spot greater than 3 mm radius can be surface-sterilized with a 0.5-1.0% sodium hypochlorite solution for 1 minute. Without rinsing with sterilized water, they can be placed on suitable media. This produces high (90.1%) recovery of *B. fabae* with low (5.2%) contamination by other fungi or bacteria on the cultures. The best temperature for fast development of this pathogen is around 23°C. A pH of 5.4 is suitable (IAR 1987, 1989).

Mass spore production of *B. fabae*. Twenty-five grams of chrysanthemum petals (*Chrysanthemum sinense* Sabine) were enriched with 15 ml of 3% dextrose solution, and autoclaved for 30 minutes at 1 atmosphere. The pure culture was inoculated with *B. fabae* and kept on the laboratory bench at the ambient temperature. Growth started in 48 hours and sporulation started after 1 week. Abundant sporulation was obtained without any special treatment. UV light irradiation was not a prerequisite as in other methods where media are used for mass production of *B. fabae* spores (Beniwal and Dereje 1988).

Nursery management and field inoculation. The chocolate spot screening nursery has three components, designated Stage-I, Stage-II and Stage-III. Stage-I comprises those materials screened for the first season; Stage-II comprises selections from Stage-I. In Stage-II the materials are screened for a second season. Stage-III is the last and advanced stage, in which materials in this nursery are selected for three consecutive years. Materials are promoted for preliminary yield tests at this stage. This screening technique has been followed for the last 8 years.

Materials to be screened for the first time, or good-performing materials from the previous season, were planted (often in single rows) in early to mid-June each year. This is an early sowing time and was used because chocolate spot pressure increases with early sowing. The plots were 3 m long for convenience in application of inoculum. Susceptible genotypes, PGRC/E 27327 or local Holetta, were placed after every 10 test entries to ensure uniformity of disease pressure. Standard checks, often CS 20DK and NC58, were included after every 20 test entries to compare some agronomic traits such as maturity and pod distribution.

A month after the onset of chocolate spot, inoculation was executed. An inoculum suspension (spores suspended in water) containing 150 000 spores/ml was sprayed on the crop using a motorized mist sprayer. The inoculation was conducted in the evenings, often on cloudy and wet days, when conditions in the crop canopy were humid. Otherwise, water mist was applied to the crop by the same mist sprayer until the next day so that adequate humidity was available for infection to take place. This procedure was successful in increasing the disease pressure early in the season, but the uniformity of infection was dependent on the coverage of inoculum during application (Beniwal and Dereje 1988).

Materials with good resistance were tested in the laboratory using a detached-leaf test to confirm true resistance. This was done only when sources of resistance for a breeding program were required.

Screening work for resistance. Extensive screening work was done in the field, greenhouse and laboratory. From these activities, two outcomes were expected. The first is confirmed sources of resistance that can be used in a breeding program as parents, and the second is materials with a good level of resistance and agronomic traits that can be directly developed as a cultivar. At present, both types of materials arising from these screening tests are being further tested in the breeding section. Thus, seeds have been supplied to the breeding section every year since 1986. The summary of screening activities is given in Table 4.

From these activities, many lines (as bulk selections) and plants (as single-plant selections) were secured and promoted to preliminary yield tests or used as parents in breeding programs for crossing. These included superior resistant plants from exotic sources. In the refinement of the materials, performance of BPL 710-A-1, BPL 1179-2, BPL 1179-B-1 and BPL 1802-1 was excellent for chocolate spot. The rest were from local sources and were chosen for yield tests (Table 5).

Table 4. Faba bean lines selected for resistance to chocolate spot in Ethiopia.

Testing year	Number of accessions	
	Tested	Selected
1984	79	0
1985	84	0
1986	100	32
1987	631	22
1988	1324	322
1989	564	245
1990	402	15
1991	460	79
1992	521	51

Source: Dereje and Beniwal 1986; Dereje *et al.* 1987, 1988; Yitbarek 1991.

Table 5. Chocolate spot resistant lines or plants selected and promoted as parents in the breeding program or for preliminary yield testing.

Tolerant/resistant		Highly resistant
BPL 266	BPL 1179-6	BPL 1179-A-1†
BPL 710-4	BPL 1179-7	BPL 710-A-1†
BPL 710-5	BPL 1179-9	BPL 1802-1†
BPL 710-7	BPL 710-2-87	BPL 1179-2†
BPL 710-A-1	N 86097-7	
BPL 710-B-1†	PGRC/E 27276-87	
BPL 1764-1†	BPL 710	
BPL 1179-1	FLIP 87-58-HR 89/1	
BPL 1179-2	7954 HR-L-89/1	
BPL 1179-3	844/50/89	
BPL 1179-5		

† Selected as parent for chocolate spot resistance breeding.
Source: Dereje and Beniwal 1987, 1988b; Dereje *et al.* 1993b.

Rust

Yield losses

Experiments were carried out to determine the extent of yield loss caused by rust (*Uromyces fabae*) in faba bean between 1982 and 1986. Seed weight was reduced by 2-10% at Melkasa and 6-11% at Debre Zeit (Habtu 1986; IAR 1985a, 1985b, 1986, 1989). Total seed yield loss was 2-15% at Melkasa and 14-21% at Debre Zeit. These reductions in seed yield were dependent on the severity of rust infection, which suggests that cultivation of faba bean might require a control measure against rust in places like Debre Zeit when rust develops to a serious level and starts early in the season.

Control measures

Chemical control. Plantavax (Oxycarboxin) in one of the fungicides selected for rust control (IAR 1985a, 1985b, 1986, 1989). Foliar sprays of this fungicide ensured a gradient of rust infection levels as spray intervals were increased. The spray intervals were every 7, 14 and 21 days starting with the onset of the disease. The maximum severity of rust in a 0-9 scoring scale was 5.6, 6.3 and 6.7 for these spray intervals, respectively, while the control (unsprayed) plot had a mean infection score of 7.7. This reduction of rust severity was accompanied by an increase of seed yield by 37, 24 and 20% over the check. Thus Plantavax at weekly intervals can be used for rust control; however, fungicide application can be costly for a crop like faba bean, which often has a low price.

Host resistance

A number of faba bean accessions, cultivars, line, populations and segregants have been screened for rust resistance since the 1984 cropping season (Table 6). Screening was done under natural infection conditions in the field at Dembi where rust occurs early in the growing season and reaches a severe infection level every year at flowering or podding. Three lines were found resistant and 11 were tolerant to rust (Table 7). The three resistant lines (BPL 1179-B-1, BPL 710-A-1 and BPL 11792) also were excellent lines for chocolate spot resistance. These lines were considered for breeding programs as parents.

Black Root Rot

Distribution and incidence

Root rot diseases, especially black root rot (*Fusarium solani*), cause considerable damage in central and northern Shewa and Gojam. They are particularly serious at Ambo, Holetta, Ginchi, Debre Tsige, Inewari and Bichena when faba bean is planted in black clay soils with a vertic character (Beniwal and Dereje 1987; Dereje and Beniwal 1988a; SPL 1986, 1988). The incidence recorded in surveys was 1-18% at Ambo, 5-45% at Inewari, 10-2% at Debre Birhan, 5-37% at Selale and 5-60% at Bichena. Complete crop failure was observed at Inewari, Selale and Bichena on Vertisols with waterlogging problems. The sick plot at Ambo usually gives 100% infection with the death of more than 80% of the plant population.

Table 6. Faba bean accessions tested and selected for rust resistance since the 1984 cropping season.

Testing season	Accessions	
	Tested	Selected
1985	69	0
1986	92	0
1987	210	9
1988	198	117
1989	0	0
1990	156	8
1991	115	0

Source: Dereje 1986b; Dereje and Beniwal 1987, 1988a; Dereje *et al.* 1988; IAR 1984b.

Table 7. Faba bean lines selected for rust tolerance or resistance.

Tolerant	Resistant
PGRC/E 25044-1	BPL 1179-B-1
PGRC/E 25073-1	BPL 710-A-1
PGRC/E 25154-1	BPL 1179-2
PGRC/E 25162-1	
BPL 260	
BPL 1179	
BPL 490	
BPL 266	
Reina Blanca	
New Mammoth	

Source: Dereje and Beniwal 1987, 1988a; Dereje *et al.* 1988.

The main feature of root rot caused by *F. solani* is a black discoloration of the main root and laterals, which starts at the soil level or a little above. Yellowing of leaves starts from the lowest parts of the plants and many of the infected plants do not produce pods. Finally the infected plants die, leaving roots black; hence the name black root rot. As it mostly kills the whole plant, the incidence and yield loss are almost equal. Therefore, incidence seems a good predictor of yield loss, although a quantitative relationship is not available.

At present, black root rot of faba bean is considered to be the third most important disease of faba bean in Ethiopia. The major distribution areas are exclusively those heavy Vertisols where waterlogging is a problem.

Epidemiology

Root rot is serious when faba bean is grown in moist conditions (Tesfaye 1991, 1992). It causes considerable damage in poorly drained soils. Crop failure was observed around Lemi where many farmers plowed under their faba bean fields in September 1993 (Dereje and Tesfaye, unpublished).

Epidemics of black root rot develop exclusively on Vertisols because the disease is favored by high moisture and waterlogging makes the plant prone to this pathogen. As Vertisols hold a lot of water, the disease develops quickly as the rainfall increases and the plants start flowering (Dereje, unpublished). Clearly there is an association between black root rot disease and waterlogging. In order to understand the behavior of this disease, studies must concentrate on the relationship of these two factors.

Control measures

Cultural control. In a recent experiment, Amare (unpublished) found that improved surface drainage tremendously decreased the incidence of root rot at Ginchi. Flat plots with waterlogging had severe root rot infection, whereas crops on broad bed and furrows (BBF) and ridges were not as diseased. This partly explains why farmers at Inewari make BBF and those in Selale mostly plant faba bean on ridges.

Host resistance

Host resistance is believed to be the most practical, economical and environmentally safe control measure for farmers. Extensive screening work is being done to develop a root rot-resistant faba bean cultivar(s) for the problem areas. A sick plot was developed at Ambo in 1985 to increase the disease pressure. Screening has been conducted every year on the same sick plot and selection performed against root rot pressure.

Propagation and sick-plot development. Isolation of the pathogen was possible from infected plant tissues and soils. Pieces of infected roots or stem parts were surface-sterilized in 1% sodium hypochlorite solution for 1-5 minutes. The central pieces were placed on potato dextrose agar and incubated at 25°C. This pathogen also grows well on autoclaved faba bean seeds from which abundant inocula can be produced for sick-plot development.

A 0.2-ha sick plot was developed by planting a mixture of highly susceptible cultivars in both the main and off-seasons in 1984 and 1985. The mixture contained seed of Kassa, Coll-178 and Ambo local. To augment this, inoculum produced on the autoclaved faba bean seed was incorporated into the soil and then the plot was immediately irrigated to increase the inoculum and the pathogen's chances of survival. This was done a week before planting of the test lines. A good sick plot was produced on which infection reached 100% on susceptible materials after 1 year.

Nursery management. Test entries usually were set in a single 3-m row. A susceptible cultivar (Ambo local) was planted on both sides of each entry. This constituted a nursery management system where the uniformity of root rot was monitored during the screening period and the inoculum was increased every time by planting a susceptible cultivar in half of the rows. The check plots were, therefore, distributed throughout the plots on 50% of the area, which maintained uniformity. Evaluation was done by counting diseased and healthy plants on each plot. Percent infection of test entries was compared with check plots from both sides of the test entries.

Screening results. A number of faba bean accessions or lines were evaluated for black root rot resistance under high disease pressure in the sick plot at Ambo as described above (Table 8). Resistant lines are listed in Table 9. In the 1987 cropping season, 143 entries were evaluated. Most cultivars tested had high root rot incidence, over 25% infection. However, some materials (KS 289/77, 581078-5, PGRC/E 208105, PGRC/E 208110 and L 82087) showed low infection levels and were considered tolerant to root rot.

In 1989, out of 150 accessions evaluated or tested, 14 were tolerant (less than 25% root rot incidence). In 1990, of the 188 accessions tested, 49 had a definite epicotyl and root resistance. Among these, the indigenous collections Bichena 86-1 and Bichena 86-3 were outstanding lines whose resistance was confirmed with blotter tests in the laboratory. The resistant exotic cultivars were 83Lat30168-208R and 79S33029-2-2-1, confirmed by blotter tests.

Table 8. Faba bean lines/accessions screened and selected for resistance to black root rot.

Year	Number of accessions	
	Screened	Selected
1986	0	0
1987	143	5
1988	137	0
1989	150	14
1990	188	49
1991	0	0
1992	30	2

Source: SPL 1986, 1988; Tesfaye 1989, 1991, 1992.

Table 9. Faba bean accessions and lines resistant to black root rot.

Accession/line	Accession/line
Bichena 86-1	CS 20 DK (STCH)4
Bichena 86-3	PGRC/E 208126(17)
CS 20 DK-3-8-2-2(eb)	PGRC/E 208102(9)
CS 20 DK-3-8-3-2	PGRC/E 288094(4)
583386-1	PGRC/E 027354(46)
282098-11-14	PGRC/E 027355(47)
74 TA 58 (La.G)-7-3-1	PGRC/E 027361(48)
L 82087 (44)	PGRC/E 203128(55)

Source: SPL 1986, 1988; Tesfaye 1989, 1991, 1992.

Future Research Directions

Surveys should concentrate in a systematic way to quantify the relative importance or occurrence of different pathogens that cause diseases in faba bean.

Studies on the biology of important pathogens should concentrate on how to overcome the problems at the farmer's level.

Loss assessment should focus on a quantitative means of relating disease severity and occurrence with yield losses, in order to develop economic thresholds for using control measures.

Studies on the epidemiology should consider relating disease development with weather conditions and changes in the cropping systems.

Studies on control measure must be oriented in such a way that integration of different control measures can be applied.

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Discussion

Dr Girefe
What is the difference between tolerant and resistant cultivars?

Ato Dereje
Tolerant cultivars are cultivars that are highly susceptible to diseases, but give reasonable yields. Resistant cultivars are those that show specific characteristics for specific disease incidence.

Chickpea and Lentil Disease Research in Ethiopia

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Abstract

Research on chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) has been conducted during the last 26 years in Ethiopia. This review, while focusing on the work done after 1985, also includes research information prior to 1985, with the intention of developing a database on diseases of chickpeas and lentil in the country. A checklist of diseases recorded on each crop is provided, along with information on their prevalence and importance. Research on disease surveys, loss assessment, seed pathology, host plant resistance, host range, host age/diseases relationship, fungicides and cultural practices is discussed, and proposed research priorities for chickpea and lentil pathology are listed.

Introduction

Chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) are among the major food legumes grown in Ethiopia (Westphal 1974). Diseases are important limiting factors to chickpea and lentil production in Ethiopia (Geletu 1984; Abebe and Seifu 1985), of which wilt/root rots of chickpea and rust (*Uromyces fabae* Pers. de Bary) of lentil have a significant place (Taye 1975; Niemann 1976b; Habtu and Dereje 1986; Million and Beniwal 1988; Seid *et al.* 1990; Seid and Beniwal 1991). Damages caused by these and other chickpea and lentil diseases were recognized as early as 1967 when Stewart and Dagnachew (1967) inventoried the plant diseases occurring in Ethiopia.

Studies made at Chilalo Agricultural Development Unit (CADU) as early as 1969 indicated that chickpea diseases, particularly root rots and Ascochyta blight, were a threat to crop production.

The importance of the diseases on these two crops also was documented by Dagnachew (1967). In the 1970s, systematic work on diseases of chickpea, especially wilt/root rots, was undertaken by Holetta Agricultural Research

Center (HRC), the Institute of Agricultural Research (IAR) and Debre Zeit Agricultural Research Center (DZARC) of the then Haile Selassie I University. After the 1970s, full-scale chickpea and lentil disease research work began at DZARC of Alemaya University, which is still continuing. However, in the late 1980s the study on wilt/root rots of chickpea was extended to Adet Research Center of IAR. Chickpea diseases reported in Ethiopia up to 1992 are listed in Table 1.

Chickpea

Disease Surveys

Surveys on diseases of chickpeas began in the late 1960s. In 1967 Stewart and Dagnachew reported the occurrence of chickpea wilt (*Fusarium oxysporum* f.sp. *ciceri* (Padw.) Snyder & Hansen) in Shewa and Kefa, collar rot of chickpea (*Sclerotium rolfsii* Sacc.) in Shewa, root knot nematodes of chickpea (*Meloidogyne* spp.) in Kefa and powdery mildew of chickpea (*Leveillula taurica* cv. Arn) in Shewa.

During the 1975/76 cropping season DZARC reported the occurrence of Ascochyta leaf spot in chickpeas around Debre Zeit, Mekele and Kobo, the severity of which was 10% or less (DZARC 1976). Ascochyta leaf spot (*Ascochyta rabiei)* was first observed at Kulumsa in 1969 (Geletu 1981). Rust (*Uromyces cicer-arietini* (Gorgn.) Jacz and Boyer) and stunt virus were the two other diseases reported on chickpea. Rust was prevalent around Arsi Negelle and Debre Zeit whereas stunt occurred around Debre Zeit, Arsi Negelle and Gonder. The severity of rust was as high as 60% and stunt incidence was about 15% (DZARC 1976). In recent years the incidence of stunt has risen up to 30% in some chickpea farms in Shewa (DZARC 1992). Chickpea stunt was first reported from Shewa (Arsi Neghelle, Debre Zeit) and Gonder (DZARC 1976) and subsequently been observed in Gojam (Woldeamlak *et al.* 1990). However, field incidence is the highest (about 30%) in Shewa (DZARC 1992).

The rust disease gets severe on chickpeas grown during the off-season (Feb-April) when the average rainfall is 200-300 mm and average daily mean temperature is 19-21°C, particularly on light soil (Alfisol/Mollisol at DZARC). Rust also can be observed on chickpea plants grown on black soil (Vertisol) at DZARC and around Debre Zeit, mostly on kabuli chickpea at flowering time. Rust has never been a serious disease of chickpea because it usually comes late in the growth stage of the crop. Farmers commonly grow the crop toward the

Table 1. Diseases of chickpea in Ethiopia.

Disease	Causal agent	Distribution†	Importance/Crop loss
Root rots and wilts			
Collar rot	*Sclerotium rolfsii* Sacc.	Sh, Goj, Gon	Prevalent in low and wet sites; important, favored by high soil moisture, warm temperature and undecomposed organic matter. Can cause seedling mortality and >50% loss in seed yield in some fields
Wet rot	*Rhizoctonia solani* Kuhn	Sh	
Dry root rot	*Rhizoctonia bataticola* (Taubl.) Butler	Sh, Goj	Favored by low soil moisture, high temperature (about 30°C); severe on old plants
Black root rot	*Fusarium solani*	Sh	
Fusarium wilt	*Fusarium oxysporum* f.sp. *cicer* (Padw.) (Erwin)	Sh, Goj	Major, occurs at all growth stages of the crop but severe on old plants
Neocosmospora root rot, wilt	*Neocosmospora vasinfecta* Smith	Sh	Minor
Foliage diseases			
Powdery mildew	*Leveillula taurica* (Lev.) Arn.	Sh	Minor
Rust	*Uromyces ciceris-arietini* (Grogn) Jacz. and Boyer	Sh	Minor
Ascochyta blight	*Ascochyta rabiei* (Pass.) Lab.	Sh, Ar, Tig	Minor
Alternaria leaf spot	*Alternaria* spp.	Sh	Minor
Viruses			
Stunt	Beet Western Yellows Virus	Sh, Goj, Gon	Moderate, incidence reaches as high as 30% in some farms

† Sh = Shewa, Goj = Gojam, Gon = Gondar, Ar = Arsi, Tig = Tigray.
Source: Stewart and Dagnachew 1967; CADU 1969; Bhasin 1975; DZARC 1976, 1993; Awgechew 1982; Allen 1983; IAR 1986; Woldeamlak *et al.* 1990; Beniwal *et al.* 1992.

end of the main rainy season on receding moisture on black pellic Vertisols. environmental conditions not favorable for development of the disease.

In an attempt to establish the relative importance of chickpea wilt/root rot, a survey was undertaken in 1984 on about 26 chickpea farms in Shewa region by the plant pathology section of IAR. Wilt/root rot syndrome was more common than other diseases. Pathogens such as *Fusarium* spp. and *Macrophomina phaseoli* and other physiological factors are mainly responsible for the development of the diseases. Fungi like *S. rolfsii*, *Rhizoctonia solani* and *Neocosmospora vasinfecta* were regarded as less important (IAR 1986).

Awgechew (1982) first reported *N. vasinfecta* when he indexed additional plant diseases recorded in Ethiopia to supplement the report by Stewart and Dagnachew (1967).

The reasons for considering *S. rolfsii* and *R. solani* as less important pathogens could be the time the survey was undertaken, i.e., in December when the environmental conditions do not favor their development, and the survey locations. For instance, the most frequently isolated fungi from post-emergence dying chickpea plants in the 1975/76 cropping season were *R. solani* and *F. oxysporum* at Debre Zeit and *F. oxysporum* and *M. phaseoli* around Ginchi (Bhasin 1975) (Table 2).

Table 2. Wilt root rot pathogens of chickpea identified in Debre Zeit and Ginchi cultivar testing trials.

Pathogen	Isolations (%) from post-emergence dying		
	Debre Zeit	Ginchi	Average
Rhizoctonia solani	28	0	19
Sclerotium rolfsii	8	2	6
Fusarium oxysporum	21	15	19
Macrophomina phaseoli	3	11	6
Others	17	37	28
No isolation yield	24	35	22
Total no. isolations	127	54	

Source: Bhasin 1975.

Minor leaf blight of chickpea caused by *Alternaria* spp. was observed at Akaki/Kilinto research site and Shenkora farmers' fields during the 1989 cropping season (DZARC 1990). Wilt and root rots (WRR) were the most important diseases of chickpea in 1985 and through 1992 and these diseases were extensively reviewed by Beniwal *et al.* (1992). Symptom(s) of individual WRR diseases are as described by Nene *et al.* (1981).

Stunt was the second most important disease of chickpea (DZARC 1991; ICARDA 1992). Chickpea plants showing stunt symptoms were subjected to Enzyme-Linked ImmunoSorbent Assay (ELISA test) to detect and identify virus(es) causing the stunt. Of the samples tested, 75% were reported to be Beet Western Yellows Virus (BWYV), which belongs to the luteovirus group (DZARC 1993).

Ascochyta blight of chickpea was considered a threat to the chickpea breeding (improvement) program and breeding work was discontinued for some time (Geletu 1984). Although there is no clear evidence, infected seeds of introduced breeding materials were thought to be responsible for the occurrence of blight in the country (Awgechew *et al.* 1986). In general, *A. rabiei* is not a problem in farmers' fields as the crop is planted toward the end of the main rainy season (late August to early September or October) when the relative humidity, free moisture (dew) and temperature are less favorable for the development of blight. However, if the crop is grown during the rainy season, *kiremt* (June-August), there is a high probability of the disease becoming a limiting factor to chickpea production (Million 1993).

Some nematodes, namely *Ditylenchus* spp., *Meloidogyne incognita*, *Pratylenchus* spp. and *Tylenchus* spp., were reported to be associated with chickpea in different parts of the country (Habtu and Dereje 1986).

Loss Assessments

Wilt/root rots (WRR)

From disease surveys made in Shewa between 1986 and 1992, a yield loss of about 30% was estimated to have occurred due to WRR on chickpea in farmer's fields (DZARC 1992; ICARDA 1992a). More than 50% of chickpea crops could be damaged in some fields around Debre Zeit due to collar rot (*S. rolfsii*) alone (Dagnachew 1967).

Stunt

Although no direct determination of loss was made, chickpea crop loss due to stunt virus(es) is up to 30% in some farms in Shewa (DZARC 1992).

Seed Pathology

Chickpea seed pathology work was reviewed by Habtu and Dereje (1986). After this review, more research was undertaken to identify mycoflora asssociated with chickpea seeds. Six fungal species in addition to those reported by Alemu and Sinclair (1979) were isolated from chickpea collected from farmers' fields, granaries and marketplaces in Shewa. The species belonged to *Rhizopus, Botrytis, Stemphyllium, Helminthosporium, Rhizoctonia* and *Colletotrichum* genera (DZARC 1992, 1993; ICARDA 1992a).

Basic Studies

Basic studies on the host range of root knot nematodes on food legumes in the field and the relationship between age of chickpea plant and infection by different WRR-causing organisms were reported in an earlier review (Habtu and Dereje 1986).

Host range studies

Wilt/root rots. A greehouse trial on host range of two root-rot pathogens of chickpea (*R. solani* and *S. rolfsii*) was made during 1975/76. Among the seven food legumes, *Vigna unguiculata* L. (cowpea), *Phaseolus vulgaris* L. (haricot bean), *Glycine max* (soybean), *Vicia faba* L. (faba bean), *L. culinaris* (lentil), *Pisum sativum* L. (pea) and *C. arietinum* (chickpea), all were found to be susceptible to *R. solani* (wet root rot). The legumes were not immune to the pathogens, but lentil was less susceptible to collar rot (*S. rolfsii*) than chickpea (Table 3) (Bhasin 1975).

Root knot nematodes. In 1974, a study to determine the role of food legumes and horticultural crops in rotation patterns for control of root knot nematodes was carried out in plots naturally infested with nematodes at Melkasa. Of the 10 food legumes tested, chickpea was among the most susceptible (Table 4).

Effect of plant age on WRR

Bhasin (1975) did a greenhouse trial to find out the effect of age of chickpea plant on the level of WRR infection. She observed that *R. solani* (wet root rot)

Table 3. Host range of chickpea wilt and root rot pathogens and susceptibility of chickpea cultivars, greenhouse trial, 1975/76.

		Rhizoctonia solani			*Sclerotium rolfsii*			Check		
Host	Cultivar	a†	b†	c†	a	b	c	a	b	c
Cowpea (*Vigna unguiculata*)	American	100	0	100	2	0	2	2	0	2
Haricot bean (*Phaseolus vulgaris*)	Seafarer	98	2	100	40	8	48	2	0	2
Soybean (*Glycine max*)	Clark 63k	100	0	100	40	10	50	5	0	5
Faba bean (*Vicia faba*)	Local	92	5	97	5	5	10	2	0	2
Lentil (*Lens culinaris*)	Local	100	0	100	0	8	8	0	0	0
Pea (*Pisum sativum*)	Local shire	92	5	97	2	10	12	5	0	5
Chickpea (*Cicer arietinum*)	DZ-10-4	100	0	100	10	28	38	5	0	5

† a = % of pre-emergence dying; b = % of post-emergence dying; c = % of total susceptibility.
Source: Bhasin 1975.

and *S. rolfsii* (collar rot) attacked chickpea plants when they were as young as 3 days to as old as 56 days whereas *F. oxysporum* (wilt) and *M. phaseoli* (dry root rot) mainly attacked older plants. This result is a clear indication for the presence of seedling plant resistance in desi chickpea for *F. oxysporum* and *M. phaseoli.* According to Bhasin (1975), *F. oxysporum* and *M. phaseoli* are weaker pathogens than *R. solani* and *S. rolfsii* because the former two attack mainly older plants.

Control Measures

Cultural control

Date and depth of sowing were the two cultural practices investigated as possible control measures for chickpea wilt/root rots (Bhasin 1975; DZARC 1976, 1990; Alemu 1979).

Date of sowing. If chickpea is planted early in the season when soil moisture is still high enough to favor development of WRR diseases, then plant mortality will be high. For instance, there was greater number of pre-emergence dying plants due to WRR from chickpea sown in September around Ginchi than from chickpea sown in October (a relatively drier month than September) (Bhasin 1975).

Sowing depth. Combined results of greenhouse and cold-frame trials conducted at Holetta showed that sowing chickpea seeds deeper than 2 cm increased pre-emergence death of plants as well as the number of fungi involved in the WRR diseases. Four pathogens were isolated from post-emergence dead plants sown at 16-cm depth, compared with three pathogens from 9 cm and one from 2 cm (Bhasin 1975) (Table 5). In general, it is worth planting chickpea in late September at a depth of 2 to 9 cm in regions similar to Ginchi.

Chemical control

Seed and soil treatment. Wilt/root rots. Work on chemical control of WRR of chickpeas was reviewed by Habtu and Dereje (1986). A number of fungicides as seed and soil treatment for control of wet root rot, collar rot, wilt and dry root rot of chickpeas were tested in greenhouse, cold-frame and field trials (CADU 1969; Bhasin 1975; IAR 1983; DZARC 1983). Promising fungicides from all these studies are listed in Table 6.

Ascochyta blight. Treating chickpea seeds with a mixture of thiabendazole (TBZ) and benomyl (Benlate) was recommended for the control of *A. rabiei* (DZARC 1983).

Table 4. Host range of root-knot nematodes and infection rates on various hosts.

Crop	Cultivar	Infection score†	
		20 Aug	8 Oct
Legume			
Adzuki bean	ex Min. Agric.	1.7	5.3
Chickpea	Local	3.0	6.5
Cowpea	Black eye ex Supermarket	0.1	2.9
Grasspea	Local	2.4	5.7
Haricot bean	Mexican 142	0.1	2.7
Hyacinth bean	A-51268	0.8	4.4
Lentil	Local	2.3	9.0
Lima bean	Early Thorogreen	1.3	6.2
Mung bean	N-109	1.9	6.1
Pigeon pea	Dr-4	0.1	0.2
Other			
Cabbage	Copenhagen market	0.4	2.9
Carrot	Chantany	1.2	3.9
Eggplant	Round purple	0.5	3.9
Lettuce	White seeded	2.9	4.8
Onion	Bombay Red	0.1	0.9
Pepper	Yolo Wonder	0.1	1.6
Potato	?	0.3	1.6
Sweet potato	White start	0.1	0.7
Tomato	Rugers	1.1	4.8
Watermelon	Ananas yokneam	3.0	9.0
LSD (5%)		1.0	1.5
(1%)		1.4	2.0

† 0 = no galls on the roots; 10 = roots and plants completely destroyed.
Source: Niemann 1976a.

Table 5. Effect of sowing depth on wilt root rot-causing pathogens and chickpea plant mortality† in soil naturally infested with wilt root rot.

Sowing depth (cm)	Plants infected or killed (%)		Pathogens‡
	Pre-emergence	Post-emergence	
2	25	8	*Fusarium* sp.
9	50	8	*Fusarium* sp., *Macrophomina phaseoli*, *Sclerotium rolfsii*
16	55	10	*Fusarium* sp., *M. phaseoli*, *S. rolfsii*, *Rhizoctonia solani*

† The total number of plants sown per sowing depth was 110, a combined result of greenhouse and cold-frame trials.
‡ Isolated from post-emergence dead plants.
Source: Bhasin 1975.

Host plant resistance

Wilt and root rots. Geletu and Abebe (1982) reported the possibility of obtaining higher seed yield from chickpea planted between early August and early September on black clay soil at Debre Zeit than from a crop planted later. According to this report, the possibility can best be realized if cultivars used are resistant or tolerant to wilt/root rots.

The importance of wilt and root rots was recognized in breeding trials at Kulumsa in which the diseases destroyed all chickpea cultivars included in the National Yield Trial (CADU 1969, 1972, 1975). Prior to 1979, four chickpea cultivars, namely Dubie, DZ-10-4, DZ-10-2 and DZ-10-11, were distributed to farmers by DZARC through the Extension and Project Implementation Department (EPID) of the then Ministry of Agriculture of Ethiopia. Except for DZ-10-2, all were reported to be very susceptible to root rot disease at locations where the drainage system was poor (Geletu 1980).

Some research on the development of WRR-resistant chickpea genotypes has been done. Twenty-seven chickpea genotypes were screened against wet root rot in cold-frame trials at Holetta in the 1970s; none of the test entries was resistant. The cultivars included Dubie, Black Dubie, DZ-10-04 and other introduced and local materials (Bhasin 1975).

Table 6. Promising fungicides for the control of wilt root rot of chickpea.

Product	Applied as	Disease	Remarks
Benlate	Seed-dressing	Collar rot, wilt, wet root rot	
Vitavax	Seed-dressing	Collar rot, wilt + dry root rot	Some phytotoxicity
Vitavax + Thiram	Seed-dressing	Wet root rot, collar rot, wilt + dry root rot	
Brassicol	Soil treatment	Wilt + dry root rot	
Bavistin	Seed-dressing	Wet root rot	Delayed development and stunting of the crop
TMTD	Seed-dressing	Wet rot rot	
PCNB	Seed-dressing	Wet root rot	
Bayleton	Seed-dressing	Wet root rot	Delayed development and stunting of the crop
Thiram	Seed-dressing	Collar rot	

In 1979, systematic work on the identification of sources of resistance to WRR was started at DZARC by developing a multiple-disease sick plot to evaluate chickpea genotypes for their resistance to wilt, root rots and collar rot (DZARC 1983). Since then many sources of resistance have been identified but the work was discontinued for some time until 1986/87 when it was reinitiated at the Center. Recently, a multiple-disease sick plot has been developed at Adet Agricultural Research Center in Gojam region.

Development of WRR-resistant chickpea lines is based on entry selection in the field, i.e., sick-plot screening. Selections are made from local germplasm and introduced materials, mainly from ICRISAT, in the form of an International Chickpea Root Rots and Wilt Nursery.

During 1987/88 and 1988/89 cropping seasons, 211 chickpea lines received from ICRISAT were sown in the wilt/root rots sick plot at Debre Zeit to identify sources of resistance to WRR. Of these, 17 lines were selected based on mean percent mortality and desirable agronomic traits (early maturity, uniformity, and good podding) (Seid *et al.* 1990).

Between 1986 and 1992, 53 entries/accessions were selected from different nurseries such as the National Chickpea Root Rots and Wilt Nursery and the Kabuli Chickpea Root Rots and Wilt Nursery. The wilt/root rot promising lines were concurrently evaluated for their desirable traits (DZARC 1990, 1991, 1992, 1993).

Three entries (ICC-12241,ICC-12445 and ICC 14400) showed a 2-year mean mortality of less than 20% both at Debre Zeit and Adet sick plots. Among these, ICC-14400, showing <10% mortality, was highly resistant to WRR disease prevailing at Adet (Gojam) and Debre Zeit (Shewa) (Negussie *et al.* 1993). Five kabuli chickpea entries (ICC-6045, ICC-14914, ICC-3141, FLIP 84-148C and FLIP-85-28) showed a 2-year mean mortality of less than 20%. Of these, ICC-6045 was highly resistant (<10% mortality) (Negussie *et al.* 1993).

Ascochyta blight. The Department of Crop Protection at DZARC attempted to screen chickpea entries against Ascochyta blight (*A. rabiei*) under conditions of both natural and artificial infection. Work at the Center and Arsi-Negelle led to the identification of seven promising entries: NEC-1433, NEC-1431, NEC-1538, NEC-979, C-235, G-543 and GG-588 (Geletu 1980; DZARC 1983). Almost all of these entries were selections from the Chickpea International Ascochyta Blight Nursery obtained from ICARDA.

Root knot nematodes. Varying degrees of resistance expressed by different chickpea cultivars where there was severe infection were reported on the experimental plots at the Jima Research Centre (Hingorani 1971).

Combined disease resistance: stunt and WRR. Considering the high incidence of chickpea stunt in Shewa, work on the identification of chickpea genotypes resistant to stunt disease was initiated at DZARC during the 1990 season. Twenty-seven chickpea entries received from ICRISAT in the form of International Chickpea Wilt and Stunt Disease Nursery and International Chickpea Stunt Disease Nursery were evaluated for their resistance to stunt virus(es) and WRR. Eight lines, viz. ICC-7254, ICC-1891, ICC-3935, ICC-10503, ICC-1583, ICC8383, ICC-10592 and ICC-11502, showed a high level of resistance to both stunt and WRR (Negussie *et al.* 1993).

Lentil

Disease Surveys

Many surveys on diseases of lentil have been made since 1967. Stewart and Dagnachew (1967) reported two root and two foliage diseases of lentil, namely *Fusarium* sp. in Shewa, *S. rolfsii* in Kefa, leaf spot (*Colletotrichum destructivum* O'Gara) in Shewa and rust (*U. fabae*) in Kefa and Harerge.

The plant pathology section of IAR tried to establish the relative importance of lentil wilt/root rot diseases in Shewa region through surveys conducted on 18 lentil farms in 1984. *Fusarium* spp., *M. phaseoli* and other physiologic factors are mainly responsible for the development of these diseases. Pathogens such as *S. rolfsii*, *R. solani* and *N. vasinfecta* were regarded as less important (IAR 1986).

Low level (10%) of Ascochyta blight (*Ascochyta lentis* Vassilievsky) infection was reported on lentil around Debre Zeit, Shenkora, Akaki and Chefe Donsa (DZARC 1990; Seid and Beniwal 1991). The blight was first reported at DZARC in 1986 and, at times, the disease reached severe levels in research fields.

Lentil plants showing stunt symptoms also were observed in some localities, especially in high-altitude areas (2000 m asl). Twenty percent of lentil samples with stunt symptoms were shown to have BWYV when tested (DZARC 1993).

Tylenchorynchus spp. and *Tylenchus* spp. are known to infect lentil; the incidence and distribution of these nematodes was reviewed by Habtu and Dereje (1986). Lentil, besides these two nematodes, was reported to be infected also by root knot nematodes (Niemann 1976a) (Table 4).

Powdery mildew, a new disease record on lentil in Ethiopia, was observed (DZARC 1991) around Tulubolo where the crop is normally planted at the end of the main rainy season, *kiremt*, i.e., in September (DZARC 1992). Stem blight caused by *Sclerotinia* spp. was the other new disease reported on lentil in Debre Zeit research fields (DZARC 1992). However, of all the diseases of lentil mentioned here and those reviewed by Habtu and Dereje (1986), rust is the single most important disease of the crop in farmers' fields followed by WRR (DZARC 1990, 1992).

Most of the diseases reviewed in this paper are summarized in Table 7 along with their causal agent, distribution and importance.

Table 7. Diseases of lentil in Ethiopia.

Disease	Causal agent	Distribution†	Importance/ Crop loss
Foliage diseases			
Rust	*Uromyces fabae* (Pers.) de Bary.	Sh, Kf, Hr, Goj	Major
Leaf spot	*Colletotrichum destructivum* (O'Gara)	Sh	Minor
Ascochyta blight	*Ascochyta lentis* Vassilievsky	Sh	Minor
Stem blight	*Sclerotinia* spp.	Sh	Minor
Alternaria blight	*Alternaria alternata* (Fr.) Kiessler	Sh	Minor
Powdery mildew	*Oidium* spp.	Sh	Minor
Root rots and wilt			
Collar rot	*Sclerotium rolfsii* (Sacc.)	Sh, Kf	Moderate
Wilt	*Fusarium oxysporum*	Sh	Moderate
Dry root rot	*Rhizoctonia bataticola*	Sh	Minor
Viruses			
Stunt	Beet Western Yellows Virus	Sh	Moderate

† Sh = Shewa; Kf = Kefa; Hr= Harerge; Goj = Gojam.
Source: Stewart and Dagnachew 1967; Seid and Beniwal 1991; DZARC 1992, 1993; ICARDA 1992a, 1992b; Negussie *et al.* 1993.

Loss Assessment

Rust

In a field experiment conducted at Akaki during 1990-92, a seed yield loss of 25% was estimated for rust infection on the susceptible lentil cultivar, Akaki local (DZARC 1993).

Ascochyta blight

A study made to control Ascochyta blight of lentil through fungicide spray in a field at Debre Zeit revealed that a seed yield loss of 71% could result in a susceptible lentil cultivar under natural infection (Seid and Beniwal 1991) (Table 8).

Table 8. Effect of fungicide sprays on Ascochyta blight intensity and lentil yield at Debre Zeit, 1986-88 crop seasons.

Treatment	Rate (kg/ha)	Percentage disease index†		100-seed wt.	Seed yield (t/ha)	
		1986	1988	1986	1986	1988
Untreated check		66.6 (54.7)	88.5 (70.21)	1.86	0.48	0.21
Bravo 500	1.00	54.0 (47.2)	65.2 (54.0)	1.06	0.66	1.33
Benlate	0.66	54.4 (48.1)	62.7 (59.39)	2.07	0.71	1.65
Calixin M	2.50	47.5 (49.3)	75.0 (60.12)	1.92	0.66	0.55
Vitavax	0.33	63.0 (52.6)	83.0 (67.76)	1.94	0.51	0.23
Topsin M	0.67	58.2 (49.7)	NT	1.99	0.64	NT
Anvil	0.72	NT‡	86.0 (68.09)	NT	NT	318
LSD (5%)		(3.43)	(5.4)	0.11	34	332

† Percentage disease index = [Sum of numerical rating/no. plants (20-25) × max. disease category] × 100. Figures in parentheses are percentage transformed values (%). Data are average of four replications in RCBED.

‡ NT = Not tested.

Source: Seid and Beniwal 1991.

Seed Pathology

Ascochyta lentis, *Colletotrichum* spp., *Penicillium* spp., *Helminthosporium* spp., *Alternaria* sp. and *Phoma* spp. were isolated from lentil seeds collected from farmers' fields, granaries and market places in Shewa administrative region (DZARC 1992, 1993; ICARDA 1992a).

Basic Studies

Host range

Ascochyta blight. Seid and Beniwal (1991) established the seed-borne nature of Ascochyta blight of lentil using the agar-plate method of the International Seed Testing Association. They reported that 20.1% of the seeds collected from blight-affected plants yielded *Ascochyta* colonies.

Seid and Beniwal (1991) tried to determine the host range of *A. lentis* using eight food legumes, namely lentil, chickpea, faba bean, field pea, grasspea (*Lathyrus sativus* L.), cowpea, haricot bean and fenugreek (*Trigonella foenum-graecum* L.). They reported that the fungus was pathogenic only to lentil and not to any of the other legume species tested. This indicates that the fungus is host-specific.

Root knot nematodes. In 1974, a study to determine the role of food legumes and horticultural crops in rotation patterns for control of root knot nematodes was carried out in plots naturally infested with nematodes at Melkasa. Of the 10 food legumes tested, lentil was among the most susceptible (Table 4).

Control Measures

Cultural control

Date of sowing. Sowing date was the only cultural practice researched to control lentil rust (DZARC 1991, 1992, 1993). The severity of lentil rust and its effect on lentil seed yield was studied for five sowing dates at Akaki. The rust was more severe on early sown (July) crops than on the late (August) ones (DZARC 1992). However, in spite of high rust infection, early sown (early July) lentils gave a significantly higher seed yield than the late-sown ones.

Physical control

The effects of sun drying and heat treatment of lentil seeds on the control of seed-borne *A. lentis* were studied during 1986-88.

Sun drying of lentil seeds. It was reported that sun drying of lentil seeds controlled seed-borne *A. lentis* significantly. Sun drying with a polyethlene sheet cover was more effective than the treatment without a polyethylene sheet cover and provided 57 and 96% control after 10 and 30 days exposure, respectively. The figures for the same exposure periods without a polyethylene sheet cover were 12 and 49%, respectively. However, sun drying adversely affected seed germination in all the treatments except those exposed for 10 days without a polyethylene sheet cover, which gave only 12% Ascochyta control (Beniwal *et al.* 1989).

Heat treatment. The possibility of treating lentil seeds with hot water and dry heat for control of seed-borne *A. lentis* was studied during 1986-88. In general, recovery of the fungus ranged from 2.5 to 13% in seeds treated with hot water (55°C for 25 min) compared with 20% in seeds without treatment. Seed germination was adversely affected by the hot-water treatment, but treatments at 50 and 55°C for 10 minutes did not affect seed germination. Recovery of the fungus from these two treatments was 12.5 and 13%, respectively (Seid and Beniwal 1991). The fungus was reported to survive in lentil seeds dried at a temperature of 70°C for 24 hours. Dry heat treatment of seeds at 50°C for 12 hours significantly reduced seed transmission of *A. lentis* without significantly reducing seed germination (Seid and Beniwal 1991).

Chemical control

Seed-dressing. At Debre Zeit, six seed-dressing fungicides were screened in the laboratory against *A. lentis.* Thiabendazole (TBZ) and benlate (Benomyl) at two concentrations (0.25 and 0.30%) provided 100% control of the fungus. These two fungicides also increased the percent seed germination over that of the untreated control (Seid 1987). These two most effective fungicides were also evaluated in the greenhouse for their effectiveness in controlling primary infection on emerging seedlings. TBZ and benlate, at the two concentrations mentioned above, completely controlled the seed-borne fungus, in that none of the seedlings emerged from TBZ and benlate-treated seeds had ascochyta blight lesions (Seid 1987).

Spray fungicides for controlling foliar diseases. From 1986 to 1988, among six spray fungicides field-tested against *A. lentis* at Debre Zeit, chlorothalonil (Bravo 500), benomyl (Benlate) and a mixture of tridemorph and maneb (Calaxin M) provided the best blight control and the highest lentil seed yields (Seid and Beniwal 1991). The high level of protection was obtained only through four or five sprays at 15-day intervals beginning with the appearance of symptoms at seedling stage until the podding stage.

Host plant resistance

Rust. At Akaki 121 lentil germplasm accessions were screened for their resistance to rust *(U. fabae)* under conditions of natural infection. Of these, 32 lines were identified as highly and moderately resistant to rust (ICARDA 1992a).

Ascochyta blight of lentil. One hundred and thirty-nine lentil germplasm accessions obtained from PGRC/E and DZARC were field screened under natural blight infection at Debre Zeit during 1986/87 and 1987/88 seasons. Of these, 35 were identified as resistant and 22 as moderately resistant (Seid and Beniwal 1991).

Future Research Needs

Work on WRR pathogens should continue to confirm field resistance of promising chickpea genotypes against individual WRR pathogens under greenhouse/laboratory conditions. Studies on genetic factors for resistance need to be launched.

The variability of *F. oxysporum* f.sp. *ciceri* needs to be known.

Characterization and study on mechanism of transmission of chickpea stunt virus is important.

Integrated pest management systems against WRR diseases must be devised after a thorough evaluation.

Evalution and screening of chickpea genotypes which can be used for *kiremt* sowing, to ward off Ascochyta blight, is required.

A study on the mechanism of lentil rust inheritance must be inititated.

The development of differential lines of lentil to identify physiologic races of rust in the country should be encouraged.

Work on the development of lentil lines resistant to WRR should be strengthened.

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Discussion

Ato Dereje

The viruses are said to be not important. Why?

Ato Negussie

In fact, the virus situation is becoming serious in some fields. It reached up to 30% in Sheno. But we are at the starting point of the program, so unceasing efforts will be made in the future to learn the extent of their importance.

Dr Saxena
Viruses as a group should not be neglected, and many areas should be covered. The resistant genotypes identified in screening should be used in future crossing work.

Dr Asfaw
The actual crossing was begun a couple of years ago. Viruses as a group have not been neglected. Detection for chickpea diseases of faba bean and field pea has already been handled by the NVRP. Powdery mildew has also been handled at Kulumsa Research Center of IAR. So, before talking about viruses, priority should be given to other diseases that cause high yield loss.

Research on Insect Pests of Cool-season Food Legumes

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Abstract

The cool-season food legumes are attacked by over 20 species of insect pests, but only a few are of economic importance. Pea aphid (*Acyrthosiphon pisum*), African bollworm (*Helicoverpa armigera*) and bean bruchid (*Callosobruchus chinensis*) have been the subject of research in Ethiopia. This paper reviews the work done for the control of these species, including insecticide screening trails to evaluate chemical control. Successful control of key insect pests has been achieved with a range of insecticides including botanicals. Some aspects of the biology and population dynamics have been studied for the most economically important species of insects and studies of economic threshold levels have been conducted for pea aphid on field pea and lentil. The influence of cultural practices on aphids and bollworm also has been investigated. Research on host resistance in field pea and lentils has been restricted to pea aphid. A few genotypes having some degree of tolerance have been identified. Future research should include surveys, monitoring, and studies on the population dynamics of these key pests, with the aim of developing effective integrated pest management.

Introduction

Cool season food legumes (faba bean, field pea, chickpea and lentil) are vulnerable to attack by several insect pests in the field and in storage, but only a few of these are of economic importance.

These crops are generally grown without pesticide protection in the farmers' fields. Such problems as cost factors, application technique, lack of trained personnel and the unavailability of pesticides are the major factors limiting the use of pesticides by subsistence farmers.

Cultural and applied biological pest control practices are not known to farmers. Thus, insect pest management in cool-season food legumes (CSFL) has seldom been used. The problem was usually left to natural controls except where insecticidal recommendations were occasionally followed by a few organized farmers in some areas.

Outbreaks of aphids, particularly *Acyrthosiphon pisum*, have been frequent in Ethiopia during the last decade. This insect has destroyed thousands of hectares of field pea and lentils through direct damage caused by the removal of plant sap.

This paper reviews the available information that has been accumulated to date in Ethiopia. A brief review is provided on insect pest surveys, and the importance, distribution and control measures of major species.

Insect Pest Surveys

Extensive surveys of insect pests of CSFL have been made throughout the country and the specimens are held in a good number of collections at Holetta Research Center.

Crowe *et al.* (1977) first compiled a report on insect pests on field crops occurring in Ethiopia. Tsedeke *et al.* (1982) amended this list on grain legumes and later these were catalogued in a review of crop protection research in Ethiopia in 1985 (Tsedeke *et al.* 1986).

Twenty species of insect pests have been recorded on these crops under field and storage conditions in Ethiopia (Delotto 1947, 1948; Delotto and Nastasi 1955; Gentry 1965; Hill 1966; Nastasi and Andemeskel 1968; Schumutterer 1969, 1971; Crowe *et al.* 1977; Tsedeke *et al.* 1982). Of these the major ones are *Helicoverpa armigera* (Hübner), *Acyrthosiphon pisum* (Harris), *Aphis craccivora* Koch, *Aphis fabae* Scopoli and *Agrotis segetum* (Schiff). The key pest is *H. armigera*, one of the limiting factors in successful cultivation of chickpea, faba bean and field pea.

Faba Bean

Faba bean is attacked in the field and in storage by about a dozen insects but only a few are regarded as important and cause severe damage in some areas

(Table 1). The African bollworm, *H. armigera*, is the most important of all the legume pests in the field. Information on the extent of loss caused by this pest is meager. However, the pod damage recorded in samples examined ranged from 1 to 72% (Tadesse and Bayeh 1989a) in northern Shewa region (Table 2). This makes it difficult for researchers to determine the overall impact of the pest on CSFL.

Table 1. Insect pests recorded on faba bean in Ethiopia.

Scientific name	Common name	Status
Callosobruchus chinensis	Bean bruchid	Major
Helicoverpa armigera	African bollworm	Major
Acyrthosiphon pisum	Green pea aphid	Minor
Agrotis segetum	Common cutworm	Minor
Aphis craccivora	Groundnut aphid	Sporadic
Aphis fabae	Black bean aphid	Sporadic
Maylabris spp.	Pollen beetle	Undetermined
Philotherma sp.		Undetermined
Sesselia abyssinica	Black leaf beetle	Undetermined
Taeniotherips sp.nr. *nigricornis*	Pea thrips	Undetermined
T. sjostedti	Bean flower thrips	Undetermined

Source: Delotto 1948, 1949; Delotto and Nastasi 1955; Schumutterer 1971; Crow *et al.* 1977; Kemal 1991; Tsedeke *et al.* 1982.

Aphids are commonly found in faba bean growing regions of midaltitude areas of Shewa, Arsi, Bale and Gojam. African bollworm (ABW) occurs in most regions of Shewa, Arsi, Bale, Gojam and Gonder. The ABW outbreaks on legumes are often sporadic and unpredictable.

Cutworm was reported as an important seedling pest in southern Ethiopia and in some places in Shewa and Arsi. High damage by bean bruchid in storage was recorded in many CSFL-growing regions at altitudes below 2200 m, sometimes reaching 100% infestation.

Table 2. Estimated amount of pod damage by *Helicoverpa armigera* to faba bean in different survey areas, 1988 and 1989 seasons.

Area	Damage (%) 1988	Damage (%) 1989	Mean (%)
Sandafa	20	1	10.5
Chache	8	1	4.5
Denneba	72	31	57.5
Inewari	25	30	27.5
Sels	45	7	26.0
Degen	5	2	3.5
Mean	29.1	12.0	20.6

The bean bruchids, *Callosobruchus chinensis* L. and *C. maculatus* (F.), constitute the major pests of stored faba bean seeds, the former being economically important. Survey results showed that the damage by *C. chinensis* was in a range of 0-97% with a mean of 41% within a storage time of 6-8 months in midaltitude areas (Tadesse and Bayeh 1989b). However, the damage was less in Arsi region with about 14% (Kemal 1989b). The status of most of the remaining pests is either minor, sporadic or undetermined.

Attempts have been made to determine the parasitoid and predator species of aphids and ABW. It has been reported that *Adonia variegata* (Goeze) is the predator and *Aphidius* sp. is the parasitoids on aphids while two hymenopterous and three deptrous species are parasitoids on ABW (Adugna and Kemal 1986; Tsedeke 1984). However, the population of natural enemies of aphids was low in all surveyed areas. They build up later after the crop has already been damaged by the pest.

Pest Management Research

Chemical control

African bollworm. Chemical control trials against ABW were conducted at different centers. It was reported that a single spray with 150 g a.i. of Cypermethrin gave effective control of ABW (Tsedeke and Adhanom 1981).

Bean bruchid. Seed treatment trials of faba bean with Pirimiphos-methyl (at the rate of 6 and 8 ppm), Lindane (5 and 7.5 ppm), Folithion (5 and 10 ppm), Danfin (8 and 12 ppm) and vegetable oil (20 and 30 ppm) were carried out at Holetta in the laboratory. Pirimiphos-methyl gave good control. Higher levels of vegetable oil also controlled the pest but for a shorter duration (Kemal 1986).

In another set of experiments under farmers' storage conditions, Pirimiphos-methyl was reported to be much superior to Phostoxin and edible oil in protecting faba bean seeds from the attack of bean bruchid (Tadesse and Bayeh 1989b).

Aphids. A verification trial on aphid control in faba bean on farmers' field was conducted with two chemical treatments, Pirimor 50% WP at 500 g a.i./ha and Actellic 50% EC at 240 g a.i./ha in Shewa region. The highest yield (2.15 t/ha) and the highest net benefit (1265 Birr/ha) were recorded by applying Pirimor (Hailu and Tadesse 1989) (Table 3).

Table 3. Partial cost analysis of aphid control on faba bean, in on-farm trials, 1989.

Parameter	Treatment		
	Control	Actellic	Pirimor
Yield (t/ha)	1.63	1.88	2.15
Value of output (Birr/ha) (0.8 Birr/kg)	1300	1508	1716
Variable costs (Birr/ha)			
Chemical†	0	19.35	32.75
Labor	316.85	386.90	451.00
Total cost	316.85	386.90	451.00
Net benefit (Birr/ha)	985.15	1121.00	1265.00

† = Cost of chemical: Pirimor = 32.75 Birr/kg; Actellic = 38.65 Birr/L.

Screening for resistance

Great efforts were made to screen a number of breeding lines of faba bean in the laboratory at Giza, Egypt and in the field in Ethiopia against *A. craccivora*.

From the regional aphid screening nursery, four lines (NC58, PGRC/E 207209, ALAD 25 and NEBC07 × 74TA) were rated as moderately resistant (S. Bishara, pers. comm.).

Work on screening for varietal resistance of faba bean against *C. chinensis* in the laboratory showed high variations in the susceptibility index (SI). The maximum number of adults emerged from cv. CS 20DK-3-4-1-5 (62.3%) while only 4% emergence was recorded from PGRC/E 203131-2. Based on SI, CS 20DK 3-4-1-5, PGRC/E 027052-2-2-1 and 82094-13 were susceptible whereas EH86120-2, PGRC/E 203131-2 and 582383-5-5 were resistant (Kemal 1990).

Biology of *C. chinensis*
Biology of two strains of *C. chinensis* was studied in the laboratory in controlled temperature (30°C) and RH (70%). Seed of faba bean cultivar CS 20DK was used in this experiment. An average of 46.9 eggs per female was laid by the Indonesian strain of the beetle and 17.4 by the Kenyan strain. The average development period from egg to adult was about 28 days. However, a few adults of both strains successfully emerged from seeds of cultivar CS 20DK. Only 8 individuals of the Kenyan strain out of a total number of 223 eggs hatched compared with 43 adults from 540 eggs of the Indonesian strain. The high rate of mortality could be due to the antibiotic effect of the seeds (Kemal 1989a).

Field Pea

Management of Pea Aphid

Green pea aphid and African bollworm are the two very important insect pests of field pea throughout the country. The status of the remaining pests is minor or undetermined (Table 4). Research on field pea pest management in Ethiopia is centered around pea aphid, as this is the key pest.

Pea aphid was reported to occur in all field pea growing regions where infestation on local cultivars reaches 90-100%. Many farmers in Shewa, Arsi, Bale and Gojam have stopped growing field pea because their fields have been devastated by this pest.

Yield loss assessment
In most cases, yield losses were estimated by comparing yield parameters from naturally infested plots with those from insect-free sprayed plots. Loss

assessment was conducted for pea aphid and African bollworm. In field experiments at Holetta and Dembi in 1987, a yield loss of 22 and 29% was recorded due to pea aphid respectively (IAR 1987). At Kulumsa, in the 2-year trial, a yield loss of 49% was estimated with a high level of pea aphid infestation on Mohanderfer cultivar (Kemal 1991).

Table 4. Insect pests recorded on field pea in Ethiopia.

Scientific name	Common name	Status
Acyrthosiphon pisum	Green pea aphid	Major
Helicoverpa armigera	African bollworm	Major
Agrotis segetum	Common cutworm	Minor
Delia cilicrura	Bean seed maggot	Minor
Lampides boeticus	Long-tailed blue	Minor
Liriomyza brassicae	Cabbage leaf miner	Minor
Phytomyza horticola	Chrysanthemum leaf miner	Minor
Thrips tabaci	Onion thrips	Minor
Aphis craccivora	Groundnut aphid	Undetermined
Taeniothrips nigricornis	Pea thrips	
Taeniothrips simplex	Gladiolus thrips	Undetermined
Trichothyra mulsanti		Undetermined

Source: Delotto 1948; Delotto and Nastasi 1955; Gentry 1965; Schumutterer 1969, 1971; Crow *et al.* 1977; Tsedeke *et al.* 1982.

A loss assessment study also was conducted in 1969 and 1971 for ABW at Kulumsa and yield loss was estimated to be in the order of 32-42% (CADU 1969, 1971).

Insecticidal control

Studies on the chemical control of pea aphid were designed for the assessment of yield losses or to determine the relative efficacy of different chemicals. Dimethoate, Pirimor and Pirimiphos-methyl have been reported to control this pest (IAR 1987).

Determination of Economic Threshold Level

There is no doubt that aphicides can keep this crop relatively aphid free, but insecticide should be applied only when aphid populations exceed the economic threshold.

Research on determining the economic threshold level was conducted for 2 years at Kulumsa Research Centre. Pirimor 50% DG at a rate of 1 kg/ha was applied whenever the percentage reached the required level. An economic analysis of the cost-benefit ratios for each treatment was performed. All results confirmed that highest grain yield losses were recorded on check plots, which received no spray (Table 5). The treatment with maximum net return and least cost was one spray at 35% infested plants (Kemal 1991). Other treatments had low net returns or relatively high return with higher costs. Grain yields in 1992 were low because of high powdery mildew incidence.

Table 5. Effect of different insecticidal treatments for pea aphid control on the number of pods and seed yield (means of four replicates).

Treatment	No. of sprays		Pods/plant		Yield (t/ha)	
	1991	1992	1991	1992	1991	1992
Spray at 5%	3		9.3		1.95	
10%	3	3	9.2	7.8	1.96	0.79
15%	2	2	9.0	8.0	1.95	0.72
20%	2	2	8.4	7.4	1.94	0.75
25%	2	1	9.0	7.3	1.94	0.60
30%	1	1	8.6	7.4	1.78	0.60
35%	1	1	9.0	7.1	1.85	0.71
40%		1		7.0		0.70
Full protection	6	6	9.8	8.1	2.08	0.83
Check			7.6	5.8	1.05	0.43
Mean			8.9	7.3	1.83	0.68
LSD (5%)			1.55	1.40	0.06	0.17
CV (%)			7.19	13.28	11.80	17.24

On-farm verification of aphid control

Attempts were made to verify aphid control in field pea on farmers' fields in Yerer-Keryu *awraja*. Yield differences for sprayed treatments were 900 kg for Pirimor and 700 kg for Actellic over the check (Table 6). A partial budget analysis also showed that Pirimor gave the highest net benefit (618.5 Birr/ha) followed by Actellic (519.05 Birr/ha) (Hailu and Tadesse 1989).

Table 6. Partial budget analysis of aphid control on field pea, 1987.

Parameter	Treatment		
	Control	Actellic	Pirimor
Yield (t/ha)	0.26	0.96	1.16
Value of output (Birr/ha) (0.75 Birr/kg)	198.75	723.25	873.75
Variable costs (Birr/ha)			
Chemical†	0	16.10	24.25
Labor	51.40	188.60	228.00
Total cost	51.40	204.70	255.25
Net benefit (Birr/ha)	147.35	519.05	618.50

† = Cost of chemicals: Pirimor = 27.25 Birr/kg; Actellic = 32.20 Birr/L.

Population Dynamics

The size of pea aphid populations that develop on field pea depends on when and how many alate (winged) females reach the plants and on factors such as weather and natural enemies that interact to affect their multiplication. These factors no doubt determine year-to-year variation in abundance of this species throughout its area of distribution.

The population fluctuations of pea aphid were studied for 4 years (1989-92) at Kulumsa Research Centre, an endemic pocket for pea aphid. Aphid populations have increased from year to year (Fig. 1). The population build-up started during mid-August and increased steadily, reaching a peak at the end of September. The population remained high until the first week of October (Kemal, unpublished).

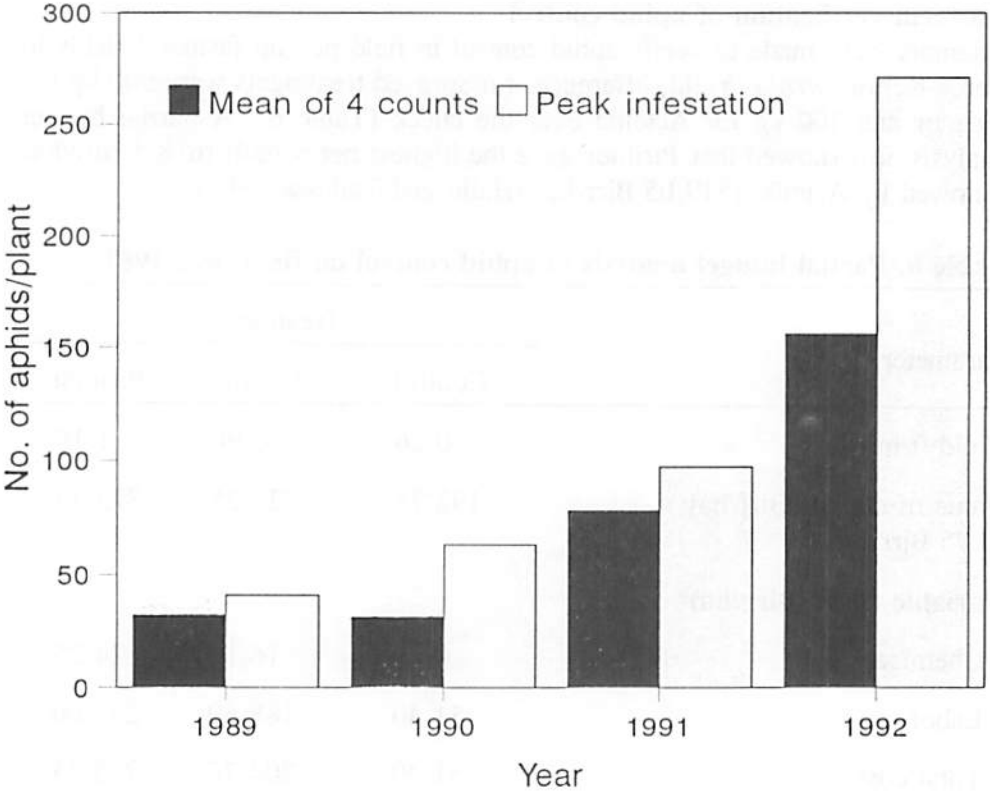

Fig. 1. Pea aphid populations in pea crops at Kulumsa Research Station, 1989-92.

Screening for Resistance

The major work on pea aphid, which was launched during the 1989/90 crop season at Kulumsa, aimed at evaluation of breeding lines and landraces of field pea for their resistance to pea aphid in order to develop resistant/tolerant cultivars. Two sets of experiments were carried out: preliminary and advanced stages of screening.

Preliminary screening stage

A total of 140 field pea genotypes received from the breeding program and 200 landraces from PGRC/E were tested in nonreplicated plots of two rows of 4 m length, under open field conditions. Natural infestations were used at Kulumsa Research Centre, with and without aphicide protection. The data recorded were number of aphids, pea yield and yield components. From 140 genotypes tested, 15 entries showed an acceptable level of resistance with low numbers of aphids and good yield compared with unsprayed plots of the same entries (Table 7) (Kemal 1990).

Table 7. Aphid counts (mean of 6 counts) and yield of field pea lines showing resistance to pea aphid.

Entry	Aphids/plant		Yield (g/plot)	
	S	US	S	US
JI 116	0.4	5.2	1040	640
JI 898	1.6	6.7	919	538
JI 91	0.3	6.7	940	607
305 Ps 210900	0.5	6.1	858	255
305 Ps 210687	1.2	5.4	867	730
061K-2P-2192	0.3	7.1	1207	483
Kyondo	0.3	4.9	926	556
HI 21	1.6	7.0	882	796
HI 7	1.8	8.9	844	764
061K-2P-14/71	1.2	8.0	890	351
305 Ps 210025	0.8	4.1	825	701
305 Ps 210572	1.2	4.0	900	672
NEP 874 UK	1.2	5.3	898	703
304 WH 1101937	2.2	9.3	785	464
KFP-103	2.6	5.1	936	668
Mean	1.2	6.2	901.5	602.2
Mohanderfer (check)	0.4	20.1	742	438
Nur 74-Bx Fiby 50(SC)	5.0	55.3	795	453

S = Sprayed; US = Unsprayed.

During the 1991/92 season, the 200 landraces were tested following the same procedure. None of these accessions was free from pea aphid attack. However, there were differences in degree of tolerance among the accessions. The results showed that most of the entries were susceptible. Seven of the landraces (accession nos. 32161, 32170, 32212, 32218, 32225, 32470 and 32498) showed resistance whereas 10 accessions were killed by the aphid (Kemal 1990).

Advanced stage
Fifteen field pea lines selected at the preliminary stage were evaluated in a randomized complete block design replicated four times in 4 rows of 4 m length at Kulumsa, Sinana and Dembi in 1990/91 and 1991/92 seasons.

The results obtained from Dembi and Kulumsa show variations between seasons and locations because evaluation was done under natural infestations. However, it is worth mentioning that three lines (JI 116, JI 91 and 305 Ps 210025) maintained their resistance to pea aphid (Table 8) (Kemal 1990). At Dembi, low aphid populations in one year resulted in no significant difference between entries.

Chickpea

Chickpea suffers from only a few insect pests (Table 9). The ABW is the most important pest, which threatens the crop from early seedling stage until maturity (DZARC 1983). Young caterpillars of different ages scrape the undersurface of leaves, causing premature defoliation. They also nibble flowers and young buds. Older larvae bore into green pods and eat away ripening seeds. The extent of damage to green chickpea pods by *Helicoverpa* in three chickpea-growing localities of Ada area ranged between 20.8 and 35.6% with a mean of 26.5% (Table 10) (Tibebu 1983). The pest appears to be more damaging in areas that are in close proximity to irrigated sites, which is characteristic of the Shimbra-Meda area (Table 10).

African Bollworm

Chemical control
It is suggested that better control of African bollworm (*Helicoverpa armigera*) with insecticides could be achieved at early stages of attack when larvae are easily killed (Tsedeke and Adhanom 1981). An experiment was undertaken at DZARC using two rates of Cypermethrin and one recommended rate of

Endosulfan in 1981. A single application of each rate at peak flowering, mid-pod set and at full podding stage of the cultivar Dubie revealed that treatments applied at peak flowering are most effective. Application of insecticides at full pod set resulted in the highest percentage pod damage, which was significantly different from the damage level of those treated at peak flowering and mid-pod set (Table 11).

Table 8. Effect of the number of aphids on pods/plant and grain yield of field pea lines advanced from preliminary screening (Kulumsa 1990/91, 1991/92).

Entry	Aphids/plant		Pods/plant		Yield (t/ha)	
	1991	1992	1991	1992	1991	1992
I 116	15.5	59.6	6.7	5.1	2.93	0.58
I 898	17.9	80.4	5.0	4.0	2.13	0.41
I 91	18.0	68.6	9.4	3.9	2.15	0.47
05 Ps 210900	18.3	63.4	7.1	5.6	2.24	0.45
05 Ps 210687	14.5	99.8	6.6	5.5	2.27	0.58
61K-2P-2192	17.3	95.2	6.9	5.4	2.72	0.31
Yondo	18.1	79.6	6.2	4.5	2.10	0.57
I 21	16.4	95.6	5.7	5.7	2.69	0.36
I 7	17.7	77.8	5.7	5.5	2.28	0.44
61K-2P-14/71	22.8	118.4	7.9	3.9	2.42	0.10
05 Ps 210025	12.4	65.8	6.5	4.0	2.51	0.53
05 Ps 210572	21.3	84.4	7.0	4.5	2.36	0.24
GP 874 UK	16.3	73.0	6.1	5.8	2.78	0.38
05 WH 1101937	19.8	82.6	7.2	4.8	1.93	0.15
FP-103	16.7	89.0	5.6	4.3	2.79	0.19
Mean	17.2	82.6	6.7	4.9	2.45	0.38

Table 9. Insect pests recorded on chickpea in Ethiopia.

Scientific name	Common name	Status
Helicoverpa armigera	African bollworm	Major
Callosobruchus chinensis	Bean bruchid	Major
Agrotis segetum	Common cutworm	Sporadic
Plusia spp.	Plusia worms	Undetermined
Spodoptera spp.	Semilooper	Undetermined
Acyrthosiphon pisum	Green pea aphid	Undetermined

Source: Tsedeke *et al.* 1982; DZARC 1983, 1987, 1988, 1992.

Table 10. Percent pod damage in chickpea by *Helicoverpa armigera* in three chickpea-growing localities of central Shewa, 50 km southeast of Addis Abeba.

Area	No. pods examined	No. pods damaged	Percent pods damaged
Dukem	136.8	30.7	23.2
Mojo	139.5	39.1	20.8
Shimbra-Meda	145.8	65.8	35.1
Mean	140.4	41.9	26.5

Cultural control

Sowing date. The effects of sowing dates and cultivars on the damage of podborer was studied at DZARC in 1981. Results showed that there were significant differences in the percentage pod damage among cultivars but not sowing dates. Although there were significant differences in grain yield among sowing dates and cultivars (Table 12), it was difficult to ascribe the yield differences to pest damage, which was not statistically significant (Tibebu 1983).

Table 11. Effects of different insecticides and their time of application on the control of *H. armigera* in chickpea.

Application time	Percentage of pods damaged			Mean†
	Cypermethrin 45 g a.i./ha	Cypermethrin 62.5 g a.i./ha	Endosulfan 472 g a.i./ha	
Peak flowering	18.93	18.55	19.15	18.37b
Mid-pod set	20.54	22.71	23.75	22.23b
Full pod set	24.33	29.10	30.99	28.14
Mean	21.26	23.45 NS	24.63	22.95
SE				1.83
LSD (5%)				5.33

† Means followed by the same letter within a column are not significantly different at the 5% probability level according to Duncan's Multiple Range Test.

Table 12. The influence of sowing dates and cultivars on grain yield (t/ha) of chickpeas.

Cultivar	Sowing date				Mean
	31 July	15 Aug	30 Aug	14 Sept	
Annigeri	3.76	3.55	2.70	2.63	3.16a
850-3/27×F378	4.94	3.63	2.75	2.08	3.35a
ILC-750	2.43	1.38	1.01	1.03	1.46b
Means	3.71a	2.85ab	2.15b	1.91b	
SE					0.375
LSD (5%)					0.110

Spacing/density. A spacing experiment carried out in 1981 showed that there were differences among plant spacings or densities. The highest pod damage was recorded from the most closely spaced plant population. Results of a similar experiment in 1986 revealed that pest population was the highest at a density of 66 plants/m^2. This density resulted in the highest percentage pod damage. The maximum grain yield was obtained from densities ranging between 25 and 33 plants/m^2 (DZARC 1988). Results of repeated experiments for several consecutive years were inconsistent owing to wide seasonal fluctuations in pest incidence and the magnitude of damage to the crop.

From the foregoing results, it is probably impossible to meaningfully reduce ABW damage by adjusting sowing date and plant spacing. Perhaps weather and other related factors need to be taken into account in identifying optimum planting date and plant spacing for *Helicoverpa* control.

Biology and population study

Field-cage studies on the nature of diapause or overseasoning habit of ABW under conditions at Debre Zeit (Tibebu 1985) indicated that the insect undergoes a prolonged pupal period (exceeding 50 days), suggesting facultative pupal diapause during the cool months of November to March. This behavior is partially responsible for the survival, build-up and carryover potential of the pest from one season to the next in the area.

A rainshower early in the season has a positive influence on the emergence of moths (Table 13). Soil texture also influences pupal duration (Table 14). The longest pupal duration which was recorded from the treatment with sand, silt and clay ratio of 42.56, 32.00 and 25.44, was significantly different from the treatment with the ratio of 1.28, 17.64 and 81.08 (Tibebu 1985).

Table 13. Moth emergence of *H. armigera* in relation to rainfall and temperature during November to March 1981.

Month	Total rainfall (mm)	Average temp. (°C)	Moth emergence (% of total)	
			Max.	Min.
November	0.0	25.4	6.9	1.64
December	3.3	25.4	7.0	29.51
January	17.8	26.0	10.3	11.48
February	60.4	26.8	11.9	21.31
March	51.0	28.9	12.5	36.07
Mean	26.5	26.5	9.72	

Table 14. Influence of three different textural compositions of soils on pupal duration of *H. armigera*.

Composition (%)			Pupal duration (days)
Sand	Silt	Clay	
42.56	32.00	25.44	102.27
14.20	28.36	57.44	82.56
1.28	17.64	81.08	56.87
Mean			80.57
SE			10.38
LSD (5%)			31.29

Host plant resistance

Laboratory study of the influence of host plant on the speed of development of larvae of ABW at Debre Zeit revealed that chickpea has a more favorable influence than field pea and faba bean (Table 15). Chickpea exhibited 95% pupation while field pea and faba bean resulted in 90%. Chickpea and field pea each gave 100% adult emergence compared with 89% in beans (Tibebu 1983).

Table 15. Weight of larvae of *H. armigera* after 5, 10 and 15 days of feeding on three different food plants.

Host	Mean weight of larvae (mg)		
	5 days	10 days	15 days
Chickpea	11.45	147.20	588.13
Field pea	7.50	82.00	398.20
Faba bean	11.65	94.33	392.08
Mean	10.20	108.11	459.47
SE	0.41	15.96	26.93
LSD (5%)	1.82	51.06	86.15

Population monitoring

Seasonal flight habit and changes in insect abundance were studied using pheromone traps at Debre Zeit and Akaki. Results revealed that patterns of abundance of moths have not been consistent between and among years, but more moths were recorded at Akaki than at Debre Zeit. Peaks of activity largely coincided with the drier months of the years. August is characterized by a significant reduction in moth populations (DZARC 1988, 1992). Further study is needed in relation to other seasonally varying factors of the environment.

Screening for resistance

Eighteen chickpea genotypes were evaluated for resistance to ABW at Debre Zeit under natural infestation in 1981. Results indicated that some genotypes have a better level of tolerance to ABW attack than others (Table 16). The percentage of pod damage varied between 33.3 and 54.4 among the cultivars. Small-seeded cultivars are generally more tolerant than large-seeded ones. The results also gave a clue that there exists a correlation between percentage pod damage and grain yield in chickpea. The incidence of ABW is unpredictable and makes it difficult to evaluate chickpea lines under field conditions (Tibebu 1983).

Seed Beetle

Post-harvest loss

An experiment conducted using chickpea cultivars Dubie and Mariye in 1992 indicated that the extent of damage by (*Callosobruchus chinensis*) was higher than that in the previous year with significant differences between insecticide-treated and untreated seeds in all the parameters considered (DZARC 1993). The mean weight loss was 51.9% for Mariye and 36.9% for Dubie after 8 months of storage. After the same duration of storage, the germination rate was 36.7 and 51.7% for Mariye and Dubie, respectively. The average germination rate (%) of Pirimiphos-treated seeds was 83.3% while that of the untreated seeds was only 5%. Observed genotypic differences indicate that Mariye appears to be preferred more than Dubie, perhaps because of variations in seed size, color and seed coat texture. Dubie is large-seeded, somewhat cream and with a rough seed coat whereas Mariye is medium-sized and dark brown with a smooth seed-coat texture.

Chemical control

Three insecticides, Actellic 2%, Danfin 2% and Folithion 1% dust, each at three rates, were evaluated for their effectiveness against *C. chinensis* under storeroom conditions at DZARC during 1985 (DZARC 1987, 1988). Significant variations among the insecticides were observed after 75 days of treatment. Actellic and Folithion gave similar and better control up to 6 months of storage.

Table 16. Evaluation of chickpea cultivars for resistance to *H. armigera*.

Cultivar	% pod damage (transf.†)	Grain yield (t/ha)
ILC-295	51.44a‡	1.20bcd
ICCL-78159	49.42ab	0.72d
ILC-66	48.05abc	0.68d
ILC-16	44.34abcd	1.84ab
ILC-19	44.28abcd	1.53abc
Dubie	43.54abcd	1.60abc
ILC-4	41.75bcde	1.39abcd
ILC-29	41.65bcde	1.36abcd
ILC-1929	39.58cde	1.44abcd
ILC-1837	39.24cde	1.03cd
CADU-54	39.09cde	2.08a
H-54-10	38.87de	1.70ab
JG-62 × Radhy	38.37de	1.92a
JG-62	37.02de	2.12a
NEC-979	36.77de	1.42abcd
NEC-756	36.51de	2.11a
SZ-10-11	35.48de	1.80abc
DZ-10-2	33.30e	1.91ab
Mean	41.04	1.55
SE	2.70	2.56
LSD (5%)	7.68	0.88

† Arcsin % transformation of % used for analysis.
‡ Means followed by the same letter within a column are not significantly different at 5% probability according to Duncan's Multiple Range Test.

A comparative study of Pirimiphos-methyl 2%, neem seed and neem leaf powder and vegetable oils (noug and groundnut) was conducted. The result revealed that Pirimiphos-methyl gave the highest mortality of adult bruchids (97%) while the highest rates (5 ml/kg) of groundnut and noug oil treatment exhibited 67 and 70% mortality, respectively. Neem leaf powder gave significantly higher level of mortality 1 day after application; after 7 days, 100% mortality was recorded. There was no significant difference between neem seed powder treatment and the untreated control in mortality. Neem leaf powder has no interference with oviposition while neem seed powder was more effective in reducing oviposition than other treatments (Teshome 1990).

Except for neem leaf powder, all other treatments reduced adult emergence significantly compared with the control and no adult emerged under higher dosage of the vegetable oil. In general, the best control of bruchids was obtained with neem seed powder at the rate of 2 and 3% and groundnut oil at 3.0 and 5.0 ml/kg seed (Teshome 1990).

Biology

The biology of this pest was studied in the laboratory under controlled temperature (27°C) and RH (70%). Seeds of unknown chickpea cultivars were used in this experiment. The mean number of eggs laid per female was 52.8, ranging between 43 and 69. The mean developmental period was 23.2 days. The mean percent adult emergence was 82.6, ranging between 76.6 and 88.4% (Teshome 1990).

Screening for resistance

A test of 20 chickpea cultivars for resistance to *C. chinensis* attack for 2 years under storeroom conditions at DZARC showed that there were significant differences among chickpea genotypes in the weights of sound (normal) seeds after 90 days of exposure. However, all genotypes were seriously attacked at 180 days of exposure with a weight loss ranging between 43.5 and 48.6% and a few were completely destroyed. Three or more emergence holes/seed significantly reduced the germination potential of nearly all cultivars (DZARC 1986).

Teshome (1990) tested 30 chickpea cultivars and 40 local chickpea germplasm accessions for their relative resistance to *C. chinensis* by exposing seeds to adult beetles in controlled laboratory conditions (27°C, 70% RH). His report indicated that the fewest number of eggs were laid on genotypes with a rough seed coat, ICC-3528, TOC-11320 and ICC-595. Generally, small-seeded genotypes were preferred for oviposition over the large-seeded ones and gave rise to larger numbers of progeny.

The maximum number of adults emerged from cultivars ICC-14079 (366), ICC-13991 (343) and DZ-10-2 (337) while only 72 and 83 were recovered from ICC-11320 and ICC-595, respectively. There were significant differences in the developmental period of *C. chinensis* among the genotypes with the longest (25 days) recorded on ICC-2528, ICC-11320, ICC-595 and ICC-82230. The shortest period was 23 days on genotypes ICC-4439, ICC-12876 and Dubie.

In a separate experiment, 40 local chickpea accessions were evaluated for their relative susceptibility to *C. chinensis* under similar conditions as the above-mentioned procedure. Highly significant differences were observed among the lines for the number of eggs laid with the lowest number on accessions 41114, 41121, and 41267 and the highest on 41118, 41116 and 41167. Number of eggs laid per female ranged from 7.7 to 39.0 with a mean of 26.1.

The number of adults emerged varied significantly and this was mainly owing to the large number of eggs laid initially. The maximum percent emergence of adults (83.4%) was from accession 41149 and the minimum number (47.5%) from accession 41121. The loss in seed weight varied according to the number of adults emerged (Teshome 1990). The local germplasm accessions were more resistant than the improved cultivars.

Lentil

Few of the insect pests reported on lentil are of economic importance (Table 17). The great exception is the pea aphid, *A. pisum*, which threatens the crop from early seedling stage until crop maturity. An extensive survey of field and storage insect pests of lentil in central Ethiopia (Shewa), Bale, Arsi, Gojam and Gonder and the observations made during the subsequent years indicated that this insect is a widespread and serious pest of lentil, sometimes resulting in complete crop failures (DZARC 1989). Infestation usually reaches 100% at peak flowering or at early pod-setting stage of the crop.

The seed beetle, *C. chinensis*, is among the commonest, most serious pest that attacks lentil among other food legumes in store. Results of survey work conducted in Shoa region showed that the level of infestation of local and introduced lentil cultivars varied between 12 and 63% (DZARC 1991).

Table 17. Insect pests of lentil recorded in Ethiopia.

Scientific name	Common name	Pest status
Acyrthosiphon pisum (Harris)	Pea aphid	Major
Epilachana spp.		Minor
Callosobruchus chinensis L.	Bean bruchid	Undetermined
Aphis fabae Scopoli	Black bean aphid	Undetermined
Taeniothrips spp.	Bean flower thrips	Undetermined

Source: DZARC 1983, 1992.

Pea Aphid

Loss assessment

The past decade witnessed unprecedented outbreaks of pea aphid (*Acyrthosiphon pisum*) populations on lentil in different parts of the country where the crop is grown. A loss assessment study was carried out for 2 years (1984-86). Results showed that the loss in the potential grain yield of promising lentil cultivars due to aphid damage varied between 15 and 25% in 1984 and between 11 and 26% in 1985 (Table 18) (DZARC 1986). The overall mean yield loss of the 2 years showed that cultivars ranked in the order of R-186, NEL-358, NEL-355 and EL-142 from more tolerant to tolerant.

Table 18. Grain yield (t/ha) of four promising lentil cultivars with and without Pirimor 50% WP protection from pea aphid at DZARC, 1984-86.

Cultivar	1984/85			1985/86			Mean yield loss (%)
	Grain yield		Yield loss (%)	Grain yield		Yield loss (%)	
	S	US		S	US		
EL -142	1.04	0.90	13.5	0.69	0.51	26.1	19.8
NEL -358	1.00	0.75	25.0	0.70	0.62	11.4	18.2
NEL -355	0.91	0.74	18.7	0.82	0.55	20.3	19.5
R - 186	1.15	1.00	13.0	0.80	0.63	21.3	17.2

S = sprayed; US = unsprayed.

Insecticide screening

Screening of insecticides was launched in order to find an effective, economic and environmentally acceptable insecticide against the pea aphid at DZARC in 1990. Significant differences were observed among 10 insecticides tested in suppressing aphid populations on lentil cultivar NEL-358 (Chalew) (DZARC 1991). However, there were no significant yield differences among treatments. Results of a similar experiment conducted at Akaki subcenter in 1992 showed significant differences among insecticide treatments in suppressing aphid population and increasing grain yield. Primicarb 50% WP, Pirimiphos-methyl 50% EC, Ofunack 40% EC and Dimethoate 40% EC sharply reduced aphid populations and gave better yields (Table 19) (DZARC 1993).

Table 19. Efficiency of different insecticides against pea aphid and yield of lentil at Akaki, 1992.

Insecticide	Aphid count†		Grain yield (t/ha)
	Pre-spray	Post-spray	
Ofunack 40%EC	0.8	0.63	1.87
Primicarb 50%WP	0.61	0.10	1.53
Fenitrothion 50%EC	0.62	0.33	1.80
Thiometon 25%EC	0.67	0.37	1.42
Deltamethrin 25%EC	0.63	0.36	1.59
PP 321 5%EC	0.71	0.22	1.58
Phosphamidon 100EC	0.75	0.29	1.42
Pirimiphos-methyl 50%EC	0.88	0.12	1.55
Dimethoate 40% EC	0.76	0.20	1.83
Untreated check	0.89	0.96	1.07
LSD (5%)	NS	0.45	0.48

† Values transformed to log(x + 1).

Cultural control

Sowing date. Significant increase in grain yield of lentil cultivar NEL-358 was achieved for consecutive years as a result of delayed sowing (DZARC 1986, 1991). Significantly higher aphid populations were recorded on early sown materials than on late-sown ones. Results of the same experiment conducted in 1992 depicted situations similar to those in the preceding years, with heavier aphid infestation and lower yield in early sown materials (Table 20). Generally, all the early sown lentil crops are severely affected as observed in the different experiments, verification trials and popularization programs in Ethiopia. Early sowing has shown yield advantage over the late sowing, but this should perhaps be accompanied by spraying of aphicides against aphids.

Economic threshold

An experiment was undertaken at Debre Zeit and Akaki in 1992 to determine the economic threshold level of pea aphid on lentil. Six levels of aphid infestation were selected at which Pirimor 50% DG, at the rate of 1 kg/ha, was applied. Economic analysis of cost-benefit ratios was made for each treatment. Results showed that the highest loss in grain yield was recorded on the check plot (50.8%) (Table 21). The treatment with maximum net return and higher yield had two sprays at 25-50 aphids/tray. However, for those farmers who can not afford two sprays, one spray at 75-100 aphids/tray can be recommended (DZARC 1993). Since this is only 1 year's result the experiment has to be repeated for 2-3 years to give valid conclusions or recommendations.

Screening for resistance

A total of 360 lentil genotypes received from the National Lentil Improvement Program of DZARC were evaluated for their resistance with and without aphicide protection under natural infestation at DZARC. Except 24 accessions which showed an acceptable level of tolerance to the aphid, the rest were unable to withstand the heavy pest population pressure even under chemical protection (DZARC 1987). The highest level of infestation was recorded at peak flowering in lentil accession Giza-9 followed by Lasta Lalibela, NEL-944, NEL-3328, NEL-2704, R-59, EL-142, EL-122 and NEL-2703. The 24 genotypes promoted for advanced evaluation are presented on Table 22.

Future Outlook

The largest proportion of the information available is on insect pest control using insecticides as a short-term solution. Basic knowledge of biology and ecology of key pests is too fundamental to allow the development of sound pest management. Future research efforts need to be directed toward the following main lines of investigations:

Table 20. Effects of sowing date of lentil on pea aphid under treatment with the aphicide Pirimicarp.

Sowing date	Aphid count†			Biomass (g)‡			Grain yield (t/ha)		
	Tr.	Untr.	Mean	Tr.	Untr.	Mean	Tr.	Untr.	Mean
20 June	1.84	1.83	1.83	233.33	316.67	275.10b	0.41	0.31	0.36c
30 June	1.36	1.78	1.57b	260.00	266.67	263.33b	0.78	0.82	0.80b
10 July	1.28	1.80	1.54b	616.67	516.67	566.67b	0.87	0.94	0.91b
20 July	1.23	1.62	1.42b	1686.67	1733.33	1710.00a	1.46	1.13	1.29a
30 July	1.32	1.65	1.49b	1683.33	1850.00	1766.67a	1.57	1.27	1.42a
Mean	1.29a	1.74b		896.00a	936.00a		1.02a	0.89b	
CV (5%)	8.11	52.24			29.42				

Tr. = treated; Untr. = untreated.
Figures followed by the same letter within a column are not significantly different according to DMRT at $P \leq 0.05$.
† Value transformed to log x + 1.
‡ Per three central rows, each 4 m long.

Table 21. Effects of frequency of Pirimor spraying and levels of aphid population on grain yield of lentil.

Infestation level (no. aphids/tray)	No. of sprays	Yield (t/ha)	% loss
0-25	3	1.92a	3.1
25-50	2	1.88a	5.0
50-75	1	1.60ab	19.1
75-100	1	1.62ab	18.0
100-150	1	1.59ab	19.4
150-200	1	1.59ab	19.8
Full protection	7	1.98a	
Check		0.97b	50.8

- A comprehensive survey, collection and identification of natural enemies in order to exploit their contribution to the control of pest species
- Studies of the biology and population dynamic of key pest species and their natural enemies
- Monitoring key pest species using different types of traps to provide an early detection and warning system
- Studies of cultural practices (sowing date, plant population, trap-crops) in relation to weather factors
- Selective use of synthetic insecticides and botancials for pest control.
- Determination of economic threshold levels for major pests of CSFL for different areas
- Screening host plant resistance through the provision of standard screening techniques, laboratory and greenhouse facilities for uniform and optimum infestation of test materials.

With this, we should be in a position to establish long-term solutions, placing special emphasis on integrated pest management of major insect pest problems in the CSFL in order to make farmers feel confident in the continuous production of these crops in Ethiopia.

Table 22. Relative response or tolerance of lentil genotypes to attack by pea aphid (*A. pisum*) under protected and unprotected conditions.

Entry	No. of pods/ 5 plants at maturity		Biomass (g) of 4-m row at maturity		Grain yield (g) of 4-m row at harvest	
	S	US	S	US	S	US
74.TA-305	183	74	150	80	14	6
4-TA0411	283	151	300	450	100	35
Jord local 4354	212	149	450	230	48	13
NEL-518	198	101	300	550	18	64
R-132	145	255	310	440	53	66
NEL-357	175	488	100	200	40	67
NEL-219	196	213	90	190	55	105
NEL-2967	176	108	210	300	40	55
R-59	181	203	300	350	25	55
R-252	205	393	200	300	23	63
NEL-944	165	316	316	450	36	126
EL-122	182	225	200	400	75	136
R-184	102	345	120	390	24	57
76-TA-660116	170	243	190	300	25	54
R-277	205	249	300	350	17	57
Lasta Lalibela	179	222	120	210	60	123
NEL-256	189	397	200	410	54	60
Giza-9	147	252	160	250	15	54
74-TA-309	133	170	200	210	5	14
NEL-226	120	288	200	310	30	88
R-158	89	231	250	400	33	68
NEL-358	81	307	180	320	34	84
NEL-355	145	287	70	110	27	60
EL-149	186	229	350	420	48	107

S = sprayed; US = unsprayed.

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Discussion

Ato Alem

Around Debre Zeit, farmers stopped planting field pea because of heavy pea aphid infestation associated with high temperature and low rainfall. What is the situation for field pea in Dembi and Kulumsa?

Ato Kemal
Farmers at Dembi and Kulumsa are also suffering from yield losses caused by pea aphid, particularly at Dembi, where yield loss of field pea because of pea aphid reached 77%.

Participant
Storage pests are among the major problems and one of the means to get rid of them is using chemical control measures. But chemicals, as we know, are expensive. Is there any economic study conducted to use other methods and integrate the system with farmers' fields?

Ato Kemal
Of course, chemicals are expensive and the use of alternative control measures which can effectively control the storage pests is unquestionable. But until other methods are found that prove effective in controlling pests, chemical control will be used and farmers have to be taught when to apply chemicals.

Participant
What is your method of identifying cultivars as tolerant and resistant?

Ato Kemal
We do preliminary and advanced screening trials to evaluate materials.

Participant
The review doesn't seem exhaustive. For example, bruchids are not included in the report. Why is that?

Ato Kemal
Bruchids are not included because they need further evaluation.

Participant
What is the view of crop protection scientists on the release of resistant cultivars?

Dr Eshetu
There are many factors that should be considered before a cultivar is released. Resistance is just one of the factors, and by virtue of being only resistant, a cultivar will not be released to farmers.

Quarantine Activities in Ethiopia

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Abstract

Ethiopia is a tropical country with favorable environmental conditions for the development of plant diseases and insect pests. As a result, diseases and insect pests attacking the cool-season food legumes (CSFL) grown in the country are numerous. In a routine survey of most CSFL-growing regions of Ethiopia, several fungal, bacterial, viral, insect pests and weed species were recorded. However, it is still felt there are some important pathogens, insect pests and weed species that are recorded elsewhere but which do not occur or their presence has not been confirmed in Ethiopia. Most CSFL are imported as germplasm for research and a few for consumption. Although the quantity imported is low when compared with cereals, it is still difficult to detect all types of infectious pathogens by conventional methods. Consequently, exotic pests and diseases can be introduced easily. To avoid such risks, consignments destined to this country as feed or germplasm are subjected to certain quarantine tests, seed cleaning and seed treatments.

Introduction

The cool-season food legumes (CSFL), mainly faba bean, field pea, chickpea, lentil and grasspea, are important sources of protein in Ethiopia, especially for the peasant farmers. Even though the diversified nature of the country's climate favors the growth of various types of CSFL in Ethiopia, there are complex problems of diseases, insect pests and weeds. All three inflict great losses in the production of these food legumes. Some of the diseases, insect pests and weed species attacking these crops seem to be restricted in distribution to certain areas while others occur in every growing region and are of great concern. One of the alternatives for maintaining a sustainable yield of these crops is to minimize the loss due to diseases by preventing the entry and spread of exotic pathogens and pests into and within the country. For this, a reasonable quarantine policy is a prerequisite.

Ethiopia is a signatory of the 1951 International Plant Protection Convention and the 1967 Inter-African Phytosanitary Convention of the OAU (Tadesse 1985). Over 40 years have elapsed since the quarantine operation came into practice in this country. During this period several crop species have been imported for research and consumption. The quarantine policy is thus intended to protect Ethiopia from incoming alien diseases, insect pests and weeds imported along with these seeds and other planting materials. The importance of plant quarantine is well realized in the country because of the increasing exchange of research materials.

Table 1. Major cool-season food legume diseases of quarantine interest recorded in Ethiopia.

Host	Common name	Causal agent
Faba bean	Chocolate spot	*Botrytis fabae*
	Zonate leaf spot	*Cercospora zonata*
	Root rot	*Sclerotium rolfsii*
	Wilt	*Fusarium species*
	Rust	*Uromyces vicia faba*
Field pea	Leaf and pod spot	*Septoria pisi*
	Powdery mildew	*Erysiphae polygoni*
	Leaf blotch	*Septoria pisi*
	Stem lesion	*Mycosphoerella pinodes*
	Downy mildew	*Peronospora viciae*
Chickpea	Wilt	*Fusarium oxysporium*
	Root	*Sclerotium rolfsii*
	Wilt	*Macrophomina phaseoli*
	Leaf blight	*Ascochyta rabiei*
Lentil	Root rot/wilt	*Fusarium* spp.
	Root rot/wilt	*Sclerotium rolfsii*
	Rust	*Uromyces fabae*
Grasspea	Rust	*Uromyces vicia fabae*

Source: Dagnachew 1967; IAR 1985a.

Survey on Quarantine Diseases, Pests and Weeds

The availability of accurate and reliable information and assessment of diseases, pests and weed distribution in the country is one of the major requirements of an effective quarantine operation. To this end, surveys were conducted in the past on those diseases, pests and weeds which are already present in Ethiopia and affect faba bean, fieldpea, chickpea, lentil and grasspea (IAR 1985). Many more diseases, insect pests and weed species are recorded on these crops globally and these are the targets and concern of our quarantine policy. The CSFL diseases of quarantine interest recorded in Ethiopia are listed in Table 1. On the basis of this information the national quarantine service determines what agents should be restricted and states the precautions to be taken.

National Quarantine Policy for Seed Importation

The national quarantine service since 1951 (Fikre and Navaratnam 1991) has exercised quarantine measures and precautions to avoid the introduction of exotic pests, plant disease agents and weed species. Prior to importation of any planting materals into the country, import permits must be obtained indicating specific conditions and quarantine requirements. A phytosanitary certificate of international standard is a basic requirement for any imported consignments. The certificate must state freedom of the imported seed, plant part, etc. from quarantine diseases, insect pests and weed contamination. Consignments fulfilling the above requirements will be scrutinized at the ports of entry upon arrival. If signs of disease infestation or contamination with weed seeds are observed, the consignment will be subjected to cleaning and chemical treatment or destruction (IAR 1985).

Materials Imported for Research

In connection with development of high-yielding, improved cultivars of faba bean, field pea, chickpea, lentil and grasspea that are free of disease or are pest resistant, a reasonable amount of seed germplasm of these crops is imported by research institutions such as the Institute of Agricultural Research (IAR) and the Alemaya University of Agriculture (AUA) every year. Realizing the quarantine risks involved the IAR has set up a quarantine service to avoid accidental introduction of exotic diseases, pests and weeds.

A plant importation permit must be obtained from the General Manager of IAR and by the Crop Protection and Regulatory Department of the Ministry of Agriculture prior to importation of any research materials into the country. Once import permits are obtained, the IAR quarantine officer is responsible for facilitating safe movement of incoming and outgoing research material on behalf of the IAR staff.

All CSFL germplasm imported in this manner will be subjected to both laboratory and field tests before release to the importer. Materials imported through IAR in the last few years are listed in Table 2.

Table 2. Germplasm on cool-season food legumes imported to Ethiopia for research since 1979.

Year of import	Crop and amount imported/entries†				
	Faba bean	Field pea	Chickpea	Lentil	Grasspea
1979/80	66	9	11	16	1
1980/81	158		156		
1982/83	1	12	23	244	9
1983/84	852	721	746	563	
1984/85	413	22		363	
1985/86	1679	6		694	
1986/87	2	15	2		
1987/88	1632	109	401		
1988/89	610		163	928	
1990/91	642	69	399	650	92
1991/92	139	16	40	121	137

† One entry ranges from 100 g to 10 kg of seed.
Source: IAR 1980, 1983, 1984, 1985b, 1986, 1987, 1988, 1989, 1991, 1992.

Prohibited Quarantine Diseases

Several diseases are recorded on faba bean, field pea, chickpea, lentil and grasspea globally as well as in Ethiopia. However, there are still some diseases which are not yet recorded in Ethiopia and their entry is prohibited. These are Broad Bean Stain Virus and Echtes Ackerbohne Mosaic Virus on faba bean and Pea Early Browning Virus on field pea and grasspea (Negarit 1992).

Quarantine Precautions and Restrictions

Quarantine rules and legislation are now legalized and strictly operational (Negarit 1992). In order to ensure that exotic diseases, pests and weed species are not introduced into the country with CSFL the following regulations are now strictly in practice (Negarit 1992).

- Plants and plant parts are strictly prohibited from import into the country.
- Prior to importation of seeds, import permits must be obtained from the Crop Protection and Regulatory Department of the Ministry of Agriculture.
- Imported seed must be treated or fumigated with appropriate chemicals in the exporting country before being dispatched to Ethiopia.
- After arrival, seeds must be subjected to post-entry quarantine tests since all types of seed-borne pathogen can not be detected during seed inspection.

Intercepted Plant Diseases

Even though quarantine regulations governing the importation of plant materials have been in practice for several years in Ethiopia, implementation practices were not effective because of inadequate facilities and/or trained manpower to detect alien pathogens in seed and clonally propagated plant species until recently. As a result, several exotic diseases have been introduced into the country. Among these, Ascochyta blight caused by *Ascochyta rabiei* (Pass.) Labr. on chickpea and seed-borne powdery mildew on faba bean were introduced with planting materials. However, with the collaborative efforts of professional societies and research institutions, both diseases were intercepted.

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Discussion

Participant
Sitona weevil on lentil was reported previously by NVRP, but you didn't include it in your report. Why?

Ato Awgechew
I am not aware of it. I have gone through all the new records in IAR but it is not included in the list. We don't have any information about it so far, but we will try to check the list.

Participant
Seeds may enter the country in various ways. What is the use of entry ports only at the airport?

Ato Awgechew
Of course, we are well aware that entry ports are numerous. But in IAR, any staff member first presents the seeds to the IAR Quarantine office. In so doing, we only save the institute, not the country.

Participant
Are there rules and regulations for importing seeds?

Ato Awgechew
Yes, there are rules and regulations. Permission is necessary to import seeds.

Participant
How are seeds that come to Debre Zeit through ICARDA handled?

Dr Geletu
The materials coming from ICARDA or ICRISAT are sent to the respective departments in IAR to be checked.

Overview of Achievements in Cool-Season Food Legume Research in Ethiopia

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Introduction

Faba bean, chickpea, field pea, grasspea and lentil are the major food legumes in the highlands (altitudes above 1800 m asl) of Ethiopia. These crops provide a major part of the daily diet of the people and their by-products are an invaluable source of animal feed. These legumes also play an important role in improving soil fertility.

Although the crops have all these benefits they are prevented by various biotic and abiotic factors from expressing their maximum potential. The constraints to increased production of faba bean include rainfall variability and susceptibility of the cultivated landraces to diseases (chocolate spot, rust, black root rot) and insect pests (podborer, aphids, bruchids). For chickpea, field pea, grasspea and lentils, a lack of improved cultivars, susceptibility to diseases (wilt/root rots, rust, Ascochyta blight, powdery mildew) and insect pests (aphids in lentil and field pea, podborer in chickpea, bruchids in all crops) are the major problems.

Insufficient diffusion and consequent adoption of the appropriate production technology were also major constraints to increased production.

Thus all these production problems as well as the potential of these crops justified a well-organized research and technology transfer infrastructure. However, this was lacking. The team responsible for improvement of these crops had insufficient trained and experienced staff and were ill-equipped or lacked the necessary laboratory and research facilities.

The Project

With funding support obtained from SAREC through ICARDA's Nile Valley Regional Program, the Ethiopian scientists have undertaken laboratory research and field trial demonstrations to improve the productivity of cool-season food legumes. The overall aim of the project is to develop and transfer improved technology to small farmers to improve the productivity of major cool-season food legume crops and ensure sustainability of production systems for these crops under Ethiopian agroecological conditions.

Achievements

The NVP (ICARDA/IFAD/Italy) and NVRP (ICARDA/SAREC) Programs from implementation in 1985 until 1993, have documented various achievements in back-up research, transfer of technology to farmers and institution development (including regional cooperation).

Back-up Research

Back-up research concentrated on solving production constraints facing the Ethiopian farmers, as determined by diagnostic surveys in all four food legume crops (faba bean, chickpea, field pea and lentil). Research work undertaken in various disciplines (e.g., agronomy, breeding, pathology, entomology, weed control, microbiology, human nutrition and socioeconomics) focused on the release of improved cultivars and the development of improved production packages taking into consideration the socioeconomic status of farmers and available resources.

Release of Cultivars

A total of 4465 entries of cool-season food legume breeding materials at different selection stages have been introduced from different countries since 1984. The breeding materials were received from ICARDA, Europe, the USA, ICRISAT, Canada and Australia (Table 1). Most of these entries (3236 selections, 72.5% of total) were received from ICARDA and most were faba bean (2107 selections, or 47.2% of total). This material in addition to the indigenous landraces was the variable germplasm pool for the cool-season food legumes on which the breeding programs in Ethiopia are based. Varietal releases were based on selection of adapted introductions as well as selections within segregating populations developed through hybridization.

Table 1. Introduction of genetic material of various cool-season food legumes to Ethiopia since 1984.

Source	Faba bean	Field pea	Lentil	Chickpea	Lathyrus	Lupin	Total†
ICARDA	2039	92	874	183	48		3236 (72)
Europe	68	566					634 (14)
USA		432					432 (10)
ICRISAT		34		120			154 (3)
Canada		2					2 (< 1)
Australia						7	7 (< 1)
Total	2107 (47)	1126 (25)	874 (20)	303 (7)	48 (1)	7 (< 1)	4465

† Values in parentheses are the percent of total.

In the early years most cultivars released simply remained in demonstration sites of the Ministry of Agriculture. However, after 1985 when trials on farmers' fields were started through NVP, faba bean lines such as CS 20DK, KHSE 2.2733 for high altitudes and Kasa and NC58 for midaltitudes reached farmers. Similar trials were undertaken with field pea such as Mohanderfer for midaltitudes, G22763-2C and Fpea ex DZ for high altitudes. Faba bean cultivars mentioned above were demonstrated in the central highlands (three subprovinces), in Arsi one subprovince, in Bale two subprovinces, in Gojam three subprovinces and in Gonder one subprovince.

In 1993 the faba bean and field pea cultivars listed in Tables 2 and 3 were recommended for release. Evaluation at field levels has been done by the National Seed Release Committee, but the results are pending except for 061K-2P-2/92 which was officially released early in 1994. Once these cultivars are accepted by the release committee, they will be given appropriate names.

The faba bean and field pea listed in Tables 4 and 5 showed improved grain performances and are therefore recommended for release in 1994. Field evaluation will be done in September-November 1994.

In chickpea, the old cultivars released through research are referred to in this book under Genetics and Breeding of Chickpea. The chickpea cultivar Mariye (K8503/27x378) released in 1985 has been popular with the farmers and covers the midaltitude of the central highlands. The more recent achievements under NVRP include the official release of chickpea cultivar ICCL-820104/85-DZ/16-

2 for midaltitude areas (1800-2300 m asl). The following lines will be evaluated for release early in 1994 by the Variety Release Committee: ICCL-84218, ICCL-84239 and DZ-10-9-2. These lines are resistant to wilt and adapted for the midaltitude areas.

Table 2. Yield performance of faba bean cultivars recommended for release in 1993.

Region	Selection	Mean seed yield (t/ha)†
High altitude	Coll 111/77	3.31
	CS 20DK-4-4-2-6	3.37
	CS 20DK (standard check)	3.10
Midaltitude	MKT Illubabor	3.16
	NEB 207 × 74TA74-6D	3.09
	75TA26026-1-2-1	3.66
	NC58 (standard check)	3.45

† Averaged over three crop seasons.

Table 3. Yield performance of field pea cultivars recommended for release in 1993.

Region	Selection	Mean seed yield (t/ha)†
High altitude	061K-2P-2/92‡	4.01
	Parvui × Upton	3.44
	G22763-2C (standard check)	3.31
Midaltitude	Ji No. 335	2.64
	Ji No. 116	2.67
	Mohanderfer (standard check)	2.25

† Averaged over three crop seasons.
‡ Released in 1994.

Table 4. Yield performance of faba bean cultivars recommended for release in 1994.

Region	Selection	Mean grain yield (t/ha)†
High altitude	CS 20DK-4-4-1-1	3.11
	CS 20DK-2-8-1-2	3.10
	CS 20DK-2-6-1-5	3.10
	CS 20DK (standard check)	3.10
Midaltitude	75TA26026-1-2-1b	3.77
	CS 20DK-3-4-1-5	3.69
	CS 20DK-3-4-1-3	3.63
	CS 20DK-2-21	3.54
	NC58 (standard check)	3.45

† Averaged over three crop seasons.

Table 5. Yield performance of field pea cultivars recommended for release in 1994.

Region	Selection	Mean grain yield (t/ha)†
High altitude	Hight sps × Upton	3.29
	FPNur74-1 × 358-1	3.42
	G22763-2C (standard check)	3.12
Midaltitude	DMR-4	2.77
	MG102733 × 310-259-1	2.41
	LG mixture × Upton	2.43
	Mohanderfer (standard check)	2.59

† Averaged over three crop seasons.

In lentil, the old cultivars released are presented under the Genetics and Breeding of Lentil. The lentil cultivar Chalew (NEL 358) released in 1984 covers the midaltitude of the central highlands. A recent achievement is the release of NEL 2704 in 1994 for the lowlands of moisture-stressed environments (< 1800 m asl). Other lines in the pipeline for release include: FLIP84-78L, FLIP86-41L and FLIP87-74L which are large seeded and rust resistant.

Development of Production Packages

After several years of applied research efforts in various disciplines and verifications under farmers' conditions, a number of production packages were developed for dissemination to farmers.

In faba bean, two improved production packages are currently available to Ethiopian farmers in the mid- and high-altitude areas. The recommendations of the package below are followed in the two agroecological zones and the main difference is the cultivars used: NC58 and Kasa for midaltitudes and CS 20DK, KUSE2-27-33 and 20 DK-sel for high altitudes. These cultivars were released in the early 1980s.

Faba bean production package

- Seeding rate (150-200 kg/ha)
- Planting period (22 June to 7 July)
- Weeding at 25-30 and 45 days after planting *or* using pre-emergence herbicide (Topogard)
- Applying fertilizer at 100 kg/ha of diammonium phosphate (DAP) at planting time
- Harvesting when pods turn black up to the middle of the canopy
- Putting the harvested crop in stook form for 30-40 days in the open field
- Threshing on clean, well-levelled, hard ground
- Storing dried and clean seeds away from moisture or high humidity.

In field pea, two improved production packages are currently available to farmers in the mid- and high-altitude areas. The components of the recommended packages for the two agroecological zones are similar (presented below) and the difference is only in the recommended cultivars because of adaptation:

Field pea production package

- Seeding rate (150-180 kg/ha)
- Planting period (22 June to 7 July)
- Weeding and cultivating 30-35 days after planting *or* using pre-emergence herbicide (Topogard)
- Applying DAP at the rate of 100 kg/ha at planting
- Harvesting when pods turn yellow up to the middle of the canopy
- Putting the harvested crop in stook form for 30-40 days in the open field
- Threshing on clean, well-levelled, hard ground
- Storing dried and clean seeds away from moisture or high humidity.

In chickpea and lentil, the research and verification efforts resulted in one improved production package for each crop which is currently available to Ethiopian farmers in the midaltitude (1800-2200 m asl) of Shewa region (Ada, Lemi, Shenkora, Tulubolo, Gimbichu and Ginchi areas). The components for the two packages are as follows:

Package component	Chickpea	Lentil
Seedbed preparations†	Broad bed and furrow (BBF) *or* ridge and furrow (RF)	BBF *or* RF
Cultivar	Mariye	Chalew
Sowing date	Late August to early September	Mid-July to end of July
Seeding rate	80 kg/ha	70 kg/ha
Hand-weeding	Once, 30-35 DAP‡	Once, 30-35 DAP‡
Pest control	None	Dimethoate for aphids

† Mainly to improve drainage to allow earlier planting.
‡ DAP = Days after planting.

Technology Transfer and its Impact

Improved faba bean production packages were demonstrated to farmers in high-altitude zones of the central, northwest and southeast and the midaltitude zone of Ethiopia in 1986-92. During this period, a total of 61 and 143 demonstrations were conducted in mid- and high altitudes, respectively. However, most of these demonstrations were conducted after 1988. The high-altitude packages (cv. CS 20DK) yielded 1.21-3.95 t/ha under farmers' conditions compared with 1.25-2.19 t/ha for local practices (local cultivar). Yield increments ranged, on the average, from 30 to 199% (78% mean) over farmers' traditional practices. The midaltitude package (cv. NC58) averaged 1.88 t/ha compared with 1.05 t/ha for local practices with an average increase of 80% over farmers' traditional practices. The marginal rate of returns (MRR) to investment in CS 20DK and NC58 packages were 322% and 337%, respectively, indicating a high profit margin.

After demonstration of improved faba bean production packages, popularization and follow-up of the spread of new packages were started in 1989 and 139 farmers participated in popularization of faba bean packages in 1989 and 1990; more farmers were involved in the last three crop seasons. Yield increases ranged from 33 to 154% as a result of the adoption of packages. Economic evaluation of popularization results gave an average MRR of 1303% indicating very high profit margin. Diagnostic survey (54 farmers at random) on adoption of recommended practices in the central zone indicated that 61% of the farmers adopted the recommended improved cultivars, 32% adopted P fertilization and 60% of the growers adopted the weed control recommendation (hand-weeding).

With respect to impact of research and transfer of technology on national production of food legumes, it is still early to tell for field pea, chickpea and lentil. However, there is a sharp increase starting in 1989 of total production, mostly due to the increase in faba bean production (Fig. 1). Both NVP and NVRP investment in research and in transfer of technology contributed, at least in part, to this increase in national production.

Institution Development

Manpower development

Staff education and training has been an important component of the NVP and NVRP programs to enhance the qualifications of Ethiopian scientists and technicians. Through the NVRP program, a total of 181 scientists and technicians were involved in staff non-degree education, training and professional visits, mostly between 1989 and 1993 (Table 6). Non-degree training involving short- and long-term group courses, individual training and visiting scientists was in various disciplines, including breeding, agronomy, pathology, entomology, virology, microbiology, weed science, on-farm trial methodology, transfer of technology (extension), computer applications and data analysis. Most of this training was done at ICARDA. In-country and subregional courses were on breeding, computer application, on-farm methodologies, pathology and data analysis and scientific writing.

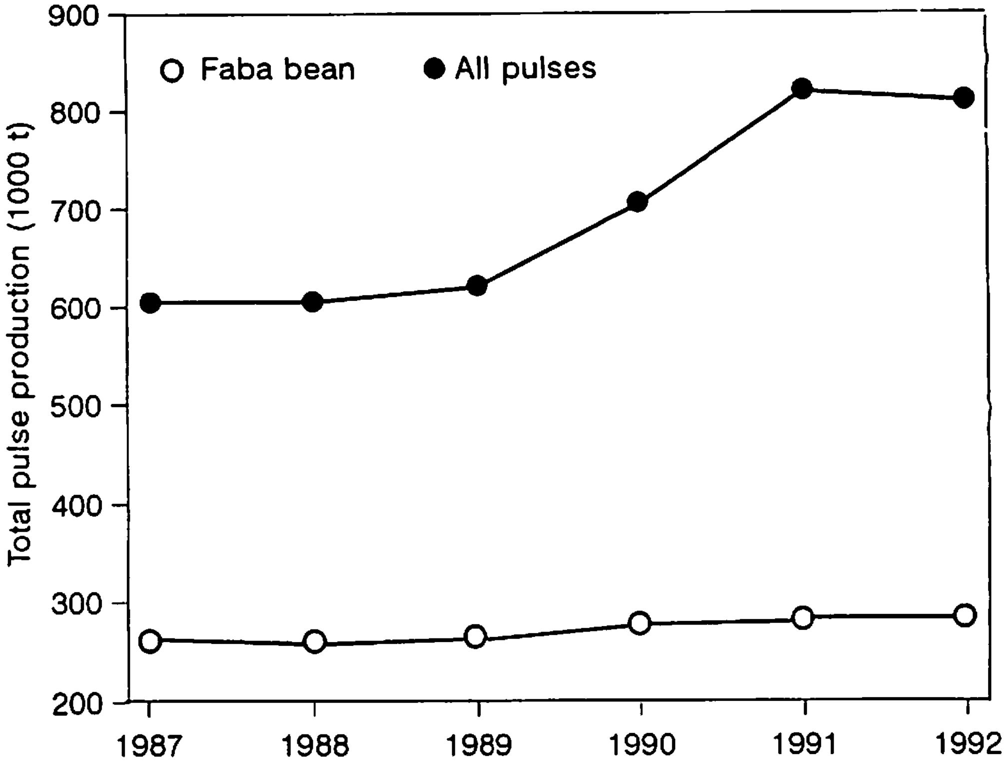

Fig. 1. Production trends of pulses and faba beans in Ethiopia between 1987 and 1992.

Table 6. Summary of participants in staff training and education (1986-93).

Type of Training	Before 1986	1986-88	1989-93
Long-term courses	6	20	13
Short-term courses		4	34
Individual non-degree			30
Country and subregional courses			68
M.Sc. degree training		5	4
Visiting scientists		2	6
Travelling Workshops/Conferences		4	39
Regional Coordination Meetings		37	45
National Coordination Meeting	NA	NA	131
Total	6	72	370

NA = Not available.

The degree training for NVP and NVRP involved 9 M.Sc. candidates in agricultural economics, microbiology, extension, pathology, entomology, breeding and agronomy.

Furthermore, conferences and travelling workshops in the three NVRP countries (Egypt, Ethiopia and Sudan) were organized and attended by 43 national program scientists. A total of 131 and 45 researchers were involved in National and Regional Coordination Meetings, respectively (Table 6).

Multidisciplinary team

Both NVP and NVRP contributed greatly to the development of a multidisciplinary team approach in the improvement of food legumes in Ethiopia. They encouraged team spirit in back-up research among agronomists, breeders, pathologists, entomologists, microbiologists, socioeconomists and extensionists. This was strengthened through the annual coordination meetings held for all national scientists from various disciplines and institutions (IAR; Debre Zeit Research Center, AUA; and Extension Department of MOA) involved in the NVRP Program. As a result of the multi-disciplinary approach, effective technologies were developed for transfer to farmers. The approach followed in NVP and NVRP through ICARDA enhanced self-reliance in the Ethiopian Food Legumes Program particularly for leadership, coordination, effective program planning, implementation and extension.

Linkages among researchers, extensionists and farmers

NVP and NVRP were also characterized by close relationships among researchers, extensionists and farmers. Research work was based on diagnostic surveys on production constraints faced by food legume farmers in Ethiopia. National researchers working in NVP and NVRP became farmer/client oriented because of their involvement with extensionists and farmers in on-farm activities such as:

- On-farm trials managed by researchers under farmers' conditions in cooperation with extensionists and farmers
- On-farm demonstrations managed by farmers only
- Adoption studies to provide feedback to researchers on farmers' perceptions of new technologies.

Contacts with farmers increased and field days were organized jointly by extensionists and researchers in cooperation with the farming community.

Regional cooperation

Regional cooperation in the improvement of faba bean among the three Nile Valley countries (Egypt, Ethiopia and Sudan) started in 1986 with NVP and was extended and strengthened further with NVRP in 1989 to involve chickpea and lentil in addition to faba bean. Through such cooperation, the three countries exchange germplasm, technical information and improved technology in addition to participating in regional coordination meetings.

Regional problem-solving networks were developed to utilize effectively the limited human and physical resources in the Nile Valley countries. Complementary research work is underway on problems of common interest. Depending on expertise and facilities available in each country, the research lead was given to one country. For example, screening germplasm for aphid resistance to Egypt and biological control of aphids to Sudan. Ethiopia is taking a lead in integrated management of wilt/root rot diseases of food legumes which is based mostly on resistant genotypes.

The following formal and informal networks, established under NVRP support, are currently operational in food legumes:

- Integrated management of wilt/root rot diseases of food legumes (formal)
- Integrated control of aphids and virus diseases (formal)
- Water use efficiency (drought and limited irrigation water) (formal)
- Development of autogamous faba bean (informal)
- Integrated control of chocolate spot (informal)
- Socioeconomic network on adoption and impact studies (formal).

Development of facilities

The NVP and NVRP contributed greatly in upgrading the research facilities of the food legumes program. This was particularly important for imported capital items including vehicles which are essential for on-farm activities. The capital items included breeding cages, threshers, balances, laminar flows, incubators, vehicles, computers and printers. Research supplies also were provided by both NVP and NVRP.

Publications

These include Progress Reports, Annual Reports and Workplans and Budgets, technical papers, field guides on biotic stresses (insect pests and diseases), M.Sc. theses, journal publications, book chapters and papers published in proceedings of national, regional and international conferences. A list of publications is presented at the end of this volume.

Summary

Faba bean, chickpea, field pea, lentil and grasspea are the major cool-season food legumes in the highlands of Ethiopia. The crops have various benefits to Ethiopian agriculture and daily diet; however, they were not given the proper research and development emphasis which could have enabled them to show their potential. With this background, ICARDA/IFAD/Italy Nile Valley Project NVP (1985-88) on faba bean and ICARDA/SAREC Nile Valley Regional Program (1989-93) on faba bean, chickpea, field pea and lentil were initiated to support the national programs. Through these projects many prominent achievements have been realized in enhancing national program development, back-up research and transfer of technology to farmers. The close linkage among researchers, extensionists and farmers has been a prominent feature of both NVP and NVRP and for the first time, researchers travelled away from the research stations to be involved with extensionists and farmers.

Other observable achievements have been in staff education and training, facility building and enhanced self-reliance in national programs for leadership coordination with close cooperation within and between the Nile Valley countries. Noteworthy is the increased interdisciplinary team spirit brought about by the projects and the impact on the outcome of back-up research and transfer of technology.

Recommendations

Members of five working groups met to assess the achievements of the project research and prepare recommendations for continued work in five areas: Transfer of Technology; Germplasm Collection and Breeding; Crop Protection; Agronomy, Physiology, Weed Science and Soils; Quality and Utilization of Food Legumes. The recommendations of all five groups were presented and discussed in a general meeting.

Group I: Transfer of Technology

Major emphasis in future work should be on agricultural economics, research and extension.

Agricultural Economics

- Diagnostic surveys should emphasize field pea, chickpea, lentil and lathyrus in new areas
- Emphasize low-input management and farmers' circumstances, examine agronomic recommendations carefully, determine farmers' assessment and continue studies on storage pests
- Use feedback from diagnostic surveys and on-farm evaluations in technology generation.
- Identify the constraints and the reasons why farmers are not adopting certain technologies or recommendations, and emphasize the impact of new technologies.
- Give consideration to price, transport, storage and packaging. Looking for new markets is inevitable when production exceeds consumption.

Research and Extension

- Continue demonstrations in new areas
- Strengthen popularization programs and share the cost of popularization work with farmers
- Produce extension bulletins that help to pass messages easily. Provide training to handle the production of bulletins
- Train extensionists and farmers; first identify their training needs and use audio-visual techniques in the training.
- Active involvement of the Ministry of Agriculture in demonstrations and popularization programs is necessary.

Discussion

In evaluating technologies, an adequate amount of stress should be given to economic evaluation of production practices. Some recommendations are economical and acceptable but fail to be feasible. So, in economic evaluation we should consider farmers' circumstances. We should not conduct diagnostic surveys only from our point of view. We should teach and show farmers all the possible alternatives and let them choose the one that best suits them.

Group II: Germplasm Collection and Breeding

Faba Bean

- Efforts should be exerted to develop improved cultivars with high and stable yields adaptable to different agroecological zones in mid- and high-altitude areas (Table 1)
- Stability analysis using past multilocation data should be conducted to determine agroclimatic zones for adaptation purposes
- The breeding method should be reconsidered, to use population improvement and bulk pedigree methods and to develop early generation yield trials for specific locations. Decentralization (regional trials) would be desirable.
- Breeding materials from F_2 onwards should be handled by breeders and pathologists.

Field Pea

- Efforts should be exerted to develop improved cultivars for mid- and high-altitude areas (Table 1)
- Testing different plant ideotypes for different agroclimatic zones also should be carried out
- The bulk pedigree breeding method should be followed.

The importance of germplasm collection both geographically and species-wise was emphasized and also the evaluation and maintenance of germplasm for the stresses important in Ethiopia.

Chickpea

- Efforts will continue to develop stable and high-yielding cultivars for lowland, midaltitude and highland areas (Table 1).

The extent of research to be conducted will depend on the potential of the chickpea-growing areas. For example, the potential of mid- and high-altitude areas is 75% and that of the lowlands is 25%. Separate research programs will be implemented for desi (70% of area) and kabuli (30%) types.

Lentil

- Efforts will be stepped up to develop stable and high-yielding cultivars adaptable to lowland, midaltitude and highland areas (Table 1).
- The bulk pedigree method will be followed since it has proved to be effective.

In general, the objective is to develop large and green lentil seeds; for mid- and high-altitude areas the exotic materials should be used, but more emphasis should be given to the Ethiopian landraces for lowland areas.

Grasspea

- Efforts should be exerted to develop improved cultivars adaptable to mid- and high-altitude areas (Table 1), with emphasis on selection for low β-N-oxalyl amino-L-alanine (BOAA) content.
- Modified bulk pedigree methods should be followed and surveys conducted on utilization aspects and on diseases.

Discussion

In lupin it is important to consider cultivar release and include it in addition to the data. Various lupin adaptability tests are going on. With regard to its breeding, it must be targeted to the removal of alkaloids and this needs manpower and facilities.

Table 1. Selection criteria to be used in breeding programs for cool-season food legumes in three agroecological zones of Ethiopia.

Crop	Lowland (<1800 m)	Midaltitude (1800-2300 m)	Highland (>2300 m)
Faba bean		High, stable yield; earliness; resistance to rust, *Botrytis*, waterlogging; independent vascular system	Resistance to *Botrytis*, black root rot, frost, rust (in Bale), waterlogging in black clay soils with BBF
Field pea		High, stable yield; large, smooth, cream seed; earliness, short plant type, high harvest index; resistance to Ascochyta blight, wilt/root rot on black clay soils; tolerance to aphids	High, stable yield; large, smooth, cream seed; less pod/seed shattering, medium to long growing duration; resistance to Ascochyta blight, wilt/root rot, powdery mildew, aphids, downy mildew (in Bale)
Chickpea	Tolerance/resistance to drought and high temperature; resistance to wilt/root rot	Medium to long growing duration; resistance to wilt/root rot, stunt virus and *Helicoverpa armigera*; tolerance to waterlogging and drought	Long growing duration; resistance to wilt/root rot and stunt virus; tolerance to waterlogging
Lentil	Early maturity; resistance to rust, wilt/root rot, aphids, drought	Early to medium maturity; resistance to rust, wilt/root rot, aphids; tolerance to waterlogging	Resistance to wilt/root rot, rust, aphids; tolerance to waterlogging, frost
Grasspea		Earliness; grey, large seed; resistance to wilt/root rot, rust, powdery mildew, aphids	Medium to long growing duration; resistance to wilt/root rot, rust; tolerance to waterlogging

Group III: Crop Protection

Diseases

Faba bean

Chocolate spot

- Screen additional germplasms and breeding materials for resistance
- Conduct a variability study on virulence of *Botrytis fabae* isolates
- Conduct a survey to assess yield losses for newly released cultivars
- Integrate tolerance, cultural practices and minimum application of fungicides.

Rust

- Screen materials for resistance and escape mechanisms.

Black root rot

- Survey for its incidence
- Assess yield loss
- Screen for resistance using sick plots
- Conduct epidemiological studies in relation to cultural practices and soil conditions.

Field pea

Powdery mildew

- Screen for resistance and appropriate fungicides
- Assess yield loss
- Study cultural practices, especially sowing date in relation to weather factors.

Spot/blight diseases

- Survey to establish relative importance of the pathogens
- Screening for resistance and appropriate fungicides
- Assess yield loss.

Downy mildew

- Assess yield loss.

Fusarium root rot

- Screen for resistance.

Chickpea

Wilt/root rot

- Screen for field resistance for specific pathogens

- Identify race and distribution of *Fusarium oxysporum*
- Survey to determine the relative importance of wilt/root rot pathogens.

Stunt virus
- Study the characterization and mode of transmission
- Screen for resistance.

Ascochyta blight
- Screen for resistance, especially for *kiremt*-sown chickpea.

Lentil

Rust
- Screen for resistance
- Study inheritance with breeders
- Perform race analysis.

Wilt/root rot
- Screen for resistance
- Determine variability of causal organisms.

Aschochyta blight
- Screen for resistance.

Minor crops (lupin, fenugreek and grasspea)

Surveys to establish the relative importance of different diseases, and a yield loss assessment study for the known disease (powdery mildew).

Insect Pests

- Comprehensive survey, collection and identification of natural enemies
- Studies on the biology and population dynamics of major insect pests and their natural enemies
- Monitoring the dynamics of insect pests and their predators, using light/pheromone traps
- Studies on cultural practices in relation to weather factors
- Selective use of synthetic insecticides and botanicals for insect pest control
- Economic threshold level assessment for major insect pests in different agroecological zones
- Screening of host-plant resistance using standard screening techniques will be emphasized.

In general, long-term solutions should be determined, with emphasis on Integrated Pest Management (IPM).

Discussion

Close cooperation is necessary among breeders, pathologists and entomologists. Segregating populations are treated by the breeders in a breeding nursery and no seed is given to the pathology section. So, this should be corrected and must be given special emphasis. Mapping of the major pathogens for chickpea wilt/root rot diseases must be incorporated in pathologists' work.

Group IV: Agronomy, Physiology, Weed Science and Soils

Agronomy

- Verify available recommentations on new ecological areas of importance
- Develop packages for those areas, with back-up research.
- Develop packages of recommendations for low BOAA content lathyrus cultivars

For maximum yield, double cropping is necessary, either by *belg* cropping or by late cropping on the residual moisture.

Information on cropping systems involving cereals and cool-season food legumes is required: **intercropping** legumes and major cereals after identifying the optimum combinations, and **crop rotation** (study crop sequence + fertilizers).

Physiology

- Strengthen capability in terms of manpower, resources and facilities in relevant locations
- Examine farmers' traditional practices
- Study detopping and partial manipulation of canopy development.

Weed Science

- Survey to determine extent of weed problems in chickpea and fieldpea
- Quantify losses in important growing areas
- Survey, monitor, assess and research parasitic weeds of importance in cool-season food legumes
- Use mechanical weeders, inter-row cultivations, etc. and popularize to overcome labor shortage during weeding.

Soil Fertility/Microbiology

- Revise blanket application of 100 kg DAP/ha, and base the recommendation on soil test results from farmers' fields
- Advise use of starter N application only when tests prove necessary.
- Assess factors (edaphic) affecting biological nitrogen fixation (BNF) for important ecological zones (these factors include micronutrient deficiency/excess, acidity/alkalinity and drainage)
- Strengthen capacity in rhizobiology in terms of manpower and facilities
- Continuously identify, collect and test superior rhizobial strains
- Strengthen soil microbiology teamwork nationally.

Generally, equity issues should be given due consideration for all crops and disciplines. There should also be quality control for agrochemicals and fertilizers.

Discussion

Emphasis has been placed on breeding for disease resistance, particularly to *Botrytis fabae*, and basic methods are being developed for germplasm screening.

A lot has been achieved in the identification of major diseases of economic importance. Quantitative estimates of losses are being determined alone, with the development of integrated methods of disease management.

Botrytis is more important than nematodes on chickpea. Four genera of nematodes were recorded on chickpea. However, there has been no detailed study made so far.

Chickpea stunt virus is becoming a serious threat in the production of chickpea in many areas. Survey work is in progress and work on identification of the participating viruses and other aspects of disease management will be initiated in the near future.

Virus diseases as a group should not be underestimated and any work done so far should be reviewed. Work on stunt virus is also in progress at ICARDA. Research proposals should be submitted for the Nile Valley network survey program of virus disease which will be started soon.

Although Sitona weevil was reported from the Tefki area, it is unlikely to be introduced into Ethiopia with seeds and as far as materials from ICARDA are concerned strong sanitary measures are taken on materials to be introduced to other countries. Several questions on the status of the national quarantine system were discussed. Although the internal quarantine service by IAR is satisfactory, the national quarantine service is inadequate because of lack of manpower and facilities. Finally, the group decided to forward a word of appeal to concerned authorities for the improvement of the fragile situation and thus avoid the anticipated hazards.

The use of neem and vegetable oils (botanicals) is advantageous in that they are cheap, readily available and safe for the user and the environment. However, available local research results are preliminary and detailed studies are needed.

In studies on the overseasoning habit of the African Bollworm, *Helicoverpa armigera*, surface soil temperature was assumed to vary with soil type thus affecting the biology of the pest, particularly the depth and pupal duration and adult emergence.

Group V: Quality and Utilization of Food Legumes

Further research emphasis on utilization and quality of food legumes is required, including:

- Documentation of traditional recipes of food legumes in Ethiopia
- Evaluation of processing methods to reduce or remove toxic substances (soaking, dehulling, roasting, germination, fermentation)
- Introduction of new food types (recipes) to widen the traditional food base, such as ready-to-eat (convenience) food
- Identification of different processing methods to reduce cooking time
- Investigation of different pre-dehulling methods in order to improve the end-product
- Studies on the end-use specificity of legumes in various traditionally prepared legume-based products
- Identification of the traditional method of preparation prone to nutrient loss.
- Basic studies on the role of legume constituents such as starch, protein and lipids with reference to some processing practices; this will help in designing formulation of new products which could be industrially processed
- Studies on canning and other industrially processed food products
- Assessment of the percentage use of each food legume in traditional recipes and total consumption requirement.

Discussion

No food legume is industrially processed in Ethiopia. When industrial processing is introduced, assessing the magnitude will be essential, but for now it is not basically important.

Looking Ahead

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Cool-season food legumes (CSFL), occupying nearly 0.6 million hectares of land and with a production of nearly 0.6 million tons, are important in the diets of masses in Ethiopia as a cheap source of protein. They contribute to sustainable production in the cropping systems because of good residual effect on subsequent cereals, a fact which is well recognized by the farmers. The by-products of these legumes are good sources of animal feed. CSFL contribute to cash flow of farmers and have entered traditionally in the international export trade.

Ethiopia is a center of diversity of these legumes and is, therefore, home of a host of landraces and some wild relatives. This genetic biodiversity is of great value to humanity at large and Ethiopia has the responsibility for collecting, conserving, evaluating and utilizing this invaluable natural resource. In this regard, the highland pulses research group also has a great responsibility, as they work to exploit the CSFL to meet the increasing demands of the population of Ethiopia.

The review of work on genetic resources has shown that although good collection has been made, further collection of landraces and wild relatives should be made soon to prevent genetic erosion. The germplasm scientists should identify areas for collections to complete the gaps and to obtain accessions with important economic traits. Any Ethiopian germplasm collected in the past that has left the country and may not be in the PGRC/E collection should be expeditiously procured from international centers such as ICARDA and ICRISAT, who have the mandates and willingness to provide these materials. There should be greater use of landraces in developing more stable and high-yielding cultivars.

Progress has been made in breeding and genetics of CSFL but release of varieties has been particularly slow in the case of faba bean and field pea. Efforts should be made to remove the bottlenecks in this regard. In this connection there is a need to clearly develop the strategy regarding specific adaptation vs. wide adaptation. In view of large variations in the agroecological conditions in different faba bean growing areas in Ethiopia, there is a need to identify and characterize major agroecological areas and to develop regional trials for these areas using material developed and selected at the research stations which are representatives of those environmental conditions. Thus emphasis on national trials should gradually be reduced in favor of regional trials in faba bean. The characterization and identification of different agroecological regions will require collaborative work between agroclimatologists, soil scientists, agronomists and breeders. This work should be given high priority and a breeding strategy for faba bean should be developed to meet the requirements of these regions. The same appears to be true for field peas. In contrast to faba bean and field peas, chickpeas and lentil have shown wide adaptation and the present breeding strategy seems to be alright.

Resistance to diseases and pests is essential for stabilizing the productivity of CSFL. This requires close cooperation of breeders, pathologists and entomologists. It is fortunate that the CSFL teams have these disciplines and are now working together. However, there is scope for further strengthening of this collaboration in the process of development of improved genotypes. There is a need for clear development of flow charts/breeding schemes, indicating at what stages evaluation for resistance to biotic stresses will be done and how that will be carried out. Emphasis in breeding for all these legumes will have to take cognizance of the need for maintaining traits that meet consumer quality preferences. In the case of *Lathyrus* where work until now has been relatively less, there is a need for improving nutritional quality by attempting to reduce the BOAA content. Since rapid screening of a large number of breeding lines for BOAA will have to be done, use of near-infrared reflectance (NIR) and transmittance technology should be explored.

Production of good-quality breeders seed of improved genotypes should be started early on to ensure that adequate seed is available to be passed on to the seed production agencies as soon as the National Variety Release Committee has identified a cultivar for release.

The breeders have identified the breeding objectives for their respective crops, but there is a need to fix priorities in view of the limitation of resources.

Good evaluation of the production situation of small farmers in central highlands with respect to the CSFL has been done and major production constraints have been identified. These should be taken into consideration as the future program of research is developed. Also, evaluation of production situations of small farmers in areas other than the central highlands should be undertaken. The issues related to supply of inputs and credits and policy issues to facilitate the production of CSFL should be brought to the notice of relevant government departments and policy makers.

A good start has been made in the transfer of technology in the earlier phases of the research on CSFL. This should be further pursued and at the same time the impact of the past transfer of technology on the production and adoption of improved technology should be quantified.

Information on agronomic requirements of CSFL including date and method of sowing, seed rate, row spacing, fertilizer needs, inoculation need and weed control has been generated, but such work has been done on the research stations. Future work should emphasize on-farm evaluation of the production practices in the context of farming systems prevalent in different production areas and they should be subjected to economic evaluation. Emphasis should be on the reduction of cost of production and the practices should be evaluated for the feasibility of their adoption by farmers and their impact on sustainability of the production systems.

Work on plant protection should heavily emphasize integrated management of major pathogens and insect pests, which have been identified. Shifts in pathogen populations should be monitored and management strategies for them developed through back-up research. In this connection plot sharing by plant protection scientists with agronomist and breeders should be given high priority.

While improving productivity of CSFL, the aspect of nutritional quality and consumer preference should be given due attention. The work done so far on the traditional dishes and weaning foods is commendable. However, there is also great scope for more sophisticated processing of these food legumes, so that the overall economics of legume production can further increase. This may include canning and development of textured products and snacks for domestic and international markets.

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ICARDA-004/500/February 1995