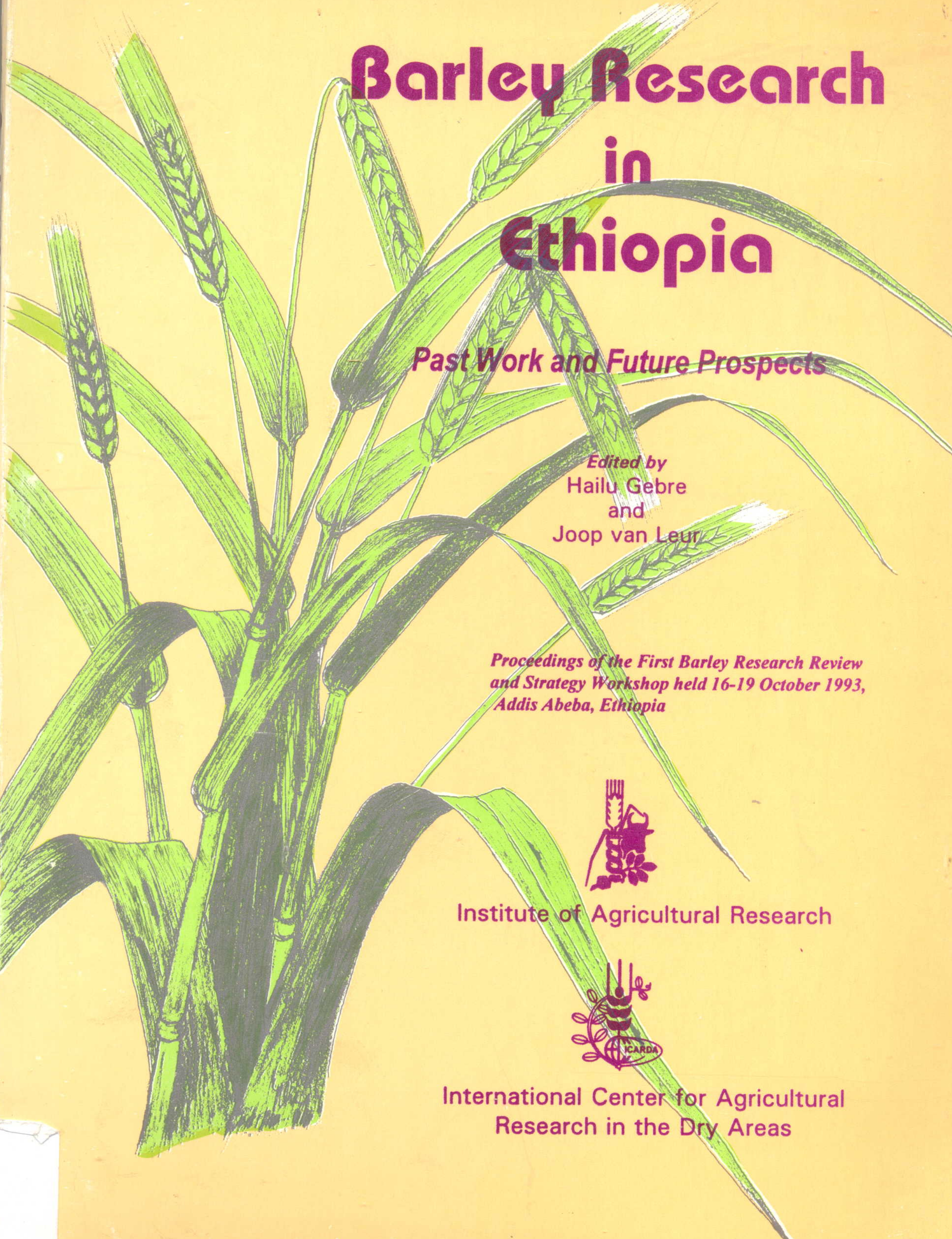

Barley Research in Ethiopia

Past Work and Future Prospects

Edited by
Hailu Gebre
and
Joop van Leur

Proceedings of the First Barley Research Review and Strategy Workshop held 16-19 October 1993, Addis Abeba, Ethiopia

Institute of Agricultural Research

International Center for Agricultural Research in the Dry Areas

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FOREWORD

Barley is believed to have been cultivated in Ethiopia as early as 3000 years BC. This long history of cultivation and the large agro-ecological and cultural diversity in the country has resulted in a large number of landraces (farmers' varieties) and rich traditional practices. Barley culture in Ethiopia is usually practiced with little or no external inputs, mainly in the higher altitudes or on steep slopes, eroded lands or in moisture stress areas.

Barley is a major staple food grain in the highlands. It is used in different forms such as bread, porridge, soup, roasted grain and for preparing alcoholic and non-alcoholic drinks. The straws are used for animal feed, thatching roofs and bedding. Production of malting barley has started in 1975 to meet the growing demand of local breweries.

Ethiopia is considered a center of diversity for barley. Ethiopian cultivars have been extensively used in breeding programs throughout the world especially to incorporate resistance to diseases such as BYDV, smuts, powdery mildew, scald, and net blotch, as well as to improve protein quality.

In spite of the importance of barley, its productivity with an average yield of 1.2 ton ha^{-1} is quite low. The main limiting factors are poor soil fertility, insect pests (e.g., aphids and barley fly), leaf diseases (e.g., scald, blotch, smuts, leaf rust), moisture stress, low yielding varieties, and inadequate agronomic practices.

To improve the productivity of the crop research was conducted over the past 38 years by the AUA, the IAR, CADU and other institutions. In 1993 the barley improvement program started to receive support from the Royal Netherlands Government, through a special project within the frame work of ICARDA's Nile Valley Regional Program. This collaborative project between IAR and ICARDA will emphasize the development of low-input technology and the transfer of newly developed technology to barley farmers.

It was found desirable to review the research done so far on barley and to discuss future directions for barley improvement. Hence, the First National Barley Research Review and Strategy Workshop was held to accomplish this purpose. Twenty papers in different disciplines were discussed during the workshop. The participants of the workshop came from different institutions including IAR, ICARDA, BIE, ENI, MSFCTD, MOA, CPRC, EGTE, ILRI, AAU, AUA, regional agricultural bureaus and breweries.

The workshop was organized by a committee including Dr. Hailu Gebre, Dr. M. Singh, Ato Yitbarek Semeane, Ato Fasil Reda, Ato Berhane Lakew. We acknowledge their dedicated efforts to achieve a successful workshop. We also appreciate all authors, chairmen and rapporteurs. We are grateful to the Information Service of IAR, especially Ato Abebe Kirub, for technical editing of the papers and designing the proceedings. The assistance of Ato Chilot Yirga, Dr Taye Bekele and Ato Yitbarek Semeane in editing some of the papers is greatly appreciated.

Hailu Gebre and Joop van Leur

PREFACE

Cereal grains such as tef, maize, barley, sorghum and wheat are the major sources of food in Ethiopia. They represent about 86% of the total yearly production of 6-7 million tons of grains. The annual production of barley is about 1 million tons. Barley is a dependable source of food as it is produced during the main and short rainy seasons as well as under residual moisture. Its production is also considered relatively stable as compared to many other cereals.

The share of malting barley in the national barley production is quite low (about 2-3%) as compared to food barley. This production, however, is very important in order to meet the demand of breweries and curtail expenditure in foreign exchange. Current malting barley production concentrates in Arsi and Bale regions. There is a need to expand the production into other suitable areas in the central highlands for a reliable and adequate supply of the malt grain.

Research on barley was initiated in the mid-1950s by the then Alemaya College of Agriculture and Mechanical Arts at its branch experiment station at Debre Zeit. The Holetta Research Center of IAR and the Chilalo Agricultural Development Unit were established in the mid 1960s and strengthened the research on the crop by opening experiment stations/ testing sites at some appropriate barley growing areas (eg., Holetta, Sheno, Bekoji, Asasa). The IAR gave emphasis to multidisciplinary research and development of workforce and facilities. The founding of the Biodiversity Institute of Ethiopia (formerly PGRC) and research centers at Mekele, Adet, Sinana and Ambo (PPRC) as well as the collaboration of the Ministry of Agriculture and Ministry of State Farms have all contributed to the overall research efforts on the crop.

This workshop reviewed the achievements of barley research during the past 38 years. Available results could be adopted by farmers to improve barley production. The workshop also made recommendations on future directions of research to promote sustainability of barley production.

The IAR appreciates all institutions, barley researchers and extension workers, and the organizing committee who have contributed to the success of the workshop. The financial assistance given by the Royal Netherlands is gratefully acknowledged. We thank his Excellency Dr. Teketel Forsido, Minister of Agriculture, who spared his valuable time to open the workshop.

Tadesse Gebre Medhin (PhD.)
General Manager, IAR

Opening Address

His Excellency Dr. Teketel Forsido
Minister of Agriculture

Mr. Chairman,
Dear participants,
Ladies and Gentlemen.

It is an honor and pleasure for me to address this important body of professionals at the Barley Research Review and Strategy Workshop. This workshop is held at the most opportune time when peace has been established in the country after a long struggle and urgent development is the need of the hour to achieve democratic reforms. Rapid agricultural development is the key to enhance the development of other sectors.

All of you assembled here are experts in one aspect of barley improvement or another and many of you are fully aware of the needs and challenges that relate to this important food crop. I do not intend to try in this address this morning to review all those needs and challenges. Others will do it much more knowledgeably and expertly than I could. I would, however, like to illustrate the issues by talking about the importance of barley here in Ethiopia in the hope and belief that what I say will have a modest contribution in setting the scene for this workshop.

Agriculture is the backbone of Ethiopian economy. It is the very foundation on which the whole socio-economic structure of the nation is based. About 90 percent of the population lives in rural areas depending on peasant farming. Agriculture as a whole contributes about 40 percent of gross national product. Among crops, the cereals (barley, wheat, tef, sorghum and maize) contribute 86 percent of total food production, It is estimated that out of the total cultivated area about 95% falls under highlands where barley is one of the important crops.

Barley is grown on about 0.9 million hectares. Its annual production is 0.98 million tones. It stands third in area and fourth in production in the country. It is not only an important food grain but malting barley is also a cash crop as a raw material for brewing industry. This crop is grown almost in all the parts of the country, but it is a main crop of highlands owing to its adaptability to low temperature and water stress conditions. Some of the barley varieties are of very short duration and fit in short duration growing seasons where other similar crops like wheat may not be grown. As a result barley is not only grown in main season (Meher) from May/June to September but it is also successfully grown on residual moisture from October to January and also in short growing season (Belg) from March/April to July in different parts of the country.

Barley has such a wide adaptability to variable soil and climatic conditions that it is grown on several types of soil ranging from Nitosols to highly eroded sandy and stony soils. On highlands short duration local varieties are grown up to 3500 meter above sea level to mature before occurrence of frost in the month of September, where no other crop can be successfully grown.

Ladies and Gentlemen

This workshop is a framework within which experts will reflect and exchange scientific and technical information on the results so far obtained from the applied as well as basic research undertaken in their various zones. Furthermore, I understand that this forum will also serve to discuss and set up future strategies of research, which could be an important baseline for barley improvement research.

I am particularly happy to see many scientists from various institutions within the country and a very useful blend of experience represented by scientists from ICARDA with a deep and detailed knowledge of the situations regarding barley improvement research.

I trust this blend will spark a great deal of debate and discussion over the next four days and by that greatly help us to ensure significant improvement in the barley crop in the future. I believe we have the opportunity to make very definite progress toward setting guidelines and strategies for research, in identifying priority problems and in making bold suggestions for alleviating some of the major food supply problems which are known to be looming in our country.

As we all know, the major portion of our national agricultural production comes from the peasant sector, where the average crop productivity is less than 10 q ha^{-1}. One of the major reasons for such low productivity is the use of traditional agricultural technologies.

Talking specifically about barley, to increase the production in this country it will be necessary to bring about the spread of improved cultivars and agronomic packages compatible with them. Satisfactory grain quality and high level of disease and pest resistance are necessary in combination with the high yields to make the improved cultivars attractive to the farmer. An important component of the production package for barley is fertilizer, whose supply so far could not match the demand, mostly due to uneven distribution. Interior villages in the country do not have access to this input that they so desperately require. Therefore, under such circumstances alternate methods of low input agriculture would be critical.

Farmers are growing barley using their landraces with very little inputs like fertilizers and agricultural chemicals. Most of the barley production is done on steep slopes and highly degraded soils. Research efforts are lacking in remote and inaccessible areas of the country where barley is extensively grown. This suggests that there is urgent need to initiate low input technology research at farmers' fields to improve the productivity of this crop. These research efforts should be based on soil and water conservation considerations for proper resource management at farmers' level on long term basis.

There is also a need to integrate barley production, resource management, agroforestry and livestock components to augment the income of farmers who normally depend only on barley production. Malting barley can be cultivated as a cash crop by farmers for breweries. It is, therefore, the task of the agricultural researchers to develop technologies as well as systems that help raise our agriculture from its current low technological base.

A collaborative and concerted effort of research and extension agencies along with proper policies of the government may go a long way in improving the income base and overall development of farming communities in the barley growing areas of the country.

The Ministry of Agriculture is interested in the potential value of this workshop. I am sure there is a lot to gain by our scientists being associated with a wider program of research on barley in international research centers such as ICARDA and research organizations in other countries. They can learn more and be able to add to our research program new ideas and techniques that others have developed and benefitted from. It is my belief that all the scientific and technical recommendations you make in your deliberations will be put in to action by concerned institutions.

Ladies and Gentlemen,

A major goal of this workshop must be to consider how to cooperate best to make effective use of each other's time, abilities and knowledge, to strengthen the net work of science through the bonds of friendship and common interest. On behalf of the Transitional Government of Ethiopia, I would like to sincerely thank the Royal Netherlands Government and

ICARDA for supporting the barley improvement research, in general, and this important workshop in particular.

Finally, I would like to extend my sincere thanks to the organizing committee members, who have contributed their time and energy to bring about the realization of this workshop. I with you success in your deliberations and hope your discussions will be enjoyable and fruitful. I also assure you that the Ministry of Agriculture will always help and encourage your developmental efforts with favorable policies and unreserved support.

With these remarks I have the privilege and pleasure of declaring the Barley Research Review and Strategy Workshop open.

Thank you!

Barley Production and Research

Berhane Lakew, Hailu Gebre and
Fekadu Alemayehu

Abstract

Despite its long history of cultivation and wide range of uses in different communities the yield of barley is very low (1.0 t ha^{-1}). The major production constraints of barley include diseases (such as scald, netblotch, spot blotch, rusts and smuts), insect pests (such as Russian wheat aphid and barley fly), poor soil fertility poor soil drainage, frost and moisture stresses.

Barley research in Ethiopia started at the Debre Zeit Research Center in 1955. Since 1967 the IAR is coordinating barley improvement efforts. Currently research on barley is being carried out at seven research centers and sub-centers with several testing sites representing the major barley growing regions. The research program follows a multi-disciplinary approach. Several high yielding food and malting barley varieties with their appropriate production packages are released. At present some of them are under production. Research on barley has several setbacks, which include inadequate research centers, shortage of trained work force and facilities and slow transfer of technologies.

Barley can be cultivated at altitudes between 1500 and 3500 m, but is predominantly grown between altitudes of 2000 and 3000 m. It is the fourth most important cereal crop after maize, tef and sorghum. On average 0.9 million hectares of land is covered by barley with average production of 1.0 million tons annually (Table 1).

Research on barley improvement was started in 1955 at the Debre Zeit Agricultural Research Center. Since 1967 the Institute of Agricultural Research (IAR) took the responsibility of coordinating the crop improvement work on food and malting barley.

At present research on barley is coordinated from Holetta Research Center and carried out at several research centers that represent major barley growing regions. A multi-disciplinary team approach is followed including breeding, pathology, agronomy, entomology, weed science, soils and water management, food science, agricultural economics and extension.

The purpose of this paper is to review production and research made on food and malting barley, the prospects of barley in the future, and research strategies.

Barley Production

Some useful characteristics of Ethiopian barley

In studies on Ethiopian barleys useful traits like resistance to powdery mildew (Mulugeta 1985), barley yellow dwarf virus, net blotch, scald and loose smut (Qualset 1975) and high protein content (Munch et al. 1971) were identified. Useful characteristics of Ethiopian barley include high tillering capacity, tolerance to marginal soil conditions and resistance to barley shoot fly, aphids and frost. Vigorous seedling establishment and quick grain filling period have also been observed (Hailu and Fekadu 1991). Ethiopian barleys show sensitivity to lodging, low grain to straw ratio and fragile rachis.

Production trends

Barley is cultivated in all regions of the country. The most important barley producing regions are Shewa, Arsi, Gojam, Gonder, Welo, Bale and Tigray (Table 2). Belg barley is produced mainly in Welo, Shewa and Bale. The estimated production of barley between 1979 and 1986 varied between 0.81 and 1.16 million tons at a ratio of 1.4 between maximum and minimum production years. In wheat, tef, maize and sorghum the ratio is considerably larger indicating the greater stability of barley over the other cereals (Table 3). Productivity of barley in Ethiopia is low as compared to some major barley producing countries (Table 4).

Trade

Ethiopia exported only a limited amount of barley. On the other hand, from 1962 to 1987 a total of 24,999 tons of barley grain was imported from different countries (Table 5). From 1962 to 1990 a total of 130,797 tones of malt and malt extracts were imported (Table 6). After the establishment of a malt factory in 1985 at Asela and with the extensive malt barley production in the Arsi and Bale regions, the local breweries were fully satisfied and no importation was made from 1987 to 1989. During this period the Asela Malt Factory processed over 19,000 tons of malting barley annually (Table 7).

Production constraints

Barley production is constrained by several problems such as poor soil fertility, water logging moisture stress, low yield potential of currently grown cultivars and instability of yield because of diseases, insect pests and weeds. The crop has also quality related problems including poor malting quality because of high protein, low extract and thin grains, tedious operation in food processing, and a slight bitterness of grain for injera preparation.

Barley Research

Establishment of research centers

The earliest organized barley breeding program in Ethiopia was started in 1955 by the Debre Zeit Agricultural Research Center. The Holetta Research Center of IAR was established in 1966 to represent the central highlands of Ethiopia. The establishment of the Chilalo Agricultural Development Unit (CADU) in 1967, the Mekele Research Center in 1973, the Plant Protection Research Center (previously the Scientific Phytopathological Laboratory) in 1976, the Plant Genetic Resources Center in 1977, the Adet and Sinana Research Centers in 1986 and the IAR/ADD joint adaptive research programs in the 1970s and 1980s have contributed to barley research.

Coordination

Research on food and malting barley improvement is handled by a multi-disciplinary team. Members of the barley research team represent breeding, pathology, entomology, agronomy, weed science, soil and water management, agricultural economics and extension disciplines.

Since 1967 the barley research is coordinated from Holetta Research Center. Currently, the research is being carried out at Holetta, Sheno, Kulumsa, Sinana, Adet, Mekele and Sirinka research centers. Some testing sites of the Ministry of Agriculture are also being used.

Cooperation

Nationally, several government organizations have been involved directly or indirectly to promote research and development activities on barley. The major ones are the Plant Genetics Resources Center of Ethiopia (PGRC/E), Ministry of Agriculture (MoA), State Farms, Ethiopian Seed Corporation, Ethiopian Nutrition Institute, Plant Protection Research Center, Alemaya University of Agriculture and Asela Malt Factory.

Internationally, the barley research program has a good cooperation with ICARDA in exchange of information and germplasm and provision of research supplies and short-term training. There is as well exchange of germplasm with CIMMYT. In the past there was good cooperation with FAO, USDA and SAREC.

HIGHLIGHTS OF MAJOR ACHIEVEMENTS

Varieties

Several high yielding food and malting barley varieties have been released. Some of the released varieties are shown in Table 8. For marginal environments farmers' cultivars have not been superseded.

Management

Optimum sowing dates, seed rates and tillage practices, weeding time and fertilizer rates are known for some barley growing areas. Improved drainage method has been developed to replace traditional soil burning practices. Efficient herbicides to control both grass and broad leaf weeds have been selected. Alternative sources of plant nutrients such as bone meal, basic slag and rock phosphate have been identified

Insect pest control

Thirty-eight insect pests and thirteen natural enemies are identified. Of these 32 are field pests and six are storage pests, with barley fly and russian wheat aphid as most important. Barley fly is best controlled by seed treatment and late planting reduces the infestation. Aphids can be controlled by spraying insecticides.

Disease control

Thirty-six pathogens (23 fungi, 2 bacteria, 2 viruses and 9 nematodes) are known on barley. Research findings revealed that late planting reduces the incidence of scald, seed cleaning eradicates ergot, and off-season planting under irrigation eradicates smut infection. Foliar fungicides are identified for controlling scald and netblotch.

Food processing

Good quality injera and bread can be prepared from flour composites of barley, with tef and wheat respectively. Malt weaning food is formulated from barley and chickpea.

Research direction

The strategy on food barley will focus on selection and improvement of landraces and low input crop management and cropping systems to improve soil fertility and moisture availability for barley production. On-farm research with participation of farmers in the selection of treatments will be emphasized. Introduction and evaluation of malting barley varieties will continue. Emphasis will be given to hybridization and selection as well as evaluation of local germplasm. Studies on fertilizer requirement and cultural practices will continue.

Table 1. Estimates of area and production of major cereals in Ethiopia (1960-89)

Year	Barley	Tef	Wheat	Maize	Sorghum
1980–89					
Area	892.5	1326.7	657.2	924.7	817.9
Production	1009.3	1103.5	750.5	1483.2	1028.2
Yield	1.1	0.8	1.1	1.6	1.2

Source: CSA (1989).
* Area ('000 ha); Production ('000 t); Yield (t ha^{-1})

Table 2. Estimates of barley area and production by region (1979-89)

Region	Area ('000 ha)	Production ('000 t)
Shewa	214.0	229.6
Arsi	138.3	212.4
Gojam	125.6	122.0
Welo	113.9	145.0
Gonder	101.3	90.8
Bale	55.0	59.5
Total(%)	**85.6**	**87.2**
Tigray	28.3	23.8
Welega	23.8	24.4
Sidamo	19.8	21.2
Gamu Gofa	20.9	24.9
Total(%)	**10.6**	**9.6**
Harerge	12.8	11.9
Kefa	12.7	12.3
Ilubabor	7.7	7.6
Total(%)	3.9	3.2
Total	**874.1**	**985.4**

Source: CSA (1989)

Table 3. Comparison of maximum and minimum production years for different crops (million mt)

Crop	Highest year (H)	Production	Lowest year (L)	Production	Ratio (H: L)
Barley	82-83	1.2	83-84	0.8	1.4
Tef	79-80	1.4	84-85	0.8	1.7
Wheat	82-83	0.9	79-80	0.5	1.7
Maize	82-83	1.6	80-81	0.9	1.7
Sorghum	79-80	1.6	84-85	0.5	3.2

Source: CSA (1987)

Table 4. Area and yield of some major barley producing countries as compared to Ethiopia (1989-91).

Country	Area ('000 ha)	Yield (t ha^{-1})
World	74642	2.3
Canada	4614	2.8
Spain	4372	2.1
Turkey	3351	2.3
USA	3272	3.0
Germany	2730	5.7
Morocco	2357	1.4
France	1749	6.1
UK	1393	5.5
Algeria	1400	1.3
Ethiopia	960	1.0
Tunisia	573	1.2

Source: FAO, 1991

Table 5. Import of barley grain (1962-1987)

	1962-70	1972-80	1982-87	Total
Quantity(t)	3,902	10,316	10,781	24,999
Value (Birr '000)	1,123	3,752	3,819	8,694

Source: Ministry of Finance

Table 6. Import of malt and malt extract (1962-1986)

Year	Quantity (tons)
1962	401
1966-1980	57455
1981	11006
1982	7698
1983	18401
1984	21045
1985	13080
1986	1711
Total	130797

Source: Ministry of Finance

Table 7. Malting barley supply (tons) to Asela Malt Factory from state farms and cooperatives (1985 to 1989).

Year	State farms	Cooperatives	Total
1985	17,377	2,573	19,950
1986	19,179	3,234	22,413
1987	19,055	6,822	25,877
1988	20,326	4,723	25,049
1989	14,201	5,294	19,495

Note: For 1 t malt 1.67 t. barley grain is needed.
Source: Asela Malt Factory (personal com.)

Table 8. Some food and malting barley varieties released for production.

Variety	Year released	Yield (t ha^{-1})	Type
IAR/H/485	1975	2.5-5.6	Food
AHOR 880/61	1980	2.9-4.4	Food
HB-42	1984	3.6-6.3	Food
ARDU 12-60B	1986	3.2-5.5	Food
Beka	1973	2.4-3.8	Malting
Holkr	1979	2.4-3.1	Malting
Proctor	1973	2.1-4.4	Malting
HB-120	1994	2.4-5.3	Malting

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Food Barley Breeding

Hailu Gebre, Berhane Lakew, Fekadu Fufa, Berhanu Bekele, Alemayehu Assefa and Tesfaye Getachew

Abstract

Food barley breeding in the 1950s and 1960s was mainly conducted at the Debre Zeit Agricultural Experiment Station of the College of Agriculture and Mechanical Arts. Local and introduced germplasm were evaluated from which high yielding selections were identified. The breeding program was expanded and strengthened with the establishment of Holetta Research Center and Chilalo Agricultural Development Unit in the mid-1960s and other research centers lately

Several exotic and local germplasm were evaluated at Holetta and other locations. Exotic varieties were poorly adapted and susceptible to diseases and insects. A number of local varieties showed good adaptation and tolerance or resistance to diseases and insect pests, but had a low yield potential.

Hybridization and selection were done on local and introduced cultivars with resistance to scald and net blotch, lodging and other environmental stresses. Several high lysine lines were identified.

Variety trials of selections from crosses, local collections, and introductions were conducted at several locations in the country High yielding varieties such as Composite 29, IAR/H/485, AHOR 880/61, HB-42 and ARDU 12-60B were released for the central and eastern highlands. Farmers' varieties were found unexcelled at locations with stress environments.

Most farmers in Ethiopia use local barley cultivars. These cultivars are landraces which are location-specific and adapted to low-input management. They have some useful traits such as vigorous seedling establishment, high tillering capacity, quick grain filling period and high seed weight. But they are prone to lodging and shedding, susceptible to leaf diseases and smuts, and a long vegetative period. The main objectives of the food barley breeding program in the IAR and other institutions were to improve grain yielding capacity and stability with good grain quality. The research efforts and achievements of the last 38 years are reviewed in this paper.

Barley Breeding at Debre Zeit Research Center

Barley breeding began in 1955 by the College of Agriculture and Mechanical Arts Branch Experiment Station at Debre Zeit. The major activities at the station were evaluation and selection of landraces and introduced nurseries. Promising cultivars were tested in replicated yield trials. During the period 1955 to 1963 the variety Erie with a grain yield of 1.44 t ha^{-1} was found best among eight local and introduced cultivars (Table 1).

Table 1. Grain yields for varieties grown at Debre zeit, 1955-1963.

Variety	Yield ($t\ ha^{-1}$)
Erie	1.44
Semerita	1.39
Maji	1.38
Hanchan	1.37
Morarian	1.28
Research	1.17
Spartan	1.17
Jima	1.12
Black barley	1.00

Source: (1)

In the mid 1960s over 815 selections of local barleys were evaluated. Disease and others nurseries from FAO, USDA and CIANO (Mexico) were also evaluated. Some promising high yielding local selections (eg. DZ-02-72) and introduced cultivars (eg. Firlbecks III, Unitan, Atlas Kindred[2]) were identified from yield tests conducted at Debre Zeit and at Simba (17).

Barley Breeding at Holetta Research Center

The Holetta Research Center of IAR represents the central highlands, with barley as one of the major crops for research. Since 1967 it is coordinating the national barley improvement program. In the early years greater emphasis was given to malting barley (11).

The main barley breeding objectives are to improve high grain yield, nutritional quality, grain plumpness, resistance to lodging and foliar diseases, such as scald and net blotch. In the early years variety testing was done with seed treatment for barley fly and with applications of fertilizers for maximum grain production. Selection under low input management was exercised in the later years, because of poor acceptance by farmers of varieties that were developed under high input management.

Evaluation of exotic germplasm

Initially the breeding program at Holetta gave emphasis to introduction and evaluation of exotic germplasm. The center served as a quarantine site as well as a disease screening site for scald (*Rhynchosporium secalis*) and net blotch (*Helminthosporium teres*). Several types of nurseries were evaluated including; observation nurseries for low rainfall, moderate rainfall, or high altitude areas, disease nurseries and international/regional yield trials. In addition special purpose nurseries such as frost resistant lines from Peru and BYDV resistant lines from USDA were tested at Sheno, and aphid tolerant lines at Maichew. From 1966 to 1993 over 22,000 entries were evaluated. However, most of the exotic lines were highly susceptible to scald, net and spot blotches and barley shootfly, and had poor plant vigor and small grains. About 6% were advanced for further selection and yield tests. Some outstanding cultivars such as C 63 and AHOR 880/61 were released from this exercise.

The major cooperators in these activities were the FAO Near East Regional Program and USDA until early 1970s, the Arid Land Agricultural Development in the early 1970s and CIMMYT and ICARDA from the mid 1970s to date. Some germplasm was received from Kenya, Sweden, Columbia, Yugoslavia, Czechoslovakia, Egypt, Brazil and India.

Improvement of landraces

In the early 1970s when exotic cultivars appeared to show narrow adaptation and susceptibility to diseases and pests, research was directed toward evaluation and selection of local landraces. About 3,300 accessions, were evaluated in nursery rows. In the 1980s 5,476 accessions were evaluated in cooperation with the PGRC/E. Most of the entries were susceptible to scald, net/spot blotches and leaf rust and were prone to lodging. Out of all accessions 547 were selected based on high tillering capacity, medium height, erect leaves, resistance to foliar diseases, good vegetative vigor and plump grains. Single plant selections were advanced and the best performing lines were tested in the national variety trials for yield, desirable agronomic characters and disease resistance. High yielding cultivars such as IAR/H/485 and ARDU 12-60B were identified from this activity. As the adoption of improved varieties that require high management conditions was found slow and unsatisfactory, a selection strategy based on low-input management (without seed treatment and fertilizer application) was undertaken. In the late 1980s landrace populations, from ecologies similar to Holetta, Sheno and Bekoji were evaluated. Some promising lines were identified (7).

Breeding for grain yield and disease resistance

A modest hybridization program was initiated in 1968 to develop high yielding varieties with resistance to scald, net/spot blotches and lodging. Twenty-two crosses were made from promising local and introduced cultivars such as Holetta Local, Atlas Kindred[2], Coast, Compound 14/20, Egypt 5 and Hiproly. Selections were advanced at Holetta and other locations using the pedigree and mass methods. The program was expanded in 1974 and 1978 by including cultivars such as Bedi Local selections, Holetta Local selections, Sheno Local, Workeye, Semereta, PI 12100, IAR/H/81, CI 3206-3, CI 4375-1, DZ-02-72, Promesa, Trabout, Composite 29, Composite 34, Compound 14/20, Coast, Chile Common and Peru.

Over the years about 378 crosses were evaluated using the pedigree method. Superior selections such as HB-7, HB-15, HB-26, HB-42, and HB-100 were identified.

Breeding for nutritional quality

Barley protein is considered generally low and deficient in lysine. A project on improvement of nutritional quality of barley, especially lysine content, was initiated in 1975 by FAO in collaboration with Sweden through the Swedish International Development Authority (SIDA) and the Swedish Agency for Research Cooperation with Developing Countries (SAREC). The rationale of the project was that there is a considerable gap between protein requirement and its availability in developing countries, especially among the rural masses whose diets mostly depend on cereals (6). In the late 1970s the importance of calorie shortage over protein was reconsidered and the breeding objectives were broadened to increase both carbohydrate and protein quality (6).

The following donor parents; Hiproly (CI 3947, from Ethiopia), SV 73608 (Hiproly x Mona [5]), SV 75240 (Hiproly x Kristina[5]), Riso 1508 (mutant of Bomi), SV 791582 (Hiproly x Mona[7]) x Alva, and B_1 (for protein, from India) were used for high protein and lysine. Twenty-nine cultivars from Ethiopia were crossed to these lines. Most of the crosses were done at Svalof Ab, Sweden. Some local crosses involving Bedi Black 6R and Composite 29 with SV 73608 were done at Holetta. Information on nutritional quality was received from Svalof Ab until a quality laboratory was established at Holetta in 1982. Lines were screened for protein and lysine content using Kjeldahl and Dye Binding Capacity (DBC) methods, respectively, based on regression of DBC value on protein content. From 1978 to 1981, 1,411 crosses/lines were evaluated at Holetta for plant vigor, plump grain, and resistance to scald and net/spot blotches. Protein analysis was made for 1,576 samples, of which 316 high lysine lines were identified. However, a large proportion of the lines were discarded for susceptibility to scald and leaf blotches and for poor plant vigor, lodging and shrivelled grains. Some high lysine lines were tested in a replicated yield trial. The results showed that the high lysine lines gave lower grain yields and kernel weights (Table 2). Among the high lysine lines, EH617/F2-B-21H gave a comparable grain yield to Baleme (the local check) under fertilized condition, but with shrivelled grain and a lower kernel weight.

Improvement of hull-less barley

Hull-less barley is commonly used for food as porridge and roasted grain. Hull-less barleys are mainly found in north and northwestern Ethiopia and in the high altitude areas of the Shewa, Arsi and Bale regions.

A selection program was started at Holetta in the early 1970s with about 200 local collections and an number of introduced lines from Peru. The most promising lines were evaluated in the national yield trials from 1974 to 1976. The best hull-less barley (entry 4–73) gave 2.6 t ha^{-1} grain yield as compared to 4.2 t ha^{-1} of Composite 29, the standard hulled barley (Table 3).

The hull-less cultivars generally had lower kernel weight and were more susceptible to diseases than the hulled barley.

Table 2. Performance of high lysine lines, Holetta, 1985.

Line	Protein[1] (%)	Lysine[1] (DBC)	Yield (kg ha^{-1})	1000 (kw g)	Grain[2] rating
Ch77/78.3212-5-91H	14.4	40.1	215	36	p
SV78/50074-38-12H	15.2	39.1	1070	46	G
SV79/52022-2H	16.4	44.1	190	42	F
SV79/52022-3H	16.5	44.7	170	42	F
EH 617/F2-B-1H	13.3	38.4	1170	42	G
EH 617/F2-B-3H	12.8	41.0	1340	44	F
EH 617/F2-B-17H	14.6	40.1	1385	38	F
EH 617/F2-B-21H	14.5	40.7	1955	40	F
EH 617/F2.W.11H	13.5	37.4	1107	38	F
EH 617/F2.W.12H	13.0	38.0	527	34	F
EH 617/F2.W.22H	15.6	40.5	1290	40	F
HB-42 (std.ck)	9.7	31.2	637	54	G
Baleme (local ck)	15.2	39.7	1850	54	G
Mean			994		
LSD 5%			780		
CV %			36		

1 = 1984 growing season samples, 2 = Grain rating, P = poor; F = fair; G = good, Source: (9)

Table 3. Grain yield of hull-less cultivars during 1974–76 seasons

Cultivar	Yield (t ha^{-1})			
	Bekoji	Holetta	Gonder	Alemaya
4-73	2.9	2.6	2.9	2.1
6-73	3.0	2.3	2.9	2.2
10-73	2.3	1.5	2.3	2.7
13-73	2.0	2.0	2.6	2.8
CI-10979	2.3	2.6	2.7	2.1
Composite 29 (check)	4.8	4.6	3.3	4.2

Source: (12)

Composite crosses

Composite 29, a high yielding cultivar, was selected from Composite Cross XXI which was received from the USDA in 1966. In the 1970s and 1980s local crosses were developed for yield and disease resistance using the male-sterile line Commander and a large number of local and introduced cultivars. About 300 crosses were mixed to inter-mate naturally and seeds from sterile heads were advanced. No outstanding selection resulted from this effort.

Variety mixtures

Variety mixture trials were conducted at Holetta in the mid-1980s to study their response with respect to yield and disease resistance when grown in mixture or pure stand. The trials were tested with and without fertilizer. Only fertilized treatments gave significant differences. Some mixtures outyielded the local check but not HB-42 the standard pure line check (9). Less disease pressure was observed in mixtures than in pure stands.

Recommended varieties

Up to 1986 several varieties were recommended for release (Table 4).

Table 4. Recommended varieties

Year	Variety	Grain yield (t ha^{-1})	Suitable locations
1969	Egypt 20	2.5	Kulumsa, Holetta and Alemaya
1971	BMC	2.9	< 2300 m
	DZ-02-72	2.7	< 2300 m
	C63	3.1	> 2300 m
	Beecher	2.9	> 2300m with short rainy season
	Atlas Kindred[2]	2.7	> 2300m with short rainy season
	Atlas 57	2.4	> 2300m with short rainy season
	Peru	3.0	> 2300m with short rainy season
	Coast	2.9	> 2300 m with long rainy season
	Chile Common	3.0	> 2300 m with long rainy season
	Cpd 14/20	3.0	> 2300 m with long rainy season
	Unitan	3.0	<2300 m with long rainy season
1975	Composite 29	4.1	Central/Eastern Highlands
	IAR/H/485	3.6	Central/Eastern Highlands
1980	AHOR 880/61	4.5	Central/Eastern Highlands
1984	HB-42	5.1	Central/Eastern Highlands
1986	ARDU 12-60B	3.6	Central/Eastern Highlands

Regional Breeding Programs

Regional breeding programs were conducted for the Bedi plateau, the north Shewa highlands and the Gojam, Gonder, Tigray, Arsi and Bale regions.

Bedi plateau

The Bedi plateau is in Welmera wereda, Shewa. Bedi is located on predominantly red soils and at an altitude of over 2600 m. A barley-fallow rotation system is commonly practiced. Rainfall amount and distribution are similar to Holetta Research Center (about 1,000 mm per year). The dominant farmer's variety Baleme yields about 1.2-1.5 t ha^{-1} in a good year. The major problems for barley production are poor soil fertility, low soil pH (4.3 KCl), frost and weed competition.

Food barley improvement for Bedi was started in 1971. About 270 cultivars from the national variety trials and some exotic germplasm were screened for adaptation. Introduced cultivars performed poorly. Acid-tolerant lines (27 local and 30 introduced from Brazil) were evaluated. The introduced lines were found unsatisfactory as compared to the local landraces. Emphasis was therefore given to selection of landraces. About 1633 accessions were evaluated until 1975 with optimum fertilizer (41 kg N and 20 kg P_2O_5 ha^{-1}).

Many cultivars showed good plant vigor, but were susceptible to scald and net blotch. Mass selection of uniform heads and plant types was done on promising entries. About 215 selections were evaluated in yield tests, however, the best selections were not superior to the local check (Table 5).

As success was not apparent from landraces, a hybridization program was initiated in 1974. The objective of the crossing program was to improve the yielding capacity of the local barleys. A number of high yielding cultivars with desirable traits such as stiff straw, long spikes and resistance to scald and net blotch were used. They were crossed to Baleme, Adaberga local and other local selections. About 140 crosses were made and selections were advanced using the pedigree method. About 150 advanced selections were evaluated for grain yield. The selections gave an average yield range of 1.9-3.6 t ha^{-1} as compared to 1.6-2.6 t ha^{-1} from landrace selections. High yields as much as 6.0 t ha^{-1} (39% higher than the yield of local check) were obtained. From 1985 to 1987, 80 selections were tested as mixtures and pure lines with and without fertilizer. The mixtures were not superior to the local checks.

Table 5. Grain yield and scald reaction of elite selections from landraces, Bedi, 1977

Selection	yield (t ha^{-1})	scald (0-9)
CI 10389	2.3	6
CI 12959	2.1	6
CI 2376	1.8	8
CI 4375-1	1.6	4
IAR/H/199	1.9	7
IAR/H/165	2.1	8
IAR/H/189	2.0	8
IAR/H/177	2.1	7
IAR/H/138	2.1	8
IAR/H/117	1.8	7
IAR/H/195	2.1	6
Local check	2.0	7
LSD 5%	0.4	
CV %	12.0	

Source: (8)

North Shewa highland

North Shewa is an extensive barley and sheep production region. The soils are mostly shallow and vary from red on the hill sides to heavy black on the bottom lands. The rainfall is bimodal with a main season (meher) and a short season (belg). Barley is produced in both seasons, occasionally on burnt soils. The annual rainfall is about 900 mm and the minimum temperature can sometimes go down to -8°C from October to January. Magie and Feres Gama are grown by the farmers in the main season and Kesele in the short season. The major limitations for barley production are poor drainage, soil fertility, frost and aphids. Moisture stress is a problem in the short season.

Barley improvement was started at Sheno in 1969. In the early years the food barley national variety trials were tested. The trials were conducted on 6 to 8 m wide cambered beds with application of optimum fertilizer rates. Some frost resistant barley varieties from Peru and BYDV resistant lines were also evaluated. Most exotic varieties were poorly adapted. In early 1970s a program was started to evaluate landraces. During 1973 to 1975, 1895 accessions were tested on cambered beds. Mass selection of uniform heads and plant types was done on promising entries. The best selections were advanced based on plant vigor, long spikes and resistance to diseases (leaf rust, scald and net blotch). In 1976 and 1977, 65 promising selections were evaluated for yield. However, none were found superior to the local checks (Table 6).

Table 6. Grain yield and disease reaction of elite selections from landraces, Sheno, 1977.

Selection	Yield (t ha^{-1})	Leaf blotch (0-9)	Leaf rust (%)
816-70	1.7	7	80MS
751-70	1.5	7	15MS
602-70	1.8	7	80S
814-70	1.3	8	90S
433-70	1.6	8	60S
CI 9724	1.2	8	80S
WGA 44-4	1.2	8	100MS
WGA 68-1	1.3	8	80S
Local check	1.7	7	40S

Source: (8)

A hybridization program was started in 1974 to improve the yielding capacity of the local barleys. A set of 12 introduced cultivars were used for desirable characters such as stiff straw, yield potential and resistance to diseases. Sheno local was used for its tolerance to frost and water logging. About 100 crosses were made and selections were advanced using the pedigree method. Some 70 advanced lines were evaluated for yield, but most lines were found inferior to the local check. In the late 1980s evaluation of genotypes with emphasis on local material was continued. Four cultivars showed better yield than the local check under improved drainage and optimum fertilizer application (Table 7).

Table 7. Grain yield and maturity date of promising barley cultivars, Sheno, 1988.

Cultivar	Days to Mature	Yield (t ha^{-1})
HB-100	151	3.7-6.4
Kulumsa 1/88	134	5.4-7.2
Kulumsa 7/88	152	5.6-7.5
IBON 34/86	149	5.4-7.9
Local check	133	3.1-3.8

In the mid 1980s cultivar evaluation for short season (belg) production was started. The objective was to identify early varieties with resistance to moisture stress, aphids and powdery mildew. About 110 selections from landraces and crosses were tested at Sheno, Debre Berhan, Chacha, Aleltu and Keba. Most lines performed poorly because of moisture stress and aphids at booting stage. Cultivars White Sasa, Black Sasa, Rei, Sheno local, and ARDU 12-9C showed some tolerance to the conditions.

Gojam and Gonder regions

These regions are among the major barley growing zones of the country contributing about 23.6% of the national barley production (4). About 70 % of the total barley production is obtained in the main season using early and late maturing cultivars and the rest under residual moisture. The major farmers' varieties include Belga, Abat Gebs, Kinkina, Tikur Gebs and Semerita. Limitations for barley production include poor soil fertility, waterlogging, diseases (mainly scald, smuts, rusts and leaf blotches) and the low yield potential of local cultivars.

Barley improvement for these regions was started in the 1970s through the joint adaptive research program of IAR and the Ministry of Agriculture. Variety trials, including released and pipe-line varieties were tested at IAR/ADD sites. Most varieties were high yielding, but later maturing and less competitive with weeds than the local checks.

In the late 1980s about 100 accessions of local landraces from PGRC/E were evaluated in the main season and under residual moisture at Adet Research Center. The most promising 16 genotypes have been tested in a regional variety trial in 1990 and 1992 at Adet, Injibara and Debre Tabor.

At Adet only selection Kulumsa 1/88 with a mean grain yield of 4 t ha^{-1} was found superior to the local check. In a trial under residual moisture nine selections with grain yields of 1.4 to 1.8 t ha^{-1} were found superior to the local check at Adet.

Correlation studies on genotypes grown under residual moisture showed grain yield to be positively correlated with plant height, but negatively correlated with vegetative period and days to maturity.

Tigray region

Barley is an important food grain in Tigray after tef and wheat. Rainfall amount and distribution are critical factors in crop production in the region. The annual rainfall at Mekele is about 600 mm. The main rains which total about 400-500 mm come in late June or early July and end in mid-September (13).

The major problems for barley production are low moisture stress, low soil fertility and susceptibility of local barley cultivars to leaf diseases, such as leaf rust and spot blotch and insect pests, like aphids and barley fly. Farmers in the region have traditionally responded to these production problems through selection of early maturing varieties and soil-moisture conservation techniques such as terraces and stone barriers. The common farmers' varieties; Sasa, Rei and Burguda, give satisfactory yields under the existing production problems.

Barley improvement was started at Mekele Research Center in 1973. Over the years a large number of cultivars were evaluated as nurseries or yield trials in cooperation with international research centers such as ICARDA and CIMMYT and the FAO NE Regional Program. At the same time landraces collected from low-moisture areas and national variety trials were evaluated. In almost all the tests the local barley checks were found superior and more stable than other cultivars.

Arsi region

Barley is an important food grain in the Arsi region. It contributes about 15.8% of the national barley production (4). It occupies about 38% of the cereal production in the region (7). Over 90% of the total production is food barley. The rainy season is bimodal. Meher is the major growing season. Barley is grown in the mid and high altitude areas with an annual rainfall of 700–1,500 mm. Chilalo is the major barley producing zone in the region. In the late 1960s the major farmer's varieties were Workeye, Aruso, Netela, Senef Kolo, Nech Gebs, Muga, Sergegna, Tikur Gebs, Kessele, Gojame and Bahrseded. The yield of these varieties was about 0.8 t ha^{-1} under farmer's conditions (3).

The major problems in barley production are net blotch, scald, leaf rust, shootfly, frost, lodging, drainage, sprouting and shattering. Research on barley in the region was conducted by the Chilalo Agricultural Development Unit (CADU) since 1967. Previously variety trials were conducted at Kulumsa (Simba) by the Debre Zeit Agricultural Research Center in collaboration with the MoA. CADU conducted variety improvement from introductions and local collections at Bekoji, Asasa and Dhera representing high, middle and low altitude areas, respectively. CADU released Mari in 1971 (2). Other varieties were released for the region through the national program (Table 4).

Bale region

The Bale region contributes about 5% to the national barley production (4). A major feature of the region is its year to year variability of weather. Erratic rainfall and occurrence of extreme temperatures cause large fluctuations in crop production. The rainfall is bimodal, except in the Genale area. There are two cropping seasons, belg (March - July) and meher (July -December). The average rainfall is about 590 mm in the belg and 560 mm in the meher season. There is normally a short dry spell between the two seasons. About 70% of the total barley area is sown in meher and the rest in belg. The largest barley producing area, Genale, produces barley only during the meher season. However, in the Mendeyo, Gassera, Hora and Goro areas the two seasons share nearly equal proportion of the area for annual barley production. The productivity of barley is lower in the belg season than in the meher because of post-harvest losses. Aruso (2-rowed with a mixed seed color) is the most widely grown farmer's variety. Other landraces are Burtuji, Barseded, Felibeye, Muga, Kessele, Akellas and Senef kolo.

The major constraints to barley production are barley shoot fly, frost, moisture stress, low yield potential of landraces, net blotch, rust, smuts and scald. Research on food barley was started in the mid 1970s by the joint IAR/ADD program at Robe. At about the same time some variety trials were also conducted in cooperation with the Ministry of State Farms Development. Coordinated research was started with the establishment of Sinana Research Center in 1986. The center cooperated in the national variety trials program and also conducted region-specific experiments. A special effort is given to study the barley shoot fly (*Delia arambourgi*)

Adaptive Variety Trials

Adaptive trials were conducted in cooperation with MoA and other organizations. This activity was started in 1968 by IAR and the Extension Division of MoA. Some varieties were tested in observation plots at many locations, but results were not satisfactory. In 1975 EPID and IAR agreed to undertake joint adaptive variety trials in major crop producing zones of the country. Hawzen and Enda Selassie in Tigray, Dabat in Gonder, Robe in Bale, Degem in Shewa, and Bure and Amanuel in Gojam were selected for barley trials. Variety trials were conducted at these sites with the application of fertilizer at the rate of 41 kg N and 20 kg P_2O_5 ha^{-1}. The results of the 1975-76 trials showed that the local check was among the top yielders at these sites.

The joint program was weakened and discontinued from 1978 to 1980. It was revived in 1981 as the IAR/ADD joint program in more sites. IAR was responsible for technical matters such as design of experiments, evaluation and reporting of results. ADD was responsible for administering the routine field work and feed back of data. Food barley trials were tested at Dabat, Debre Tabor, Goha Tsion, Shashemene, Bure, Mota, Shambu and Robe. The trials were conducted without and with fertilizer (57 kg N and 26 kg P_2O_5 ha^{-1}) at all sites. The trials in the early 1980s confirmed the high yield potential of cultivar AHOR 880/61 at Bure, Debre Tabor and Goha Tsion under fertilized and unfertilized conditions (Table 8). The main disadvantage of tne variety was its longer maturity over farmers' varieties. The trials in the mid 1980s indicated that HB-42 and ARDU 12-60B were superior to local checks at Debre Tabor and Bure (Table 9).

Table 8. Grain yield of varieties grown at IAR/ADD sites, with (57 kg N and 26 kg P_2O_5 ha^{-1}, F1) and without (FO) fertilizer 1981-1983

Location	Variety	Yield(t ha^{-1})	
		FO	F1
Bure	Ahor 880/61	3.6(2x)[2]	3.1(1x)
	Local check	2.3	2.6
Debre Tabor	Ahor 880/61	2.7(1x)	3.2(2x)
	Local check	2.2(1x)	1.7(2x)
Goha Tsion	Ahor 880/61	3.7(1x)	3.5(2x)
	Local check	1.7	1.9
Mota	IAR/H/485	2.4	3.8(1x)
	Local check	1.9	2.6
Robe	Ahor 880/61	1.3	3.5(1x)
	Local check	1.3	2.2
Shambu	Ahor 880/61	4.3	4.6(2x)
	Local check	2.4	3.6
Mean		2.5	3.0

Figures in parenthesis = Number of seasons the cultivar yielded higher than the local check (P=0.05).

Table 9. Grain yield of varieties grown at IAR/ADD sites in 1984-86

Location	Cultivar	Yield(t ha^{-1})	
		F0	F1
Debre Tabor	HB-42	4.2	4.4
	Ahor 880/61	3.4	4.1
	Local check	2.4	2.4
Bure	ARDU 12-60B	3.6	4.4
	Ahor 880/61	1.6	4.4
	Local check	2.6	3.5

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Malting Barley Breeding

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Abstract

Research on malting barley was started with introduced malting barley varieties. Between 1964 and 1985 over 900 exotic varieties were evaluated for adaptation, disease resistance and other agronomic characters. Between 1964 and 1971 many exotic varieties were tested out of which three out-standing malt barley varieties; Beka, Proctor and Kenya Research were identified and recommended for production. Varieties Holkr and Balkr were identified from the hybridization program between 1975 and 1978. None of the local germplasm showed the required malting quality from the early research work.

Research on malting barley was started in the early 1960s at the Debre Zeit Agricultural Experiment Station of the Alemaya College of Agriculture. After IAR was established the program was transferred to Holetta Research Center in 1968. The Malting Barley National Yield Trial was organized in cooperation with the Debre Zeit Experimental Station and CADU. Later more locations were included. Results of the breeding program are reviewed in this paper.

RESEARCH ACTIVITIES

Evaluation of introductions

Between 1964 and 1992 about 900 introduced malting barley varieties were evaluated. Of the total introductions tested about 10% were from USA, 10% through FAO, 17% from Kenya, and the remaining 63% from several European countries. The lines were evaluated for general adaptation, disease resistance and other desirable agronomic characters. Some of the adapted varieties were also tested at Bedi in 1973 and 1974 in low soil pH and poor soil fertility condition, but none of these varieties performed better than the local check.

Evaluation of local germplasm

CADU compared in 1968 four introduced varieties with commonly cultivated varieties in Chilalo. The introduced varieties were not superior to the local two-row variety Aruso. Aruso and the introduced varieties Union and Beka were better than the local six-row cultivars, Muga, Black barley and White barley (Table 1).

Table 1. Mean grain yield disease and other agronomic character of barley varieties compared Chilalo.

Variety	Days to heading	Scald (0-5)	Leaf rust (%)	TKW (g)	H.W (kg hl^{-1})	Yield (q ha^{-1})
Aruso (L)	64	2	30	36.5	65.6	22
Union (I)	83	trace	25	32.9	64.4	22
Beka (I)	87	3	40	31.8	71.4	21
Zephyr (I)	87	2	10	28.5	70.2	16
Birgitta (I)	87	4	25	31.0	69.2	15
Muga (L)	86	1	40	36.4	64.8	12
Black barley (L)	83	trace	50	34.2	67.6	11
White barley (L)	86	-	85	33.6	65.4	9

I - Introduced, L - Local

Source:CADU results of trials and observations of 1968/69.
CADU publication No. 28, 1969.

Between 1970 and 1974 about 1300 single plant selections from 41 local landrace populations were evaluated for malting, high tillering capacity, good grain set and disease resistance. Seven promising selections were retained and promoted to the NYT. None of the local germplasm showed desirable malting quality.

Hybridization and selection

The hybridization program between 1968 and 1974 focused at improving disease resistance of exotic malting barley varieties. The varieties used for back-crossing were Zephyr, Kenya Research, Proctor and Beka. Since 1974 the program was expanded and other factors such as yield, lodging resistance, resistance to low pH (for Bedi plateau) and waterlogging (for Sheno) were considered.

All crosses involving Zephyr and Proctor performed poorly. Therefore, both parents were excluded from the program and replaced by Holkr and Balkr. The remaining three varieties have been used as recurrent parents for a long time. Selections from the hybridization program, promising introduced cultivars and landraces have been used as non-recurrent parents. In addition to back-crosses, single, three-way and double crosses have also been made (Table 2).

Initial crosses have been made at Holetta and selections (F2 to F8) were made for similar agro-ecologies. For Bedi and Sheno selections from F2 to

F8 have been done at the respective sites.

Currently, the malting barley NYT is entirely dependent on materials generated from this activity. So far several outstanding malting barley varieties have been recommended for release.

Table 2. Malting barley crosses made at Holetta between 1968 and 1992

Year	Cross no.	No. of crosses
1968-70	EH 1 - EH 32	48
1974	EH 96 - EH 158	72
1975	EH 159 - EH 229	71
1976	EH 258 - EH 275	29
1977	EH 276 - EH 303	32
1978	EH 524 - EH 543	32
1979	EH 548 - EH 547	7
1980	EH 647 - EH 708	12
1982	EH 709 - EH 763	55
1985	EH 923 - EH 937	15
1986	EH 1054 - EH 1070	17
1992	EH 1088 - EH 1097	10

Sources: IAR, Holetta Guenet progress reports, 1968-1976, IAR, Dept. of field crops progress reports 1977-1981 and IAR, Barley team progress reports 1982-1992

EH - Ethiopian Hordeum

Note: All crosses made between 1976 and 1978 were for Bedi and some crosses made in 1978 were for Sheno.

National Variety Trial

Since 1968 more than 100 improved varieties of malting barley have been assessed in 26 tests for wide adaptation, yield stability and disease resistance. A standard variety was assigned for each test.

During 1968 to 1971 several varieties from introductions were tested. Some of the outstanding varieties that showed good malting potential at a number of locations are presented in Table 3.

The trial results showed that the best malting barley variety for Holetta red soil was Kenya Research. For Chilalo highlands variety Beka was the best followed by Proctor.

The best malting qualities were observed at Holetta red soil (1.58 to 1.78% N), Holetta black soil (1.33 to 1.48% N) and Sheno (1.38 to 1.62 N% DM basis)

Table 3. Grain yield (q ha⁻¹) of 6 malting barley varieties tested between 1968 and 1971

Variety	Alemaya (2075 m)	Asela (2350 m)	Holetta (2400 m)	Sagure (2350 m)	Bekoji (2650 m)	Sheno (2800 m)	Holetta Black soil	Mean
Beka	30	40	22	49	28	13	17	28
Firlbeko III	28	36	26	54	28	13	14	28
Kenya Res.	20	37	29	41	32	14	14	27
Proctor	23	39	26	43	28	12	12	26
Pallas	29	38	24	45	31	14	13	28
Zephyr	26	34	24	46	31	12	12	27
Mean	26	37	25	46	30	13	14	27

Source : IAR, Holetta Guenet progress report 1971/1972

In 1972 and 1973 National Variety Trials (NYTs) with seven selections from landraces were tested at Holetta, Bekoji, Sheno, Alemaya, Asasa and Bedi, Suba and Azezo. Firlbecks III was included as standard check. Grain yields were high at Holetta, Bekoji, Sheno, Alemaya and Asela, but very poor at other locations (Table 4). Grain quality as well as other agronomic characters of landraces were not acceptable for malting purposes.

Table 4. Mean yield (q ha⁻¹) of barley varieties of local origin tested in 1972 and 1973

Variety	Holetta	Bekoji	Sheno	Alemaya	Asela	Suba	Azezo	Bedi	Mean
PI 11742	25	47	22	33	35	15	12	6	24
PI 9751	29	49	22	23	32	21	14	14	26
PI 12562	26	49	21	22	31	14	12	12	23
IAR/H/408	27	47	22	21	29	23	12	13	24
IAR/H/481	27	34	19	25	9	11	11	7	18
Firlbecks III	21	41	18	38	29	8	11	6	22
Mean	26	45	21	27	28	15	12	10	23

Source: IAR, Holetta Guenet progress report 1972-73

In the 1973 NYT, 15 six-row malting barley varieties were tested with Firlbecks III and Kenya Research as checks. The trial was tested at Holetta, Alemaya, Sheno, Bekoji, Suba and Azezo. Grain yields were high at Alemaya and Bekoji but very low in other locations. (Table 5)

Between 1975 and 1978 eight malting barley varieties were tested in the NYT program at Holetta, Bekoji, Sheno, Sagure, Degem, Arsi Negle, Alemaya and Bure. Four selections were superior to Beka, the standard check, at most locations (Table 6). Three of the four selections also showed superiority over Beka in malting quality.

Table 5. Yield (q ha^{-1}) of 6-row malting barley varieties, 1973.

Variety	Alemaya	Bekoji	Holetta	Sheno	Suba	Azezo	Mean
Atlas kindred[2]	44	36	21	5	13	13	22
Composite 21	35	47	18	5	8	8	20
Composite 29	55	71	27	13	25	11	34
Firlbecks III	33	44	15	8	13	10	20
Kenya Research	34	43	15	7	16	12	21
Larker A	43	16	14	3	8	6	15
124 Testigo	39	19	8	9	6	11	15
P.I.12100	54	47	20	15	8	6	25
II 8790.5t...	42	26	21	11	12	8	20
II 10945-9b...	40	23	23	11	16	8	20
II 11268.1b...	33	22	18	10	11	7	17
II 11571.3b.1t	41	22	22	13	12	11	20
II 11361.1t.2t	40	39	19	13	9	11	22
II 11361.3t.	38	31	18	7	10	13	20
II 11364.1b...	51	33	22	8	16	12	24
II 16441.17b...	39	31	16	14	10	13	21
II 16443.5b...	33	21	14	5	10	11	16
Mean	41	34	18	9	12	10	21

Source: IAR, Holetta Guenet progress report of 1973/74

Table 6. Performance of malting barley varieties from the MB/NYT program tested between 1975 and 1978 at several locations.

Variety	Days to mature	Height (cm)	Scald (0-9)	Leaf blotch (0-9)	Leaf rust (%)	TKW (g)	Grain (N% DM)	Grain plumpness (2.8 mm sieve)	Yield (q ha^{-1})
EH 8B/F4.E.L.6.L	140	96	5	5	10MS	42.8	1.51	98.0	31
EH 8B/F4.E.L.7.L	139	95	6	6	20S	41.1	1.48	96.1	31
EH 8B/F4.E.L.1.L	139	97	6	5	20S	44.3	1.46	97.6	29
Beka	141	86	8	5	20S	33.6	1.51	82.2	25
Mean	140	96	6	5	-	40.5	1.49	93.5	29

Source: IAR, Department of field crops progress report 1978/79

NB: Values for maturity, plant height, diseases and TKW were averages of Holetta, Bekoji, Sheno and Segure. Leaf rust from Ambo for one season. Grain plumpness from Holetta. % N values were averages from Holetta and Shena. Grain yields were averages from Holetta, Bekoji, Shana, Segure and Degem.

Between 1978 and 1980 thirteen malting barley varieties, including the standard check Beka were tested in NYT at Holetta, Bekoji, Asasa, Dixis and Sheno. Most varieties were significantly superior to Beka. At Asasa and Dixis, HB-16 was significantly superior to Beka. Grain yields at the other locations were very poor. Three of the varieties had satisfactory grain physical qualities for malting. The grain samples from Holetta, Bekoji and Asasa showed that two gave acceptable malting qualities (Table 7).

Table 7. Some characters for three malting barley varieties

Variety	Scald[1] (0-9)	TKW[2] (g)	Grain N DM	Yield (q ha^{-1})
HB-16	5.6	35.3	1.46	37.0
HB-28	4.7	37.2	1.44	36.5
Beka	8.0	31.1	1.53	27.5

Source: IAR, Barley research team progress report, 1982/83

1-2 - means from Holetta and Sheno

3-4 - mean from Holetta and Bekoji

Between 1981 and 1992 four malting barley NYTs were conducted at Holetta, Sheno, Bekoji, Asasa, Sinana, Adet, Sirinka, Ambo SPL, Arsi Negele, Garadella, Goffer and Lole. In these trials 28 lines including Beka were tested. All lines were selection from local crosses. A number of lines were significantly better than Beka at most locations in terms of grain yield, disease resistance and grain qualities. The varieties that showed good results during the testing years were HB-52, HB-68, a selection from Beka and HB-120.

Adaptive Trials

Observation trials

In 1971/72 nine malting barley varieties were grown in small observation plots through the Extension Project Implementation Department (EPID) of MOA at several locations (Table 8).

Table 8. Yields (q ha $^{-1}$) of malting barley varieties tested in adaptation plots at 5 locations in 1971/72 season

Variety	Chancho	Dillela	Sendafa	Addis Alem	Lumame	Mean
Aurore	8	13	8	20	33	16
BB/2/1 sel.B	12	15	11	11	33	16
Beka	7	22	6	18	29	16
Firlbecks III	7	22	15	15	29	18
Kenya research	9	25	13	17	13	15
Pallas	7	23	13	17	13	15
Proctor	8	19	14	16	29	17
Union	4	20	15	15	16	14
Zephyr	11	16	11	9	11	12
Mean	8	19	11	15	23	16

Source: IAR, Holetta Guenet progress report of 1971/72

Yield trials

In the mid-1970s several malting barleys were tested at nine locations, however, yield data were only obtained from four locations (Table 9).

Ten food and malting barleys were tested between 1980 and 1983 with and without fertilizer at Bure, Mota, Debre Tabor, Goha Tsion, Robe in Bale and Shambu. Yield of the three malting barley varieties under two fertility conditions is shown in Table 10.

Table 9. Grain yield (q ha $^{-1}$) of malting barley varieties tested in a special yield trial at IAR/EPID sites in 1975/76.

Variety	Dabat (2575m)	Robe (2450m)	Bure (2100m)	Hawzen (2380m)	Mean
Kenya Research	23	36	31	13	26
Beka	21	21	28	7	19
Proctor	16	30	24	6	19
Mean	20	29	28	9	21

Source: IAR, Holetta Guenet progress report of 1975/76

MALTING QUALITY

Since 1982 more than 2500 samples of malting barley have been tested for protein content, moisture percent, germination energy and kernel weight at the Holetta quality laboratory. This analysis suggested that:

- germination was very good (above 96%),
- moisture content was around 10%,
- thousand kernel weight was good (above 35 g)
- protein content was good (8.5 -12%).

In 1988 protein content of the varieties was high at most locations except at Sheno (Table 11). Varieties in Table 12 showed acceptable protein content all the time. In 1984 a variety trial with four improved malting varieties was conducted at 4 state farms, where protein percentages was found very high at Garadella and Herero (Table 13). A satisfactory protein content was obtained from Lole only.

Table 10. Mean grain yield (q ha^{-1}) of malting barley varieties tested with (F1) and without fertilizer (FO) at IAR/ADD sites, 1980-83

Locations	Variety	FO	F1
Bure	Beka	21	24
	Proctor	14	16
	Holkr	27	28
	Mean	21	23
Debre Tabor	Beka	9	12
	Proctor	7	13
	Holkr	28	26
	Mean	28	30
Mota	Beka	19	32
	Proctor	15	32
	Holkr	22	32
	Mean	19	32
Robe	Beka	19	37
	Proctor	11	32
	Holkr	15	24
	Mean	15	31
Shambu	Beka	17	27
	Proctor	12	25
	Holkr	27	35
	Mean	19	29

NB: Fertilizer: 41/46 (N/P_2O_5) kg ha^{-1}
Source: Barley Team Progress report, IAR 1987

Table 11. Protein content (%) of malting barley lines.

Variety	HRC 1987	HRC 1988	HRC 1989	HRC 1990	Asasa 1988	Lole 1988	Bekoji 1988	Sheno 1988	Sheno 1989	Sheno 1990	Adet 1989	Adet 1990
HB-120	10.9	13.2	7.8	8.6	18.2	16.7	14.5	9.9	13.4	9.6	8.9	9.2
HB-122	12.3	13.5	7.7	8.2	18.1	14.8	14.7	10.3	13.1	9.0	9.3	9.1
HB-123	10.4	12.5	7.1	8.1	17.1	15.8	13.9	9.8	12.0	9.5	8.9	8.1
HB-127	10.7	13.3	7.6	8.4	17.8	15.8	15.4	8.8	12.7	8.4	10.4	7.9
HB-128	11.8	14.4	7.8	8.4	16.1	16.1	14.7	10.2	13.7	9.0	9.5	8.4
HB-129	12.8	14.7	7.7	8.7	19.3	16.9	16.0	9.3	13.	19.7	9.4	8.4
KLDN 209/85	-	11.9	7.4	8.5	16.7	15.4	13.3	8.6	13.6	8.4	9.4	8.2
Beka	11.1	14.9	8.5	9.7	18.8	17.0	17.8	10.1	14.6	10.2	10.0	9.6
Local check	12.9	17.0	9.5	10.7	-	-	-	10.1	12.8	9.4	14.6	12.3
Mean	11.6	13.9	7.9	8.8	17.8	16.0	15.0	9.8	13.2	9.2	10.0	9.2

Table 12. Protein content (%) of malting barley lines.

Variety	Sheno 1990	Sheno 1992	HRC 1990	HRC 1991	HRC 1992
EH 738/F2-3H	8.8	8.8	10.4	10.7	102
EH 738/F2-6H	10.9	8.2	12.4	10.7	107
EH 738/F2-9H	10.4	9.5	9.7	10.8	113
EH 738/F2-12H	10.1	8.6	10.9	10.9	113
Local check	9.2	8.8	12.8	11.4	127
EH 763/F2-1H	9.9	8.5	11.3	11.2	104
EH 763/F2-4H	10.2	9.2	10.3	11.3	109
EH 763/F2-11H	10.1	9.5	11.6	11.4	107
EH 728/F2-3H	11.6	9.6	12.3	12.1	121
EH 740/F2-2H	10.2	9.4	10.4	10.1	118
Beka	10.1	9.2	10.8	10.8	115
Mean	10.1	9.0	11.1	11.0	112

Table 13. Protein content (%) of four malting barley varieties tested in MB/NVT conducted in 1984 at three state farms

Variety	Herero	Lole	Garadella
Holkr	19.9	11.6	18.9
Proctor	15.3	13.8	16.2
Beka	15.6	9.7	17.9
Balkr	17.6	9.8	18.4
Mean	17.1	11.3	17.9

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Importance of Specific Adaptation in Breeding for Marginal Conditions

S. Ceccarelli and S. Grando

Abstract

The paper discusses evidence showing that the use of breeding principles developed for and successfully applied in favorable environments may be the main reason for the lack of breeding progress in marginal environments. Very little breeding work has been done in marginal environments, although the theory of correlated responses to selection suggests that selection conducted in good environments or in well-managed experiment stations is not expected to be very efficient when genotype by environment interactions of a cross-over type exist. The assumptions that heritability is higher under good conditions and that there is a carry-over effect of high yield potential are not supported by experimental evidence. If the target environment is below the cross-over point, selection has to be conducted for specific adaptation to that environment. The concept of wide adaptation is more geographical than environmental and it reduces genetic diversity and increases genetic vulnerability Eventually the issue of genetic heterogeneity versus genetic uniformity is discussed in relation to specific adaptation to marginal environments.

The objective of this paper is to discuss three issues related to breeding for marginal conditions, namely the effect of genotype by environment (G x E) interaction on the choice of selection environment, specific versus wide adaptation and genetic uniformity versus genetic diversity. In more general terms, the paper addresses if breeding philosophies, methodologies and strategies developed for favorable environments are useful in marginal environments.

Most of the data are from one type of marginal environment and from one crop, barley. The environment is continental-mediterranean, where winter cereals and barley in particular are grown without irrigation. The features of this environment are low annual rainfall, erratic rainfall distribution and low winter temperatures. High temperatures and hot winds during grain filling are also important abiotic stresses. The frequency, timing, intensity and duration of each of these stresses, as well as their specific combinations vary from year to year. However, low yields are common, crop failures occur once or twice in five years and yields above 2.5 t ha^{-1} are very rare (Fig. 1). Low yields in these environments are highly predictable, while the causes are not. Therefore, the environment has typical characteristics (variable, unpredictable and low yielding) which are often indicated as "impossible" for breeding work.

Barley is a useful crop for discussions of general issues related to breeding for marginal conditions because in many developing countries it is a typical crop of marginal, low-input, stressful environments (Ceccarelli 1984). In these environments barley yields more than wheat and is often the only possible rainfed crop.

Yield stability, perceived by farmers as minimization of crop failures, is the most important socio-economic breeding objective in such marginal environments. This also applies to Ethiopia where barley is an important source of food.

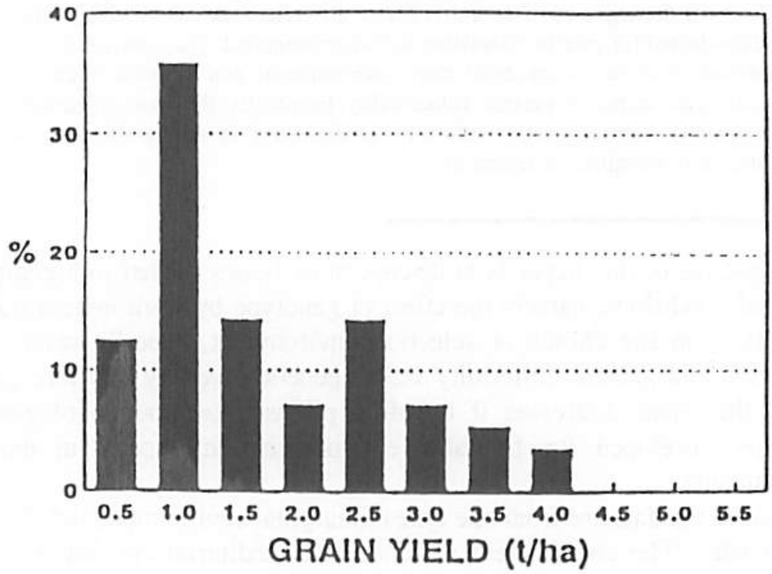


Fig. 1. Frequency distribution of barley yields in dry areas of Syria (less than 250-300 mm annual rainfall) between 1983 and 1993

WHY BREEDING FOR MARGINAL CONDITIONS?

Results obtained with fertilizer applications (Table 1) or with irrigation (Table 2) are spectacular and yield increases are greater than the most optimistic breeding expectations. They are so spectacular and have been well known for a long time that one wonders why they have not been adopted on a much wider scale and why crop yields are still commonly reduced because of low use of fertilizer and/or by drought.

In case of fertilizer, there are basically three reasons why this obviously beneficial agronomic practice has a low adoption rate in marginal environments: cost, availability and risk. Farmers are reluctant to use fertilizer in marginal environments because they cannot afford its cost, or because the fertilizer is allocated to better environments or more profitable crops. They know that in very dry years there will be no crop, irrespective of fertilizer applications and that they will loose the additional investment made on fertilizer.

In case of irrigation the water used in many dry areas is often a non-renewable resource. The depth of the water table at ICARDA's main experiment station, located near Tel Hadya, 30 km south of Aleppo, in northern Syria, has fallen more than 10 m during the last 10 years as a consequence of dramatic increase in the use of supplementary irrigation by farmers around the station. In addition, irrigation brings problems of salinization. The accumulation of salts in agricultural soils is a problem that has plagued civilizations for thousands of years. Therefore, irrigation can only be a partial solution to drought (Boyer 1982). The conclusions are inescapable: water and nutrient resources are often limited, and economic and environmental problems are likely to restrain their use.

BREEDING FOR MARGINAL CONDITIONS

Breeding has been very successful in environments that are either naturally favorable or can be made profitable by adding irrigation and fertilizer, and by chemical control of weeds, pests and diseases. The annual genetic gain in bread wheat in the U.S. from 1919 to 1987 has been 16 kg ha^{-1} yr^{-1} (Cox *et al.* 1988) and in the U.K. between 1908 and 1985 38 kg ha^{-1} yr^{-1} (Austin *et al.* 1989). The genetic gain in maize hybrids released between 1930 and 1980 was 54.2% (Russel 1984).

By contrast, yield improvements have been very elusive in marginal environments, to the point that the role of breeding for those environments is often questioned. What it is not questioned is why it has not been possible to improve agricultural production by simply transferring into marginal environments cultivars and/or methodologies which have made breeding for favorable conditions so successful. The obvious hypothesis is that these cultivars, although often defined as "widely adapted," are specifically adapted to conditions which are at or near the optimum for crop growth. Therefore, the superiority they have in these environments is not expressed in sub-optimal environments.

This brings up one of the major topics in discussing breeding strategies, namely G x E interaction, the importance of selection environment and of specific adaptation.

GENOTYPE BY ENVIRONMENT INTERACTION, SELECTION ENVIRONMENT AND SPECIFIC ADAPTATION

Theory

The theory dealing with the relationship between selection environment and performance has been mainly developed by Falconer (1981) as a case of indirect selection. Selection is indirect when the breeder aims to improve a primary character by selecting for a secondary character. The justification for indirect selection is a higher heritability of the secondary character compared to the primary character. As pointed out by Falconer (1981), measures of the same character in two different environments should be regarded as two different characters.

If X is a marginal environment and A an hypothetical trait, selection can be made in the same environment aiming at a direct response to selection (R_X), or select for A in a more favorable environment (Y) aiming at a correlated response to selection in X (CR_X). The efficiency of indirect selection in Y versus direct selection in X is given by:

$$CR_X/R_X = r_G\ h_Y\ /h_X$$

where r_G is the genetic correlation coefficient between A_X and A_Y, h_Y and h_X are the square roots of heritabilities of A in the two environments (Falconer 1981).

When $h_Y = h_X$, the maximum value of CR_X/R_X is 1 when $r_G = 1$. Therefore, when heritabilities are the same, direct selection will always be more effective because the genetic correlation coefficient will always be less than one. The argument commonly used in favor of selecting in good environments is that heritabilities are higher in favorable environments than in poor environments (Blum 1988). With low genetic correlation coefficients (0.1 - 0.2), h_Y must be at least 5 to 10 times higher than h_X for CR_X to be greater than R_X. Therefore, heritability alone is not sufficient to determine the optimum selection environment. Moreover, when r_G is negative the magnitudes of h_Y and h_X are irrelevant.

With specific reference to selection in stress and non-stress environments, Rosielle and Hamblin (1981) showed that selection for tolerance to stress will reduce yields in non-stress environments and also reduce the average yield in stress and non-stress environments. By using numerical simulation Simmonds (1991), concluded that selection for low yielding environments must be conducted in low yielding environments, using selection environments with intermediate yield levels is ineffective and alternating selection cycles in low and high yielding environments (shuttle breeding) is also ineffective, a conclusion reached earlier by Patel *et al.* (1987). Similarly, Smith *et al.* (1990) concluded that selection under low input conditions is essential if significant yield gains for such conditions are to be achieved.

Therefore, theory is very much straightforward: response to selection is maximized when selection is conducted in the environment where future varieties will be grown. The theory also predicts that the environment of selection affects the pattern of response of genotypes to varying environments (Jinks and Connolly 1973, 1975).

Experimental evidence: Selection environment and performance

Experimental evidence in barley comes from different sources. Comparison of the lowest yielding (LYE) and highest yielding (HYE) sites, i.e., the average yield of all lines, yield of the best 5% of the lines selected in low yielding sites (G_{LY}) and yield of the best 5% of the lines selected in high yielding (G_{HY}) sites are presented in Table 3. The average yield of the HYE sites (4.14 t ha^{-1}) was almost four times that of the LYE sites (1.07 t ha^{-1}).

In LYE sites lines with the highest yields in high yielding conditions had yields similar to the population mean and, on average, yielded 39% less than the lines which had been selected as high yielding in stress conditions. In HYE sites the situation was reversed. High yielding lines under stress conditions had similar yields to the population mean and, on average, were 24% lower yielding than lines selected as high yielding in non-stress environments. The trade-off between high yield potential in favorable conditions and high yield in marginal conditions is still present when genotypes with identical flowering dates and similar early leaf area growth are compared (Hamblin 1992). Therefore, indirect selection in the absence of stress to improve yield in the presence of stress will be less effective than direct selection in the presence of stress.

The choice of the selection environment affects the introduction of germplasm for a breeding program. In marginal environments, local barley landraces outyield non-landrace material (Table 4). However, in high yielding environments the reverse is true. The data suggest that repeated cycles of selection in a given environment will reduce the frequency of lines specifically adapted to other environments.

Tables 3 and 4 indicate that correlated selection differentials in low yielding conditions for selections made in high yielding conditions are either negative or low. However, if the genetic correlation coefficient is known these differentials are only useful in predicting correlated responses to selection (Falconer 1981). Estimates of genetic correlation coefficients between grain yield measured in low and high yielding sites were obtained from 58 pairs of yield trials in four cropping seasons (Ceccarelli *et al.* 1992). Among the 58 estimates of r_G, 27 were negative (Table 5). Of the 31 positive values, only 8 were greater than 0.4 and 6 of those were associated with low average yields ranging between 1812 and 3180 kg ha^{-1} in the highest yielding sites. These yields are at or around the value where, in barley, a cross-over between genotypes with specific adaptation to different environments often occurs (Fig. 2). In only one case was a positive r_G associated with heritability estimates in the two environments, such that the CR_X/R_X ratio was greater than 1. In this case the pair of trials had the smallest difference between LYE (618 kg ha^{-1}) and HYE (1812 kg ha^{-1}) environments among all comparisons. Both these values are below the cross-over point.

When the values of genetic correlation coefficients are considered in relation to yield levels of the two environments used, it seems that high grain yield in high-yielding conditions and high grain yield in low-yielding conditions are under the control of different sets of alleles at most of the several loci that presumably control grain yield. This is in agreement with the few estimates of genetic correlation coefficients available in literature (Atlin and Frey 1989, 1990; Ud-Din *et al.* 1992).

Experimental evidence: Selection environment and stability

Jinks and Connolly (1973, 1975) showed in *Schizophyllum commune* that environmental sensitivity was reduced if selection and environment effects were in opposite directions; sensitivity was increased if selection and environment effects were in the same direction. Recently Falconer (1990) reviewed published experiments to see if they agreed with the expectations based on the Jinks-Connolly model. He concluded that exceptions to expectation are possible where large differences in additive genetic variances in both low and high environments were coupled with a high genetic correlation.

Although the possibility of predicting or influencing environmental sensitivity is of great interest to plant breeding programs, surprisingly little data (Jinks and Pooni 1982; Crossa *et al.* 1989) are available on crop plants which can be used to validate the Jinks and Connolly model. Ceccarelli and Grando (1991a) compared the stability across environments with the highest grain yield under low yielding conditions and the 10 genotypes with the highest grain yield under high yielding conditions. The comparison was repeated twice, using two independent groups of 332 and 234 genotypes, respectively. Genotypes stability within each group was evaluated by linear regression analysis (Finlay and Wilkinson 1963) and by the descriptive method of Francis and Kannenberg (1978) based on the relationship between mean and coefficient of variation.

The regression analysis produced a typical cross-over type of G x E interaction. In both groups the genotypes selected in poor conditions had a significantly lower slope and a lower coefficient of variation than the genotypes selected in good conditions (Table 6). There were no differences between the selection groups when the environmental means were near the cross-over point. This suggests that sites with intermediate levels of stress are unlikely to be useful for selection. Therefore, experimental evidence agrees with theory and indicates that the choice of selection environments affects both performance of genotypes in specific environments and response of genotypes to changing environments.

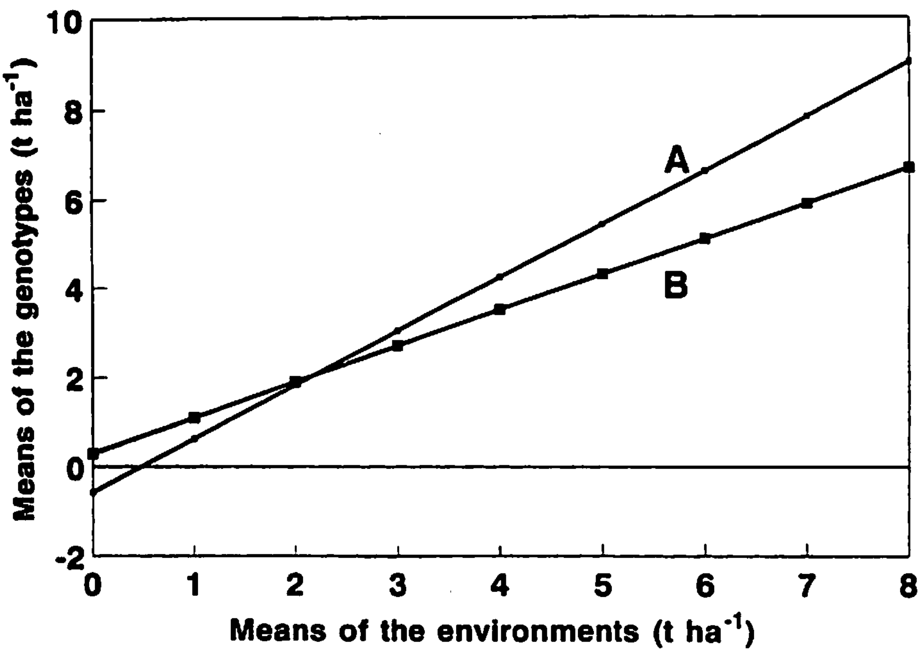


Fig. 2. Cross-over type of G x E interaction: A and B are typical genotypes selected in high and low yielding environments, respectively

Genotype by environment interaction of cross-over type

In general, when different genotypes of a given crop are evaluated in a sufficiently wide range of environments, a cross-over type of G x E interaction is very common (Fig. 2).

There are four points to make about Fig. 2. Firstly, the definition of "stress" environments plays a key role in determining breeding strategy. If "stress environments" defined as those with an average yield above the cross--over point, then line A is "widely adapted" to all environments. However, if "stress environments" defined as having an average yield below the cross-over point, the "wide adaptation" of line A has a lower limit at the cross-over point.

The second point relates to the type of comparison made in the regression analysis. The regression of a typical line A selected in optimum environments is often compared either with the average of all lines in the experiment or against a local check. Very seldom line A is compared with lines selected in stress environments below the cross-over point such as line B. This is because it is assumed that high yielding environments allow the greatest expression of yield potential. One must ask why we need yield potential when we breed for environments such as those illustrated in Figure 3, where the frequency of years with yield levels above 3 t ha^{-1} is less than 5%.

The third point is that the presence of a cross-over G x E interaction has often been neglected by either testing breeding material developed for favorable environments in foreign countries or by conducting selection and testing only above the cross-over point and particularly in well managed experiment stations. Figure 3 shows that conditions in which selection is conducted in experiment stations could be above the hypothetical cross-over point in relation to farmers' conditions. When testing is conducted in many locations and selection is made for high average yield across locations, this is equivalent to selection for high regression coefficients (Simmonds 1991). Even shuttle breeding can miss the presence of a cross-over G x E interaction if both environments are above the cross-over point. As the yields of many poor farmers are below the cross-over point, the chances of their being supplied with improved and stable germplasm is low.

The fourth point is that the existence of a cross-over G x E interaction has been allegedly disproved by the release of varieties for low yielding environments. This argument neglects the fact that many of these varieties have never been adopted by farmers or have been adopted in a different environment.

Hildebrand (1990) and Stroup *et al.* (1993) have presented similar concept by discussing negative and positive interpretation of G x E interaction. The negative interpretation of G x E interaction implies that, in the presence of cultivars with the same overall mean yield and the same deviations from regression, the cultivar with b ≅ 1 is selected because it is more widely adapted according to Finlay and Wilkinson (1963). Cultivars with b > 1 are discarded because they perform poorly in poor environment and cultivars with b < 1 are discarded because they are unable to exploit high-yielding environments. In practice, since most of the selection work is traditionally conducted either in favorable environments or under well managed conditions of experiment stations (Simmonds and Talbot 1992), cultivars with b ≥ 1 are frequently selected on the assumption that their high yield potential will have a carry-over effect in marginal environments. The positive interpretation recognizes the importance of specific adaptation and leads to selecting cultivars with b > 1 for good environments and of cultivars with b < 1 for poor environments.

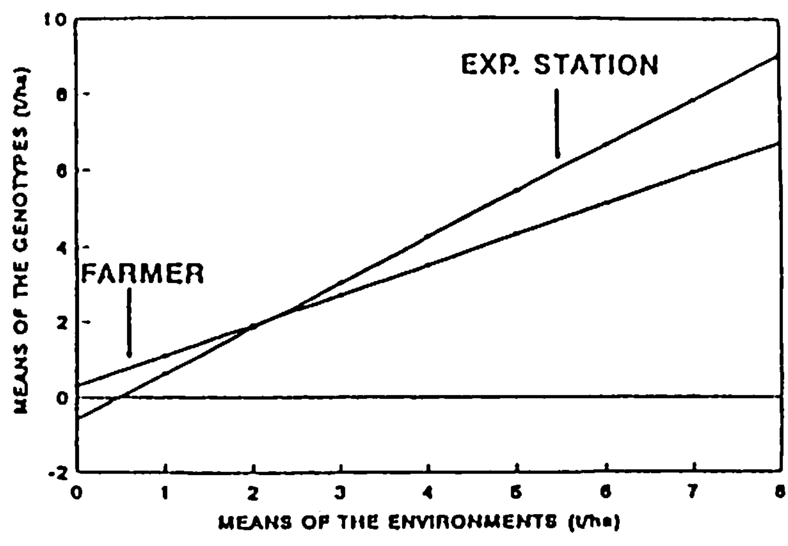


Fig. 3. Hypothetical G x E interaction of cross–over type between experiment stations and farmers fields

Heritability in Low Yielding Environments

The most common justification for conducting selection in optimum environments, regardless of the nature of the target environment, is the lower heritability found in low yielding environments. The theory of correlated responses to selection shows that not only heritability, but also the genetic correlation coefficient has to be considered before deciding the optimum environment for selection. However, even if heritability considered alone, the experimental evidence that heritability in low yielding conditions is lower than in high yielding conditions is far from unanimous (Table 7). Of particular interest are the data of Pederson and Rathjen (1981) (Table 8), which suggest a high degree of independence between yield levels and magnitude of heritability (r = - .034). Singh and Ceccarelli (1993) also suggested no relationship between yield level and magnitude of heritability in barley. Therefore, the conclusion that heritability in low yielding environments is lower than in high yielding environments is not supported by experimental evidence. The magnitude of heritability is affected by the type of genetic material. It is suspected that the genetic material used in those studies where heritability in low yielding environments was lower than in high yielding environments was selected in high yielding environments and then tested in low yielding environments. If G x E interaction of cross-over type exists, it implies a low average adaptation of this material to low yielding conditions, hence low heritability.

Wide Adaptation

Many national and international breeding programs consider wide adaptation as a primary objective in a breeding program. Most of the evidence on wide adaptation comes from wheat and rice breeding where the use of dwarfing and photoperiod-insensitivity genes allowed the spread of the same genotype over a wide geographical area. The hypothesis underlying wide adaptation is that high yield potential is an advantage even in marginal conditions when adaptation barriers such as photoperiod sensitivity are removed.

An example of wide adaptation is shown in Table 9 (Rajaram *et al.* 1984). The comparison of advanced bread wheat lines tested under well-watered (5 irrigations) and stressed (2 irrigations) conditions shows that "there are lines, such as Genaro 81 and Lira 'S' suitable for both regimes" and, therefore, widely adapted. The stress environment, in this example, is an environment with average yield of about 4.5 t ha^{-1}, and, therefore, these data agree with Figure 2. The adaptation of these lines is wide only in an environmental range above 4.5 t ha^{-1}.

Another example of widely adapted genotypes illustrates one of the points made earlier. Based on the data of Figure 4 (Osmanzai *et al.* 1987) Veery 'S' is classified as an input-efficient and input-responsive cultivar with high yield potential and superior yield performance over the entire range of environments, including moisture stress conditions. What the data suggest is only that the performance of Veery 'S' is better than the mean of all genotypes. The critical comparisons with the top yielding cultivars in moisture stress environments and with the top yielding cultivars in high yielding environments are in fact missing. The importance of these comparisons is shown in Table 10. Within two groups of breeding lines those selected with the same selection pressure lines specifically adapted to low- or high-yielding conditions (top lines in LYE or HYE) as well as those performing well in both (widely adapted). The widely adapted lines yielded more than the best check in very contrasting environments. However, they have a yield disadvantage of 10-30% when compared with lines selected for specific adaptation. This yield disadvantage is the cost of wide adaptation.

These examples, as well as those presented earlier, suggest that most of the controversy on wide versus specific adaptation and related breeding strategies is due to definitions of stress environments which are often very different.

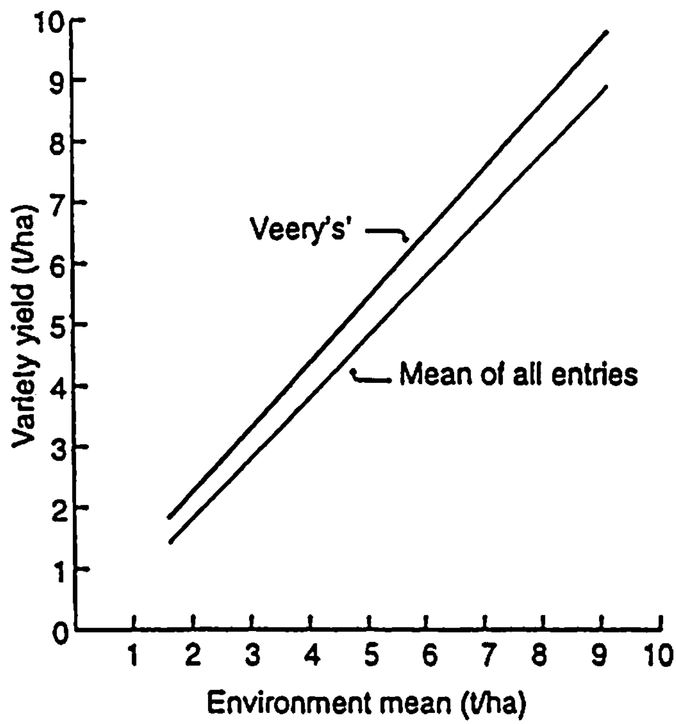


Fig. 4. Grain yield of Veery S regressed over the mean yields of 72 locations (from Osmanzai *et al.* 1987)

The widespread adoption of high yielding wheat and rice varieties in many countries has been taken as a demonstration of wide adaptation. An analysis of the environments where "widely adapted" cultivars have been successfully adopted shows that all the environments are either similar, or are made similar by the use of irrigation and/or fertilizer. Therefore, the term "wide adaptation" has been used more in a geographical than in an environmental sense. In fact the adoption of "widely" adapted cultivars in marginal environments has been negligible (Byerlee and Husain 1993). While the advantages of wide adaptation over time are obvious, it is less clear why breeders have been fascinated by the possibility of finding cultivars widely adapted over space i.e. cultivars which are superior in very different environments.

Farmers are basically interested in a constantly superior performance of a cultivar on their own farm. Farmers are indifferent to spatially widely adapted cultivars, but are interested in cultivars specifically adapted to their conditions, needs and uses, and which have a high degree of stability over time. Even assuming that breeding for truly wide adaptation is possible, it will result in few cultivars being grown throughout very large areas. It is now recognized that this is potentially a very dangerous philosophy in relation to resistance to pests and diseases. Human beings are already depending for their food supplies on too few species. Reducing the number of genes within a species can only increase the vulnerability of crops and jeopardize food supplies. It has been documented that the release of a few successful new cultivars over large areas has led to the displacement of many old cultivars, many of which may possess useful genes for future needs. Wide adaptation, therefore, is not a healthy or sustainable solution to the long-term problem of maintaining genetic diversity.

Specific Adaptation: a Lesson from Landraces

A feature of plant breeding in developed countries and for favorable environments has been the narrowing of the genetic base accompanied by a trend toward homogeneity: one clone, one pure line, one hybrid (Simmonds 1983). Although genetic uniformity is being questioned in developed countries (Wolfe 1991), it is still very popular in breeding programs and seed production systems of developing countries. This is in contrast with one of the characteristics of agriculture in marginal environments: genetic diversity either in a form of mixed cropping or a form of genetically heterogenous cultivars or both. Genetically heterogeneous landraces also called farmers' varieties, old cultivars or primitive cultivars are still the backbone of agricultural systems in many developing countries, mainly in marginal environments. In these environments the replacement of landraces by modern, genetically uniform varieties bred for favorable environments has become difficult at the levels of inputs farmers can afford. Not only will germplasm such as landraces play an important role in the success of a breeding program for marginal environments, but its study may teach the breeder an important lesson about adaptation strategies to marginal environments.

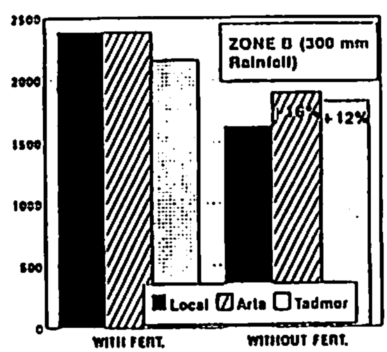
Landraces are typically mixtures of different genotypes. In self-pollinated crops they are mixtures of probably a high number of homozygote genotypes (Brown 1978, 1979, Grando and McGee 1990). Therefore landraces contain a large amount of genetic variation within an adapted genetic background. In the case of self-pollinated crops, this genetic variation is readily usable. Selection within landraces is one of the easiest, oldest and cheapest methods of plant breeding, but often scientists in developing countries are discouraged from using their locally adapted germplasm on the basis of its low yield potential and susceptibility to diseases.

Landraces played two important roles in barley breeding for marginal environments at ICARDA. First, they have shown a breeding avenue based on the combination of appropriate selection environment with the exploitation of specific adaptation of landraces and their genetic variability. Second, they have contributed to a better understanding of adaptation to marginal conditions.

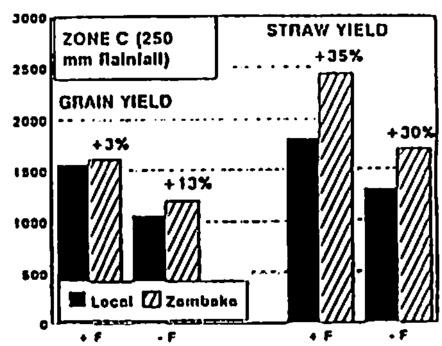
Selection environment and use of landraces

A large collection of barley landraces was made in 1981 in Syria and Jordan (Weltzien 1988) by visiting 70 farmers' fields and collecting 100 individual heads from each field. A preliminary evaluation of the progenies of individual heads (pure lines) revealed variations between and within collection sites for many important agronomic characters (Ceccarelli *et al.* 1987) and for disease reaction (van Leur *et al.* 1989). Because of the large number of pure lines, only 600 to 700 new lines are evaluated each year in yield testing with lines derived from the crossing program and unrelated to landraces. The sites used for yield testing range from marginal (average yields of about 0.5-1 t ha^{-1}) to favorable (average yields of about 4.5-6.0 t ha^{-1}). In 1991 the data of three yield testing cycles (1986-1988, 1987-1989 and 1989-1990) in which a total of 6252 lines (1742 landraces and 4510 non-landraces) were tested were analyzed. It was found that only 36 lines (0.6%) outyielding consistently the local landrace in marginal environments. Of those, 33 were pure lines extracted from landraces which were identified in the driest experiment site (Bouider) and 3 were non-landraces identified at the highest yielding site. A breeding strategy for marginal environments, which combines direct selection under farmers' conditions (specific adaptation) and use of locally adapted germplasm is, therefore, 28 times more efficient than a strategy based on selection in high yielding conditions and using non-landrace material (Table 11).

Selection of pure lines from landraces conducted in marginal conditions and at low levels of inputs is a promising avenue. Figure 5 shows the performance of three pure lines (Arta, Tadmor and Zambaka) selected from Syrian landraces and tested in farmers' fields on 1 ha plot in two rainfall zones: zones B and C with long-term average rainfall of 300 and 250 mm, respectively. Through this strategy yield increases of 12-16% are possible in these difficult conditions even without fertilizer. Pure line selection within landraces is only a short-term strategy used to prove that this type of germplasm has an important role to play in breeding for marginal conditions. In the longer term, the best pure lines are used in crosses either with other pure lines from landraces or with non-landrace material or as mixtures of pure lines. The latter is likely the best long-term avenue to cope with the unpredictable variability of abiotic stresses. Only limited data are available on performance and stability of mixtures (Grando and McGee 1990) and it is premature to draw conclusions.



a



b

Fig 5a. Mean yield advantage of three pure lines selected from barley landraces (Arta and Tadmor) in environments with 300 mm rainfall on 12 locations, plot size 1 ha.

Fig 5b. Mean yield advantage of three pure lines selected from barley landrace (Zambaka) in environments with 300 mm rainfall on 12 locations, plot size 1 ha.

PURE LINES OR MIXTURES

Landraces are very well adapted to marginal conditions both climatically and agronomically. Understanding the basis of adaptation of landraces is therefore, important in a breeding program aiming to increase barley yield and stability in marginal conditions. A number of morphological and developmental traits in landraces and non-landraces were evaluated to find a simple explanation to the superiority of landraces under farmers' conditions in marginal environments. The choice of traits was limited to those that are easy, cheap and quick to measure, as these are essential requisites for use in a breeding program (Table 12). Landraces differ from non-landraces in a number of traits which together appear to form an adaptive complex. Moreover, these traits are not present in just one combination within landraces, but they are present in different combinations in different individuals. When we classified 322 lines derived from Syrian landraces in 9 classes according to all possible combinations of three scores for early growth vigor (<2.5 = good, 2.5-3.5 = intermediate, and >3.5 = poor) and three scores for growth habit (<2.5 = erect, 2.5-3.5 = intermediate, and >3.5 = prostrate) we found the combinations shown in Table 13. Genotypes with different combinations of traits are likely to have a specific advantage in specific combinations of the abiotic stresses occurring in a continental-mediterranean environment.

If the genetic structure of landraces is considered as an evolutionary approach to survival and performance under arid and semi-arid conditions (Schulze 1988), then it appears that during millennia of cultivation under adverse conditions, natural and artificial selections have not been able to identify either an individual genotype possessing "a trait" associated with its superior performance or an individual genotype with a specific architecture of different traits. On the contrary, the combined effects of natural and artificial selections has led to an architecture of genotypes representing different combinations of traits. In marginal environments a population with such an architecture of genotypes is probably the best solution to long-term stability (Ceccarelli *et al.* 1991).

CONCLUSIONS

The tradition of breeding for marginal environments has consisted of either testing germplasm developed for other environments or selecting under favorable conditions. This is based on the assumption that it is not possible to detect and use genetic differences at low yield levels and there is a carry-over effect of high yield potential in favorable environments. Very little breeding work for marginal environments includes selection of parents and segregating populations in environments climatically and agronomically similar to farmers' conditions.

In most developing countries experiment stations are concentrated in favorable environments. Those which are in marginal environments are managed according to "recommended" agronomic practices and yield levels are much higher than in farmers' fields. Therefore, the success of the concept of wide adaptation has been based on this combination of breeding and training. Varieties developed under favorable conditions in one country were tested and released by collaborators trained to test and select under equally favorable conditions in other countries.

Both theory and experimental data show that this type of breeding has a low probability of success in marginal conditions because of G x E interactions. But instead of recognizing that it is possible to make use of G x E interaction by breeding for specific adaptation, it has often been concluded that breeding for conditions below the cross-over point is not possible. Two solutions are usually recommended for these conditions. Firstly, when the same crop is grown both in favorable and marginal conditions, breeding efforts should concentrate on favorable conditions. At a country level, larger increases of national production can be obtained by increasing production in good environments through the joint effect of improved varieties and improved agronomic practices. However, such a strategy will neglect the majority of farmers in the country. It is possible to increase agricultural production at a country level and at the same time to serve resource-poor farmers by recognizing that the two types of environments need separate breeding programs, with different objectives, methodologies and type of germplasm.

Second, it is recommended that the introduction of inputs, such as fertilizer and irrigation, are essential prerequisites for successful breeding work (Austin 1989). However, breeding for an agronomically improved environment dictates the type of germplasm which will best exploit it and is based on genetic uniformity—the reverse of the biological diversity requisite for minimizing risk in most natural systems (Wilkes 1989).

Exploiting specific adaptation implies that the number of varieties (not necessarily homogeneous) of a given crop grown at any time will be large. The benefits of maintaining genetic diversity within a crop over large areas has been discussed extensively in the literature in relation to resistance to pests and diseases and does not need further justification. The major disadvantage of disseminating many varieties among farmers is seed production. However, the dissemination of specifically adapted varieties among resource-poor farmers does not have to follow the conventional schemes used in developed countries.

Eventually, if the concept of G x E interaction is extended to cover different levels of management within the same environment, the question is whether yield levels attainable with environmentally friendly levels of inputs are above or below the cross-over point. It is obvious from the previous discussion of the cross-over type of G x E interaction that, if these levels are below the cross-over point, the optimum compromise between productivity and sustainable use of inputs cannot be achieved by the use of cultivars specifically bred for high-input agriculture.

Table 1. Grain yield of barley (kg ha^{-1}) in five cropping seasons, rainfall (mm) without and with fertilizer (20 kg N and 60 kg P_2O_6 ha^{-1}).

Cropping season and rainfall	without fertilizer	with fertilizer	Increase (%)
1981/82 (229)	1720	2130	23.8
1982/83 (324)	1320	2220	68.2
1983/84 (284)	1040	1740	67.3
1984/85 (204)	740	1540	108.1
1985/86 (278)	750	2380	221.6

Table 2. Grain and total biological yield of barley (kg ha^{-1}) under rainfed conditions and with supplementary irrigation.

Moisture regime	Moisture (mm)	Grain yield	Total biological yield
Rainfed (R)	185	400	2050
Irrigated (I)	417	3370	7570
Ratio (I/R)		8.4	3.7

Table 3. Grain yield (t ha^{-1}) in low and high yielding sites of the top 5% of barley lines selected for grain yield either in low yielding (LYE) or in high yielding (HYE) sites

	Testing site		Top lines in LYE		Top lines in HYE	
Year	LYE	HYE	G_{LY}	G_{HY}	G_{LY}	G_{HY}
1985	0.74	3.49	1.28	0.78	3.34	4.21
1986	1.14	4.01	1.94	1.34	4.14	4.97
1987	0.67	2.67	1.02	0.65	2.74	3.61
1988	2.91	4.42	4.20	3.38	4.67	6.10
1989	0.69	5.82	1.29	0.66	4.87	7.81
1990	0.47	3.35	0.79	0.43	3.07	4.12
1991	1.05	4.74	1.69	0.95	4.71	6.07
1992	0.90	4.63	1.31	1.03	4.80	5.79
Means	1.07	4.14	1.69	1.15	4.04	5.34

Source: Ceccarelli *et al.* 1992 (modified)

Table 4. Grain yield (kg ha^{-1}) of barley breeding lines classified according to type of germplasm under stress (YS) and grain yield under non-stress (YNS)

Type of germplasm	Number of entries	YS[a] Yield	YS[a] Range	YNS[b] Yield	YNS[b] Range
Non landraces	155	488	0-893	3901	2310--4981
Landraces[c]	77	788	486-1076	3413	2398--4610
Best check		717		4147	

[a] Average of two stress sites

[b] Average of three non stress sites

[c] Pure line selections from landraces

Table 5. Range of genetic correlation coefficients between yield in low yielding and in high yielding sites; and the ratio between correlated and direct responses to selection (CR/R) in 58 trials conducted from 1986 to 1991 cropping seasons.

Year	negative	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	CR/R > 1
1986-87	6	1	4	2	2	2	1
1988-89	13	2					0
1989-90	5	7	2				0
1990--91	3	4	2	2		1	0
Total	27	14	8	4	2	2	1

Source: Ceccarelli *et al.* 1992 (modified)

Table 6. Grain yield (kg ha^{-1}), linear regression coefficients (b) and coefficient of variation of barley lines selected for high grain yield in high (HY) and low (LY) yielding environments from 332 and 234 barley lines, respectively

Selection environment	Testing Environment HY	Testing Environment LY	b	C.V.
Group 1 (n=332)				
HY	5420	522	1.13	0.72
LY	4505	1186	0.82	0.54
Group 2 (n=234)				
HY	6354	389	1.26	0.65
LY	4786	930	0.87	0.90

Source: Ceccarelli and Grando 1991a (modified)

Table 7. Heritability estimates of different crops for grain yield at low and high yield levels.

Crop	High	Low	Reference
Cocksfoot	0.89	0.50	Breese, 1969
Maize	0.52	0.71	Selmani and Wassom, 1993
Wheat	0.78	0.32	Allen et al., 1978
Soybeans	0.56	0.31	Allen *et al.*, 1978
Barley	0.47	0.54	Allen *et al.*, 1978
Oats	0.56	0.63	Allen *et al.*, 1978
Flax	0.44	0.56	Allen et al., 1978
Barley	0.65	0.66	Weltzien and Fischbeck, 1990
Oats	0.38	0.52	Johnson and Frey, 1967
Oats	0.67	0.32	Atlin and Frey, 1990
Wheat	0.89	0.74	Pfeiffer, 1988
Wheat	0.25	0.03	Roy and Murty, 1970
Wheat	0.33	0.68	Pederson and Rathjen, 1981
Barley	0.47	0.68	Singh and Ceccarelli , 1993
Oats	0.45	0.32	Frey, 1964

Table 8. Heritability estimates in wheat from a set of 31 trials conducted in 9 locations over 5 years

Grain yield (t ha^{-1})	Heritability
4.96	0.38
3.67	0.41
3.20	0.00
1.04	0.64
0.68	0.41
0.59	0.00
0.58	0.43

Source: Pederson and Rathjen 1981 (modified)

Table 9. Grain yield (kg ha^{-1}) of six wheat varieties under two irrigation regimes in Cd. Obregon, Sonora, 1982

Variety	Grain Yield	
	5 irrigations (well-watered)	2 irrigations (stress)
Genaro 81	7461	4745
Lira 'S'	6920	4747
Veery 'S'	6819	4378
Neelkant 'S'	6758	4585
Junco 'S'	6346	4681
Tanager 'S'	5202	3637

Source: Rajaram *et al.* 1984

Table 10. Grain yield (kg ha^{-1}) of barley lines selected from two breeding lines for performance across environments (widely adapted) and for performance in specific environments (top lines in LYE or HYE).

Material	No.	YS	YH
First group			
Widely Adapted	5	908 (-28.2%)	5811 (- 9.6%)
Top Lines in LYE	5	1265	4410
Top Lines in HYE	5	574	6430
Best check		678	5544
Second group			
Widely Adapted	4	945 (-12.4%)	6025 (-11.2%)
Top Lines in LYE	4	1079	4013
Top Lines in HYE	4	449	6783
Best check		887	5587

LYE - low yielding environments, YS - Yield in low yielding environments, HYE - high yielding environments and YH - Yield in high yielding environments

Table 11. Number and frequency of lines outyielding the best check in marginal conditions with adapted germplasm and in favorable conditions with improved (non landraces) germplasm

Breeding strategy	Number of lines tested	Number	frequency (%)
Selection in marginal conditions and use of adapted germplasm	1742	33	1.89
Selection in favorable conditions and use of improved germplasm	4510	3	0.07

Source: (Ceccarelli and Grando 1991b)

Table 12. Means of morphological, developmental and agronomical traits in 1041 modern (unrelated to Syrian landraces) barley genotypes compared with 322 pure lines extracted from Syrian landraces*.

Traits	Non landraces n=1041	Landraces (n=322)
Early growth vigor (1 =good; 5=poor)	2.5 b	3.2 a
Growth habit (1 =erect; 5= prostrate)	2.8 b	4.0 a
Cold tolerance (1 =toler.; 5= susc.)	3.0 a	1.3 b
Days to heading	117.9 b	121.2 a
Grain filling duration (days)	39.3 a	35.5 b
Yield potential (kg ha^{-1})	4398.0 a	3293.0 b
Yield under stress (kg ha^{-1})	483.1 b	984.0 a

* Means followed by the same letter are not significantly ($P<0.05$) different based on *t*-test for samples of unequal size.

Table 13. Frequency of different combinations of early growth vigor (GV), and growth habit (GH), and mean values of cold tolerance (CT), days to heading (DH), and length of the grain filling period (GF) in a sample of 322 lines of barley landraces collected in the dry areas of Syria.

Groups		%	GV	GH	CT	DH	GF
Good vigor	Erect	0.0	-	-	-	-	-
Good vigor	Semiprostrate	1.2	2.2	3.3	1.6	118.8	37.4
Good vigor	Prostrate	5.3	2.4	3.9	1.4	119.8	36.6
Intermediate vigor	Erect	0.0	-	-	-	-	-
Intermediate vigor	Semiprostrate	6.2	2.9	3.4	1.5	119.7	35.8
Intermediate vigor	Prostrate	65.1	3.1	4.0	1.4	121.2	35.4
Poor vigor	Erect	0.0	-	-	-	-	-
Poor vigor	Semiprostrate	0.0	-	-	-	-	-
Poor vigor	Prostrate	22.1	3.9	4.2	1.3	121.9	35.4
$LSD_{0.05}$			0.2	0.1	0.1	0.6	0.7

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Barley Genetic Resources

Dawit Tadesse and Hailu Mekbib

Abstract

Barley in Ethiopia is a rain fed crop and predominately grows in the highlands over 2,800 m altitude. It is produced both in the main and short rainy seasons. The cultivation of barley is being pushed to the marginal areas, therefore, genetic erosion is at an accelerating rate due to several factors. Operations for germplasm collecting are undertaken in both seasons by the Plant Genetic Resources Centre/Ethiopia (PGRC/E). Collections made before the establishment of PGRC/E by foreign explorers and Ethiopians are described. The total number of accessions conserved by the gene bank is 14,591. until the end of 1992 cropping season PGRC/E has collected and conserved 4,462 germplasm accessions from various regions of the country. The distribution of these collections both in regions and altitudes is described. Some qualitative characters of barley by regions are also elaborated.

In Ethiopia barley grows under rainfed conditions predominantly in the highlands. It is better adapted than other cereals to poor soil fertility, frost and soil acidity (Hailu and Fekadu 1991). It is produced both in the main rainy season (meher) and short rainy season (belg).

BARLEY GERMPLASM COLLECTION

According to Harlan (1969) barley was introduced to Ethiopia from west Asia. It stayed long in Ethiopia and has developed a series of endemic varieties. According to Vavilov (1927) Ethiopia is a center of diversity for barley. Since the early 19th century barley germplasm collections were made by various scientists for different purposes (Chiovenda 1912, Vavilov 1927). In 1927 Vavilov collected 390 barley samples from various regions of the country. Subsequent morphological and agronomic studies on these materials were made by Orlov (1929). American and British explorers have collected barley germplasm from the mid 1920s to the early 1950s. The Institute of Agricultural Research also collected about 2,000 accessions from various areas of the country to evaluate them for desirable agronomic characters (IAR 1986). Sakamoto et al (1972) collected 208 accessions of barley from December 1967 to March 1968.

Plant Genetic Resources Centre for Ethiopian collections

As barley is a top priority of PGRC/E, about 7582 samples were collected in various germplasm collection operations. The center's collection comprises repatriations (1470), donations (60), other institutes' (3056) and own collections (4462). Apart from the PGRC/E's own collections, others lack basic ecological and environmental data, which should accompany the accessions. Table 1 shows the number of missions to each region. The highest number of collections were made from Shewa and Gonder and the least was from Ilubabor and Kefa.

Table 1. Number of barley germplasm collected from different parts of Ethiopia by PGRC/E

Region	No. of collection operations	No. of samples collected
Arsi	11	552
Bale	6	227
Gamo Gofa	10	185
Gojam	9	366
Gonder	11	649
Harer	9	285
Ilubabor	4	36
Kefa	9	46
Shewa	19	858
Sidamo	11	162
Tigray	10	314
Welega	6	131
Welo	11	389
Unknown	-	59
Total		4255

Fig. 1 Shows the distribution of barley germplasm collected from different attitudinal ranges. The highest number of collection (42%) came from altitudes ranging from 2451 to 2950 m followed by altitude range $\geq$ 2951 m (27%). The occurrence of barley is small in altitudes below 1950 m.

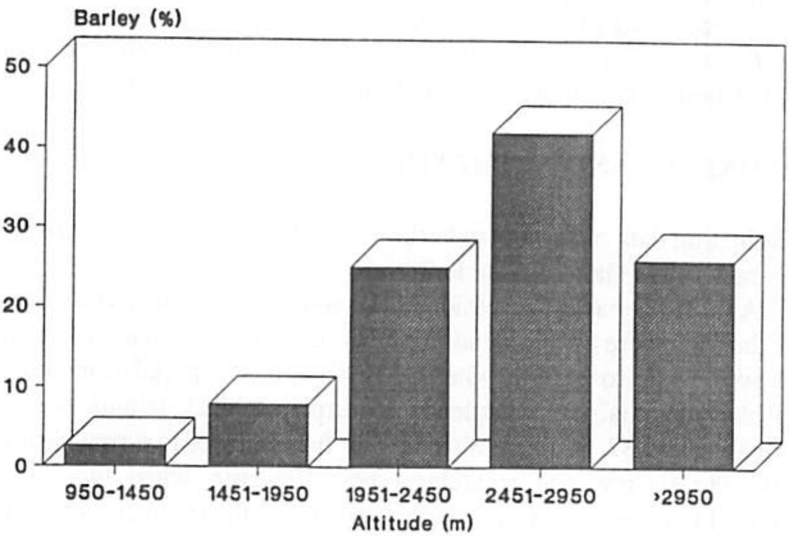

Fig. 1. Altitudinal range and frequency of occurrence of barley

GENETIC EROSION

Barley growing areas are gradually diminishing because of the expansion of wheat cultivation. Cifferri (1944) identified three ecosystems where barley cultivation dominates in Ethiopia. They are 900-1800 m, 1800-2400 m and 2400-3000 m. Presently the crop is pushed to marginal areas (to very high altitudes and where frost prevails) and threatened by genetic erosion. Therefore, rare morphotypes are declining in frequency of occurrence through time. According to Zemede (1988) some morphotypes, which were reported by Orlov (1929) to occur in abundance in a given region or locality were either never encountered or found only in a rare admixture.

EVALUATION AND UTILIZATION

Evaluation data of Ethiopian barley germplasm accessions for five qualitative characters are shown in Table 2.

Almost all barley accessions have rough awns. Only 0.57% and 0.05% of the total were awnless and mixtures. Eighty-one percent of the population showed white to brown, whereas 18.46% of the population showed purple to black lemma. The frequency of purple to black lemma was 47.60% in Ilubabor and 37.14 % in Welega. The frequency of two-row barley is higher than the six-row and irregular types. However, when two-row types are divided into sterile and rudimentary categories the frequency of six-row barley was 29.68% followed by rudimentary 26.61% and sterile type 25.97%. Tigray and Welega showed low frequency of six-row barley. The highest spike density is intermediate type, 58.63%, followed by lax 28.82% and dense 12.43%.

Results of agronomic evaluation (Table 3) showed that barleys from Tigray, Kefa and Welega were early in flowering and maturity and short in stature as compared to those from Gojam, Gonder and Arsi. Highest number of kernels per ear and spikelet per spike was observed in Gamo Gofa, Arsi and Ilubabor and the lowest in Gojam, Bale and Gonder.

Table 2 Evaluation data of Ethiopian barley germplasm accessions for five qualitative characters

Region	No. of samples	Awnedness(%)			Lemma color (%)			Awn roughness(%)		Row number(%)					Spike density(%)			
		awned	awnless	mixture	white to brown	purple to black	missing data	rough	missing data	6	2	2	X irreg. rude.	missing data	lax	inter	dense	missing data
Arsi	622	99.7	0.3	-	79.4	19.9	0.6	99.8	0.2	27.2	19.7	34.1	18.9	-	7.7	81.4	10.7	-
Bale	102	100.0	-	-	84.3	13.7	1.9	99.0	0.9	45.1	10.8	11.7	32.5	-	36.3	48.0	14.7	0.9
Gamo Gofa	51	100.0	-	-	78.4	21.6	-	100.0	-	54.9	17.6	9.8	17.6	-	31.4	50.9	17.6	-
Gojam	144	99.3	0.7	-	71.5	27.1	1.4	100.0	-	41.7	11.8	27.1	19.4	-	39.6	50.7	9.0	0.7
Gonder	431	98.4	0.8	0.5	82.4	17.4	0.2	100.0	-	39.7	16.9	29.0	14.4	-	42.9	48.9	8.1	-
Harer	226	100.0	-	-	75.6	24.3	-	100.0	-	53.9	7.5	20.3	18.1	-	30.9	42.0	26.9	-
Ilubabor	17	100.0	-	-	47.1	47.1	5.9	94.1	5.9	41.2	11.7	17.6	29.4	-	64.7	23.5	5.9	5.8
Kefa	151	100.0	-	-	64.2	35.1	0.6	100.0	-	32.5	26.5	20.5	20.5	-	32.5	56.3	11.3	-
Shewa	1592	99.6	0.4	-	83.2	16.4	0.4	100.0	-	26.0	29.8	25.4	18.7	0.1	28.3	59.7	11.9	0.1
Sidamo	68	100.0	-	-	75.0	25.0	-	97.1	2.9	42.6	14.7	29.4	13.2		47.1	33.8	19.1	-
Tigray	467	98.5	1.5	-	91.2	8.3	0.4	99.7	0.2	8.6	53.9	29.9	7.5	-	27.2	61.2	11.6	-
Welega	70	100.0	-	-	62.3	37.1	-	100. 0	-	17.1	37.1	41.4	4.3	-	41.4	52.8	5.7	-
Welo	213	98.6	1.4	-	76.1	23.0	0.9	100.0	-	47.4	7.5	15.0	30.1	-	34.7	45.5	19.7	-
Total		99.4	0.6	0.1	81.0	18.5	0.5	99.8	0.1	29.8	25.9	26.6	17.5	0.1	28.8	58.63	12.43	0.09

Table 3. Maximum, minimum, mean and standard deviation of some agronomic characters of barley germplasm by region.

Region	Characters	N	Max.	Min.	Mean	SD	CV
Arsi	Days to flowering	614	110	44	79.9	12.8	16.0
	Plant height	614	135	50	98.5	15.1	15.7
	Days to maturity	614	153	95	122.5	12.2	10.0
	Spikelets per spike	613	39	12	23.7	3.9	17.2
	Kernels per ear	614	99	9	41.5	15.1	36.8
Bale	Days to flowering	100	106	58	77	11.3	14.8
	Plant height	100	125	50	97.4	12.8	13.8
	Days to maturity	100	139	97	118.9	12.1	10.2
	Spikelets per spike	99	33	13	22.3	3.5	16.1
	Kernels per ear	99	73	3	36.6	12.9	35.6
Gamo Gofa	Days to flowering	51	99	60	74.2	8.3	11.2
	Plant height	51	118	70	99.9	12.5	12.8
	Days to maturity	51	113	91	116	11.1	9.6
	Spikelets per spike	51	32	16	24	3.8	16.3
	Kernels per ear	51	69	21	42.3	14	33.6
Gojam	Days to flowering	141	116	49	81.5	13.8	17
	Plant height	139	130	50	99.5	17.9	18.4
	Days to maturity	141	154	91	120.5	12.5	10.5
	Spikelets per spike	138	29	11	21.9	3.9	18.4
	Kernels per ear	140	70	10	34.9	13.5	38.9
Gonder	Days to flowering	428	116	40	76.6	12.5	15.8
	Plant height	428	197	60	98.7	13.4	13.9
	Days to maturity	428	154	89	122.8	10	8.2
	Spikelets per spike	427	40	12	23.1	3.8	16.7
	Kernels per ear	427	85	5	34.4	14.5	39
Harer	Days to flowering	226	105	52	76.1	10.4	13.7
	Plant height	226	130	55	98.8	17.9	18.6
	Days to maturity	428	142	96	117.6	9.7	8.2
	Spikelets per spike	226	33	7	21.9	4.7	21.8
	Kernels per ear	226	78	12	41.6	15.7	38.3
Ilubabor	Days to flowering	16	144	46	82.9	23	27.2
	Plant height	15	110	70	97	9.5	9.9
	Days to maturity	16	145	100	118.7	11.6	9.9
	Spikelets per spike	16	28	20	25	2.4	9.9
	Kernels per ear	16	77	23	40.4	15.9	39.9

Table 3 (cont'd)

Region	Characters	N	Max.	Min.	Mean	SD	CV
Kefa	Days to flowering	151	104	49	73	11.7	15.9
	Plant height	151	120	55	94.6	15.3	16.5
	Days to maturity	151	140	79	113.3	12.7	11.2
	Spikelets per spike	151	31	7	24.2	4.4	18.7
	Kernels per ear	150	78	10	37.2	15	40.8
Shewa	Days to flowering	1587	113	37	75.9	12.5	16.5
	Plant height	1587	133	45	94.7	15.8	17.1
	Days to maturity	1587	153	90	118.1	10.5	8.9
	Spikelets per spike	1587	42	10	23	4.3	19.1
	Kernels per ear	1587	86	8	35.6	14.4	40.9
Sidamo	Days to flowering	68	105	49	75.3	10	13.4
	Plant height	68	110	49	91.2	13.1	14.5
	Days to maturity	67	140	70	114.2	12.9	11.3
	Spikelets per spike	68	31	17	24.8	3.6	15.1
	Kernels per ear	68	71	21	40.2	15.4	38.7
Tigray	Days to flowering	465	155	45	73.8	11.6	15.8
	Plant height	466	133	50	95.1	15	16.2
	Days to maturity	466	199	91	116.2	10.8	9.4
	Spikelets per spike	466	36	16	24	3.5	14.7
	Kernels per ear	465	75	13	31.6	13.4	42.9
Welega	Days to flowering	69	96	52	72.6	8.9	12.6
	Plant height	69	132	60	96	12.6	12.2
	Days to maturity	69	139	96	114.3	10.8	9.5
	Spikelets per spike	68	30	16	23.3	3.5	15.1
	Kernels per ear	69	60	16	28.7	11.6	41.2
Welo	Days to flowering	213	113	49	78.7	10.2	13.1
	Plant height	213	127	50	91.3	13.6	15.3
	Days to maturity	213	149	94	117.3	10.1	8.7
	Spikelets per spike	209	29	13	22.9	3.6	15.9
	Kernels per ear	212	72	12	40.06	12.9	32.1

Plant breeders and explorers have recognized the economic importance of Ethiopian barley germplasm to the world. Since 1923 more than a dozen international expeditions took place in Ethiopia to collect barley landraces. Table 4 shows the number of collections from 1923 to 1964 and the percent of samples observed by different explorers to be resistant to barley yellow dwarf virus (BYDV). No systematic change in frequency of resistance was observed during this period.

Table 4. Frequencies of resistant types to BYDV in barley collections from Ethiopia.

Collector	Year	No. of collections	Resistant (%)
H.V. Harlan	1923	97	26.8
N.I. Vavilov	1927	93	12.9
G.R. Giglioli	1937	14	15.4
K.Troil/R.Schokemlohv	1938	82	8.5
H.E. Myers	1945	49	28.6
W.A. Archer	1951	255	24.3
J.R. Harlan	1961	21	14.3
I.E. Siegenthder	1961	42	21.4
E.L. Smith/C.E. Thomas	1964	396	12.4

According to Qualset (1975) the frequency of BYDV resistance types increased as one moves from lower to higher elevations. This suggests that high elevations favor the virus and/or the vector, resulting in natural selection for resistance. Apart from disease resistance, Ethiopian barley germplasm have been used for their high protein and lysine since 1968 particularly in Scandinavian barley improvement programs.

CONCLUSION

Genetic erosion of barley germplasm in the country is high, thus, specific collecting operations have to be carried out to fill gaps in terms of geographical coverage of the existing collections. From the preliminary evaluation data it can be recognized that there is still abundant genetic variability within the collections. This suggests the potential of local landraces for breeding programs.

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Food Barley Agronomy Research

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Abstract

Sowing date experiments showed that optimum sowing time for food barley depends upon location, soil type, varietal maturity period, and seasonal distribution of rain fall. Seed rates could vary due to soil type and method of covering.

Fallowing did not appear economical at Bedi. Rotation of food barley with legumes and oil crops was found beneficial for grain yield of barley At Holetta, linseed, field pea, faba bean, rapeseed or fodder oats were good precursor crops to barley At Sheno vetch and faba bean were the best precursor crops. Fertilization of preceding crops showed no residual effect on succeeding barley On Vertisols at Adet, using improved drainage, double cropping of main season barley with chickpea on residual moisture was found beneficial. Tillage experiments on both red and black soils at Holetta showed that mould board plowing by a tractor in mid-March, or twice plowing by the local plow (maresha) after mid-April was beneficial for barley production . In drier areas at Mekele and Quiha frequent tillage by local plow showed no effect on both barley grain yield and moisture content of soil.

Since the late 1960s agronomic trials have been conducted at different centers and demonstration sites in major barley growing areas. As a result, several research innovations such as improved packages of management and inputs were distributed to the farmers. This paper reviews research on cultural practices conducted on food barley in Ethiopia.

SOWING DATES

Sowing date experiments conducted at different locations by the Institute of Agricultural Research (IAR) and other organizations in the late 1960s and early 1970s gave results specific to location, variety and rainfall pattern.

Experiments conducted at Holetta in 1968 and 1969 for different maturity groups of food barley varieties showed that early July is optimum for sowing early maturing varieties like Atlas 57 and Atlas Kindred[2] (14,15). Early to mid-June is optimum for sowing medium duration varieties like Firlbeck III (Table 1 and 2). Highest response to N/P application was also obtained with optimum sowing dates. High damage by scald disease was observed with early sowing (14,15,16). Another set of experiments at Holetta compared sowing dates in relation to soil type and varieties from 1970 to 1972 (16,17,18). Soil type showed a substantial effect on optimum date of sowing for different maturity groups. Sowing early maturing varieties in mid-July, medium duration varieties in late June were optimum on red soil, and sowing all maturity groups in early to mid-July was optimum on black soil (16,17,18).

A one year experiment conducted at Areka indicated that sowing food barley around mid-June was optimum (15). At the drier site of Mekele sowing dates from 1 to 15 June gave the highest grain yield (20). Mid to last week of June and early July were optimum for sowing both improved and local varieties at Bedi (Table 3). Mid June to early July was optimum for sowing local variety at Sheno (9). At Kulumsa the best sowing date was from mid June to late July (3). The first week of July is optimum for sowing food barley at Bekoji (4). In another experiment conducted in south Asela, attack of barley fly declined with delayed sowing (2,4).

At Sinana, early July sowing of two food barley varieties (AHOR 880/61 and HB-17) gave better grain yields in 1987 meher cropping season (22). In another experiment conducted in 1988 to 1989 belg season, sowing food barley from late March to early April gave the highest grain yield in Sinana (Table 4).

A sowing date by variety experiment conducted at Adet in 1991 and 1992 on varieties HB-100, HB-99 and Adet local showed that sowing from May 26 to June 15 is optimum (11). Improved varieties out-yielded Adet local (Table 5). In a sowing date trial at Debre Zeit in 1968 using varieties Atlas Kindred and Saxonia (29), the best yield was obtained when sowing on July 5. In earlier sowing dates there was considerable damage by barley fly, whereas in later sowing dates moisture stress and birds reduced yield.

A summary of results from 1972 to 1982 shows inconsistent trend of barley yield with sowing date. It can be concluded that the trial data do not support the value of any message based on planting dates different from normal farmers' practice (27).

Table 1. Effect of sowing dates and NP fertilizer application on grain yield (kg ha^{-1}) food barley varieties at Holetta on red soil, 1968.

Sowing dates	Atlas kindred[2] (early)			Firlbecks III (medium)			Mean
	FO	F1	mean	FO	F1	mean	
May 23	2201	2746	2474	1670	2307	1989	2231
June 6	1580	2199	1890	2020	2437	2229	2059
June 20	1797	2656	2227	1768	2231	2000	2113
July 4	2402	3181	2792	1967	2421	2194	2493
July 18	2364	2533	2449	1446	2100	1773	2111
August 1	1659	1942	1801	626	1247	937	1369
Mean	2005	2543		1583	2124		
	Sowing dates		Fertilizer		Variety		
LSD (0.05)	617		473		132		
CV (%)	16.6		11.8		5.0		

FO= No fertilizer, F1= 40 kg N and 18 kg P_2O_5 ha^{-1}

Source: (14)

Table 2. Effect of sowing dates on grain yield (kg ha^{-1}) of food barley varieties at Holetta on red soil, 1969.

Sowing dates	Atlas 57 (early)	Firlbecks III (medium)	Local (medium)	Mean
June 5	3029	3516	2329	2958
June 19	3709	3397	3496	3534
July 3	3745	3033	3928	3569
July 17	4153	2776	3777	3569
Mean	3659	3181	3383	
		Variety	Sowing date	Interaction
LSD (0.05) kg ha^{-1}		333	253	454

Source: (15)

Table 3. Effect of sowing dates on grain yield (kg ha^{-1}) of two food barley varieties at Bedi, 1981-1983.

Sowing dates	Hooded-16	Bedi-local	Mean
May 20	1684	1369	1527
June 6	1976	1719	1848
June 20	2045	1885	1965
June 6	1808	2189	1999
Mean	1878	1791	

Source: (9)

Table 4. Effect of sowing dates on grain yield (kg ha^{-1}) of three food barley varieties in belg season at Sinana, 1989.

Sowing dates	ARDU-12-9C	HB-78	Local	Mean
March 30	1700	2180	2290	2057
April 9	1535	1160	1995	1563
April 19	1955	1205	2075	1745
April 29	535	320	1460	772
Mean	1430	1215	1955	

Source: (21)

Table 5. Effect of sowing dates on grain yield (kg ha^{-1}) of three food barley varieties at Adet, 1991-1992.

Sowing dates	HB-100	HB-99	Local	Mean
May 26	2105	1884	1422	1820
June 5	2277	1680	1503	1820
June 15	2163	1815	1563	1847
June 25	1882	1801	1480	1721
July 5	1501	1668	1571	1580
July 15	1288	1224	1345	1285
Mean	1869	1679	1489	

Source: (11)

SEED RATES

Seed rate studies in relation to seed covering and fertilizer placement methods were conducted at Holetta in the late 1960s (14,15) and in relation to soil types and varietal maturity in the early 1970s (16,17,18). For broadcasting 115 kg ha^{-1} of seed was optimum (Table 6). The seed rate by broadcast exceeded the seed rate of drill sowing by 25%. The effect of seed covering method was not reflected in grain yield (15). Seed covering by local plow reduced the total expected plant population by 25% and resulted in 15% lower plant population than covering by spike tooth harrow Seed rates of 120 and 80 kg ha^{-1} were optimum for broadcast sowing using local plow and spike tooth harrow, respectively (Table 7). For medium duration varieties, broadcasting of 125 kg ha^{-1} on red soil and drilling of 75 kg ha^{-1} on black soil were optimum seed rates at Holetta (16,17,18). For early maturing varieties broadcasting 75 to 100 kg ha^{-1} on red soil and drilling the same rate on black soil were optimum seed rates. Seed rate studies ranging between 75 and 150 kg ha^{-1} were continued in the early 1980s at Bedi and Sheno. The results suggested no significant yield difference among rates (12) (Table 8), but 75 kg ha^{-1} was optimum for food barley production in these areas. Seed rates ranging between 75 and 150 kg ha^{-1} were also studied from 1985 to 1987 on red soil at Holetta (5). The highest grain yield was obtained from 125 kg ha^{-1} seed rate, which was considered optimum for food barley production at Holetta.

Table 6. Effect of seed rate (kg ha^{-1}) and fertilizer placement method on grain yield (kg ha^{-1}) of food barley at Holetta, 1968

Fertilizer placement methods	32	115	138	161	184	Mean
Nil	1663	2117	1683	1987	1635	1826
Band	2774	2774	2782	2739	2438	2701
Broadcast and incor.	2405	3544	2762	2591	2546	2769
Surface broadcast	2233	2933	2128	2183	2587	2412
Mean	2269	2842	2338	2375	2314	

Source: (14)

Table 7. Effect of seed rate (kg ha^{-1}) and seed covering methods on grain yield (kg ha^{-1}) of food barley (var. Egypt 20) at Holetta, 1968.

Seed rate	Local plow	Spike-tooth harrow	Mean
40	1116	1252	1184
60	1392	1258	1325
80	1472	1830	1651
100	1895	1748	1822
120	1968	1733	1851
Mean	1569	1564	

Source: (15)

Table 8. Effect of seed rate (kg ha^{-1}) on grain yield (kg ha^{-1}) of food barley varieties at Bedi and Sheno, 1981-1983.

Seed rate	Bedi		Sheno	
	Hooded-16	Bedi local	Sheno local	mean
75	1776	1359	1689	1608
100	1751	1370	1692	1604
125	1769	1499	1677	1648
150	1867	1511	1747	1708
Mean	1791	1435	1701	

Source: (12)

An experiment using broadcast sowing with varieties, seed rates and time of weeding of food barley was conducted at Adet Research Center in 1986/87 cropping season (9). Grain yield differences due to main or interaction effects of factors were not significant. Variety AHOR 880/61 at 125 kg ha^{-1} seed rate and weeding at 30 days after emergence gave the best grain yield. Five seed rates ranging between 85 and 175 kg ha^{-1} were studied on varieties HB-100, HB-99 and Adet local in 1991 and 1992 (11). Seed rates and varieties did not show statistically significant grain yield difference (Table 9), although all varieties showed a slight reduction in yield with increasing seed rates. Seed rates between 85 and 100 kg ha^{-1} are optimum for food barley production at Adet.

Table 9. Effect of seed rates (kg ha^{-1}) on grain yield (kg ha^{-1}) of three food barley varieties at Adet, 1991-1992.

Seed rates	HB-100	HB-99	Adet local	Mean
85	2496	2209	2007	2237
100	2209	2238	2004	2184
125	2201	2200	1967	2123
150	2441	2186	1940	2178
175	2350	2154	1920	2174
Mean	2350	2218	1969	

Source: (11)

Different seed rates between 82 and 142 kg ha^{-1} were compared using the variety Saxonia by drilling on light soil at Debre Zeit in 1968 (29). There was little difference in grain yield response on fertilized and unfertilized plots of the same seed rate. The highest grain yield was obtained with a seed rate of 122 kg ha^{-1}.

SOWING DEPTH

In a replicated experiment conducted at Holetta in 1968 three sowing depths (2, 5 and 10 cm) on varieties Egypt 20, Unitan and local mixed were compared (Table 10).

Table 10. Effect of sowing depth (cm) on grain yield (kg ha^{-1}) of food barley varieties at Holetta, 1968.

Sowing depth	Egypt 20 (large-seeded)	Local mixed (intermediate)	Unitan (Small-seeded)	Mean
2	862	1533	1500	1298
5	2041	1562	1433	1679
10	2074	1660	1438	1724
Mean	1659	1585	1457	

Source: (14)

At Mekele traditional sowing in 30 cm ridges and sowing in 30 cm ridges with mulch cover were compared in 1975 (20). There was no significant grain yield difference among sowing methods.

ROTATION

Little information has been generated on the importance of fallow in the fallow-barley cropping system at Bedi, where about 50% of the arable land is left fallow each year and 50% put to barley crop. From 1970 to 1972 experiments were conducted on the effect of fallow and different two-year rotations with precursor crops such as barley, triticale, field pea, flax rapeseed and fodder oat (21, 22). The crops were sown with the application of 60 kg N and 26 kg P_2O_5 ha^{-1}, and without fertilizer in 1971 on a plot that was bulk cropped to food barley in 1970. The performance of the precursor crops was poor due to severe infestation by wild oats, insect pests, root rot, mildew and frost. In 1972 all plots were sown to the local food barley both with 60 kg N and 26 kg P_2O_5 ha^{-1}, and without fertilizer. Barley lodged severely on plots that received fertilizer in both years. Fertilization of barley increased grain yield when sown after barley, triticale, wheat, lupin, flax, rapeseed (Table 11). Due to severe lodging, yield of barley decreased when barley was sown after fallow and field pea that received fertilizer. There was no carry-over effect of fertilization of previous crops on grain yield of succeeding barley. Plots that received similar fertilizer treatments in both years gave comparable grain yield after different precursor crops and after fallow. On plots that received fertilizer in both years, yield of barley increased substantially when sown after barley, fallow, triticale, lupin, field pea and flax. Yield was reduced when sown after rapeseed and fodder oats. On plots that received no fertilizer in both years, the highest grain yield was obtained from barley sown after fallow, followed by barley sown after field pea and lupin. The lowest barley yield was obtained after another barley crop. On unfertilized plots when grain yield of barley after fallow was compared with barley after barley and after wheat a 40% advantage of fallowing was found. When yield of barley after unfertilized fallow was compared with non fertilized precursor crops (triticale, lupin, field peas, flax, rapeseed and fodder oats) a 31 % advantage of fallowing was found. It was estimated that fallowing could build-up at least 30 kg N ha^{-1} and controls oats infestation for the succeeding crop (18). However, such gains did not appear as economical as any of the other cropping systems. Fodder oat prior to barley, for instance, gave a green fodder yield of 12,000 kg ha^{-1} in 1971 (17) and succeeding barley yield of 2,015 kg ha^{-1} in 1972 (18). Based on this observation, a six year cropping system was suggested for food barley production for Bedi plateau (Table 12). With varieties that could escape frost and resist root rot and mildew, field pea and lupin can be used as precursor crops for food barley production at Bedi (Table 11).

Table 11. Effect of precursor crops and fallowing on grain yield (kg ha^{-1}) the local food barley variety at Bedi, 1972.

Fert. trt.* 1971	1972	Precursor crops: Barley	Fallow'	Triticale	Wheat	Lupin	Field peas	Flax	Rapeseed	Oats	Mean
-	+	2025	2142	2225	1483	2271	2125	2334	2459	2171	2137
+	+	2317	2617	2560	1979	2646	2604	2804	1971	1900	2378
-	-	1808	3038	2123	1858	2417	2717	2254	1608	2015	2204
+	-	1454	3400	1992	1376	2113	2250	2254	1863	2117	2091
Mean	-	1917	-	2174	1671	2344	2421	2294	2034	2093	2119
	+	1886	-	2276	1677	2380	2427	2529	1917	2009	2138
	+	2171	2380	2393	1731	2459	2365	2569	2215	2036	2258
	-	1631	3219	2057	1616	2265	2483	2254	1736	2066	2148
Mean		1901	2780	2225	1674	2362	2424	2416	1976	2051	

' Fallow was not fertilized in 1971; * + 60 kg N and 26 kg P_2O_5 ha^{-1}

- no fertilizer

Source: (16)

Table 12. Suggested cropping pattern for Bedi area, 1972

Year	Crop	Remark
First	Fallow	
Second	(Local) barley/wheat	- Clean seed, unfertilized, post-emergence herbicide.
Third	Fodder oats	- cut at flowering for hay, fertilization with 30 kg ha^{-1} of N.
Fourth	Barley	- clean seed, fertilization with 27 kg N and 30 kg P_2O_5 ha^{-1}, post emergence herbicide.
Fifth 15	Wheat	- clean seed, fertilization with 48 kg N and kg P_2O_5 ha^{-1}, post emergence herbicide.
Sixth	Rapeseed/Linseed	- clean seed, fertilization of rapeseed with 23 kg N and 10 kg P_2O_5 ha^{-1}, and of linseed with 46 kg N ha^{-1}.

Source: (8)

At Bedi, another study was conducted in 1974 to compare the effect of three alternative cropping systems and the fallow- barley systems on N/P fertilizer requirement of food barley (19). In 1974, the fallow plots did not receive fertilizer but the three cropping systems (oats-barley, trifolium-barley and barley-barley) were treated with different levels of N/P fertilizer. In 1975 each plot was split into two, half receiving the same fertilizer level as in 1974 and the other half was without fertilizer. Separate statistical analysis were performed for fallow system and for the other three cropping systems. In the fallow-barley system, fertilization did not affect barley grain yield significantly (Table 13). Also in the other systems there was no yield difference between fertilizer treatments and systems. The interaction effects of fertilizer levels and the three cropping systems were significant. Fallow-barley system increased grain yield over the other systems.

A two-year cropping sequence trial was carried out for food barley at Holetta from 1975 to 1977 using barley, broad bean, linseed, oats, field pea, rapeseed and tef as precursor crops (12). Both precursor and barley were grown with and without fertilizer. Significantly lowest grain yield was recorded on barley sown after tef or barley (Table 14). Barley grain yields were not statistically different when barley was sown after broad bean, linseed, fodder oat, field pea and rapeseed. There was no residual fertilizer effect, but current fertilizer effect was significant.

An experiment carried out at Sheno in 1986 and 1987 crop seasons evaluated the relative benefit of crop rotation and succession on succeeding crop of food barley (1). In 1986, seven different precursor crops (linseed, potato, oat, vetch, faba bean, wheat and barley) were grown at two different fertilizer levels (no fertilizer versus 18 kg N and 20 kg

P_2O_5 ha^{-1}). In 1987, food barley was grown without fertilizer to examine the effect of different precursor crops on the succeeding barley yield. Precursor crops significantly affected yield of barley (Table 15). High grain and straw yields of barley were obtained from barley following vetch and faba bean. There was no significant response of barley yield to fertilizer applied on precursor crops. Results of this study indicated that vetch and faba bean are suitable precursor crops and current fertilization is advantageous for food barley production at Sheno.

Table 13. Effect of cropping systems and NP fertilizers on grain yield (kg ha^{-1}) of barley at Bedi, 1975.

N-P	Fallow-Barley	Oat-Barley		Trifolium-Barley		Barley-Barley		
(kg ha^{-1})	FO F1	F1FO	F1F1	F1FO	F1F1	F1FO	F1 F1	Mean
0-0	1610	1220	1340	1910	1930	830	810	1379
0-10	2040	1240	1640	1970	2000	990	1710	1656
0-20	2280	1410	1600	2370	2240	1070	1660	1804
23-0	2550	1480	2030	1960	2720	1250	1580	1939
23-10	2810	1580	1560	1630	2110	1400	1500	1799
23-20	2550	1090	1620	1920	2580	1290	1950	1857
46-0	2340	1530	1660	2270	2640	1610	1880	1990
46-10	2210	1600	1700	2210	2830	1450	1850	1979
46-20	2700	1880	1900	1280	2120	1330	1370	1797
Mean	2343	1448	1672	1947	2352	1247	1590	

FO F1 - No fertilizer in the first year but fertilized in the second year

F1 FO - Fertilized in the first year but not on the second

F1 F1 - Fertilized in both years.

Source: (19)

DOUBLE CROPPING

An experiment was conducted at Sheno in 1987 to identify a suitable double cropping combination for barley production. Crops grown in belg season were barley, faba bean and oat/vetch mixture. Barley and faba bean did not yield due to lack of moisture in April. Faba bean was infested by aphids. Growth of vetch was stunted due to the dry spell. Only forage oats showed some promise giving fresh weight of 10 t ha^{-1}. In meher season it was possible to plant succeeding crops only following forage oat. Crops grown in meher season were potato, faba bean, barley, oats, linseed, and wheat. The grain/tuber yield obtained from meher season crops was 17 t ha^{-1} for potato, 1 t ha^{-1} for faba bean, 2.1 t ha^{-1} for barley, 4 t ha^{-1} for oat, 1.2 t ha^{-1} for linseed and 3 t ha^{-1} for wheat.

Table 14. Effect of precursor crops and NP fertilizer on grain yield (kg ha^{-1}) of food barley at Holetta, 1977.

Precursor crop	FOFO	FOF1	F1FO	F1F1	Mean
Barley	219	192	1446	954	703
Broad bean	895	1066	2407	2405	1693
Linseed	887	1087	2554	2298	1707
Fodder Oats	650	997	1832	2319	1450
Field pea	1077	651	2615	2438	1695
Rapeseed	1718	594	2454	2525	1823
Tef	297	143	1890	1987	1079
Mean	820	676	2171	2132	
	Precursor	Residual fertilizer	Current fertilizer		
LSD (kg ha^{-1}) 5%	457	NS	268		
1%	634	NS	618		

FOFO- unfertilized in both years.

F1FO- Fertilized in the 1st year, 46 kg N and 20 kg P_2O_5 ha^{-1} for wheat, barley and tef

FOF1- Fertilized in the 2nd year, 18 kg N and 20 kg P_2O_5 ha^{-1} for broad bean and field pea. F1F1- Fertilized in both years, 46 kg N and 10 kg P_2O_5 ha^{-1} for linseed, 46 kg N and 22 kg P_2O_5 ha^{-1} for rapeseed.

Source: (13)

Table 15. Effect of precursor crops on grain and straw yield of barley at Sheno, 1987.

Precursor crops	Grain (kg ha^{-1})	Straw (kg ha^{-1})
Vetch	1750a	2840a
Faba bean	1740a	2580a
Wheat	1540ab	1560b
Linseed	1470ab	1860b
Barley	1440ab	1530a
Oat	1380b	1940a
Potato	1290b	1580b

Means followed by the same letter are not significantly different at the 5% level of Duncan's Multiple Range Test.

Source: (1)

The traditional fallow-chick pea system was compared with double cropping of barley with chickpea under improved surface drainage at Adet from 1988 to 1990 (10). Improved surface drainage, using broad bed and furrow maker, was quite suitable for early sowing of barley during the main season on Vertisols (24), also to sow chickpea after harvesting barley. Yield advantages of 370 kg ha^{-1} grain and 1,290 kg ha^{-1} straw from barley, and 500 kg ha^{-1} from chickpea were observed from the barley-chickpea double cropping, compared to the fallow-chickpea production system which gave only 670 kg ha^{-1} seed yield of chickpea (10).

TILLAGE

Tillage experiments were conducted from 1979 to 1983 at Holetta and Mekele. At Holetta, four tillage treatments operated under different dates by tractor and oxen-drawn tillage implements were compared with and without fertilizer on red and black soils. Main effects of tillage and interaction effects of tillage by fertilizer were not significant for grain yield of barley on both soil types (Table 16). In tractor–drawn tillage operations, mould board plowing in mid-March on both soils gave the highest grain yield. In oxen–drawn tillage operations, twice plowing by maresha after mid- May gave the highest grain yield.

Table 16. Effect of tillage methods on grain yield (kg ha^{-1}) of barley at Holetta.

Tillage treatment	Tractor–drawn			Oxen–drawn		
	Red soil	Black soil	Mean	Red soil	Black soil	Mean
T1	1502	1004	1253	1537	1192	1365
T2	1522	1323	1423	1749	1164	1457
T3	1266	1231	1249	1780	1178	1479
T4	1427	1218	1323	1419	1232	1326
Mean	1429	1194		1621	1192	

Source: (unpublished data, Holetta)

Using tractor drawn implements an experiment was conducted at Holetta from 1982 to 1985 to compare conventional, minimum and zero tillage with and without fertilizer on red and black soils. There was no harvest in 1984 due to severe drought on red soil. Barley grain yields were not significantly different for all tillage treatments (Table 17). Grain yield differences of barley due to tillage by fertilizer interaction were not significant. Minimum tillage out-yielded conventional tillage by 29% on black soil.

The effect of oxen plow tillage frequency on soil moisture content and grain yield of barley was studied from 1981 to 1983 at Quiha (6). One to four tillages were done from early July to late August. The effect of plowing frequency did not show significant difference on grain yield or on soil moisture content.

Table 17. Effect of tillage and soil type on grain yield (kg ha^{-1}) of food barley at Holetta, 1982-1985.

Tillage system	Red soil	Black soil	Mean
Zero tillage	1492	1515	1504
Minimum tillage	1535	1724	1630
Conventional tillage	1655	1338	1497
Mean	1561	1526	

Source: (unpublished data, Holetta)

Continuous barley cultivation in all tillage experiments conducted from 1979 to 1985 increased the build up of soil borne diseases such as root rot and take all. Reduced tillage frequency and continuous barley cultivation also increased grass weeds such as *Digitaria abyssinica* and *Cynodon dactylon.*

VERTISOL MANAGEMENT

Some major limitations of barley production on Vertisols are poor drainage, difficulty of seed bed preparation and low soil fertility. Traditionally, farmers overcome these problems by early plowing whenever draft power is available, by making drainage furrows at 2-3 m interval, soil burning or guie and fallowing. Great efforts have been made to replace soil burning and long-term fallowing by using improved surface drainage methods and fertilizer.

The long-term effect of guie with four levels of N/P fertilizer was studied at Sheno from 1979 to 1984 (28). In both guied and non-guied plots grain yield of barley increased with increasing fertilizer rate (Table 18). When no fertilizer was applied, guie plots gave comparable grain yield to that of non-guie plots with 30 kg N and 13 kg P_2O_5 ha^{-1}.

Most of the agronomic research done at Sheno from 1972 to 1984 dealt with seed bed preparation methods and fertilizer application (7,25,26,28). Grain yield of food barley increased with improved drainage methods, mainly narrow camber beds and application of 60 kg N and 26 kg P_2O_5 versus 90 kg N and 40 kg P_2O_5 ha^{-1} (Tables 19, 20, 21, 22). Grain yield declines and fluctuations were recurrent over the years (7,28) due to drainage problems, guie practice variability and barley mono-cropping patterns throughout the trial periods.

Table 18. Effect of guie and N-P fertilizer on grain yield (kg ha^{-1}) of food barley at Sheno, 1979 to 1984

N-P (kg ha^{-1})	Guied plot	Non-guied plot	Mean
0-0	582	348	465
30-13	1008	568	788
60-26	1307	815	1061
90-40	1520	1087	1304
Mean	1104	705	

Source: (28)

Table 19. Effect of seed bed preparation methods and NP fertilizer on grain yield (kg ha^{-1}) of food barley varieties at Sheno, 1972.

Treatment		Atlas Kindred[2]	Magie	Proctor	Sheno local	Mean
Guie	FO	795	422	172	339	432
Camber bed (6 m)	FO	916·	562	608	1106	798
	F1	1518	1399	1066	1734	1429
Camber bed (8 m)	FO	877	420	759	647	676
	F1	1517	1039	1545	1362	1366
Camber bed (10 m)	FO	386	262	505	605	440
	F1	811	789	682	1253	884
Mean		974	699	762	1007	

FO - No fertilizer, F1 - 60 kg N and 30 kg P_2O_5 ha^{-1}

Source: (26)

Table 20. Effect of seed bed preparation methods and NP fertilizer on grain yield (kg ha^{-1}) of food barley at Sheno, 1972.

Seed bed preparation	N/P fertilizer (kg ha^{-1})		
	0/0	68/30	Mean
Disc plow	843	727	785
Camber bed (10 m)	1533	1927	1730
Camber bed (8 m)	1361	2296	1829
Camber bed (6 m)	1787	2290	2039
Mean	1381	1810	

[*] Average of two varieties- Atlas kindred[2] and Sheno local.

Source: (26)

Table 21. Effect of seed bed preparation methods and NP fertilizer on grain yield (kg ha^{-1}) of food barley at Sheno, 1976-1977.

Seed bed preparation method	N/P fertilizer (kg ha^{-1})				
	0/0	60/13	60/26	60/40	mean
Local plow	62	541	655	693	488
Mould board plow	473	1052	1059	1166	938
Camber bed (4 m)	730	1430	1716	1781	1414
Mean	422	1008	1143	1213	

Source: (25)

Table 22. Long-term effects of seed bed preparation methods and NP fertilizer on grain yield (kg ha^{-1}) of food barley at Sheno, 1979-1984

Seed bed preparation method	N/P fertilizer (kg ha^{-1})				
	0/0	30/13	60/26	90/40	Mean
Local plow	200	628	865	1092	696
Mould board plow	400	687	1225	1407	930
Camber bed (6 m)	783	1200	1668	1983	1409
Mean	461	838	1253	1494	

Source: (28)

INTERACTION AMONG PRODUCTION FACTORS

The yield potential of food barley is constrained by several factors. Most of the agronomy experiments conducted in Ethiopia have quantified food barley yield losses due to specific production constraints, examining single factor or at most two factors. Such approach makes it difficult to determine the relative importance of other factors limiting barley production. A one year experiment conducted at Holetta in 1986 examined combination of three factors and the results revealed that soil fertility is the most important factor limiting barley production, followed by variety and weed competition (8). Based on these results, a series of comprehensive trials comprising factorial combinations of two levels of each factor limiting barley production were designed and executed in 1987 and 1988 at Holetta and Sheno and in 1990 at Sinana Research Centers. All trials examined varietal differences, response to fertilizer, hand weeding and the effect of insecticide.

The local food barley variety at Sheno and Sinana significantly outyielded the improved varieties HB-100 and AHOR 880/61. The local barley variety Baleme gave comparable grain yield to that of improved variety AHOR at Holetta. Fertilizer application improved barley grain yield by 36 to 195% at Holetta and by 369% at Sheno and by 15 to 49% at Sinana (Unpublished data, Sinana). The effect of weed control was specific to cropping seasons and sites. The effect of insecticides to control aphids and barley fly was also variable depending on infestation level and season. Improved drainage method, using broad bed and furrow, increased barley grain yield by 111% at Sheno.

At Holetta, grain yield response of an improved variety, AHOR 880/61, to fertilizer was much better than Baleme. Baleme showed better response to weeding and fungicide spray. Weeding and fungicide spray improved yield response of all varieties to fertilizer application. Aldrin seed dressing improved yield of local and improved varieties on unfertilized and fertilized plots, respectively (Unpublished data, Holetta).

At Sheno, grain yield of the local variety on flat seed bed was higher than that of the new variety. The response to fertilizer was much higher on broad bed and furrows than on flat seed beds and the local variety showed better response to fertilizer than the new variety. Weeding improved fertilizer response.

The relative importance of factors limiting barley grain yield tended to be location specific. Poor soil fertility, barley fly, weeds, variety and fungal diseases, in that order, are the most important factors limiting food barley yield at Holetta. Similarly, the order of importance of production factors at Sheno is poor soil fertility, poor soil drainage, variety, weeds and aphids. Variety is the most important factor limiting food barley grain yield, followed by either poor soil fertility or insect pest at Sinana. Generally, the interaction effects suggested the advantage of combining better yielding production practices in a package.

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Malting Barley Agronomy Research

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Abstract

Sowing malting barley in mid-June to mid-July was optimum at Lole, Dixis, Goffer and Garadella farms. At these farms, early planting without fertilizer resulted in higher grain yield and lower protein contents than late planting dates. Sowing from March 29 to April 8 at Robe and Sinana, and early sowing until mid-March at Gololcha farm in 'belg' season were optimum for variety Beka, while in 'meher' season sowing early until mid-August was optimum at Sinana farm. Optimum sowing date for malting barley production was around June 25 on red soil and June 15 on black soil at Holetta, mid-June at Sheno, first week of July at Bekoji and late March to early April (in belg) and early July (in meher) at Sinana.

Earlier studies at Holetta suggested that broadcasting 100 to 125 kg ha^{-1} seed on red soil and drilling 100 kg ha^{-1} seed on black soil were found optimum rates for large-seeded varieties, while for small-seeded varieties 75 to 100 kg ha^{-1} seed was optimum on both red and black soils. From seed rate studies conducted by the Arsi Agricultural Development Enterprise at different farms, 100 and 125 kg ha^{-1} with application of 18 kg N and 20 kg P_2O_5 ha^{-1} were recommended for drill and broadcast sowing, respectively

Two–cycle cropping sequence experiment on malting barley variety Holkr at Bekoji indicated that the first crop malting barley after faba bean or rapeseed out yielded continuous barley by 37%, while the second crop malting barley after faba bean or rapeseed had 17% yield increment.

On Vertisols grain yield of malting barley can be substantially increased by improved surface drainage with optimum fertilizer application.

In the late 1960s agronomic trials on malting barley were started at different centers of the Institute of Agricultural Research (IAR) and on farms of the Ministry of State Farms Development (MSFD). In this paper agronomic research conducted on malting barley in Ethiopia is reviewed.

SOWING DATES

Six sowing date trials were conducted by Arsi Agricultural Development Enterprise (AADE) at Lole, Dixis, Goffer and Garadella farms. These sowing dates ranged from May 27 to August 9, but the optimum sowing dates ranged from mid-June to mid-July. Grain yields responded positively by applying 41 kg N and 20 kg P_2O_5 ha^{-1}. The optimum level of application was 40 kg N and 40 kg P_2O_5 ha^{-1}. With early sowing dates, grain yield was higher and protein content was lower (unpublished data AADE).

The Bale Agricultural Development Enterprise conducted sowing date trials on malting barley at different locations both in belg and meher seasons. In the belg season, higher grain yields of the variety Beka was obtained with late sowing (March 29 to April 8) at Robe and Sinana, while early sowing (early to mid-March) gave higher grain yield at Gololcha (2). At Sinana a higher grain yield was obtained from sowing in early to mid-August in meher season. Sowing in late July to early August gave higher grain yield at Gololcha (2).

Unreplicated studies conducted at Holetta in 1971 (9) and 1972 (10) using large (Kenya Research) and small (Beka and Aurore) seeded varieties on two major soil types indicated that the optimum sowing date of malting barley varieties on black soil is ten days earlier than on red soil. Optimum sowing date on red soil is around June 25, and on black soil it is around June 15.

A sowing date trial during 1981 to 1983 at Sheno, showed no significant effect on grain yield of the variety Holkr (11). The highest grain yield was recorded with sowing on June 15 (Table 1).

Trials at Bekoji suggested that sowing in the first week of July is optimal (5). Net blotch was lowest when malting barley was planted around mid-July (4,5).

Sowing in late March to early April at Sinana Research Center gave the highest grain yield for all varieties studied (Table 2) (12). Another sowing date experiment conducted in 1986 meher season indicated that sowing Holkr and Beka in early July was optimum at Sinana Research Center (13).

Table 1. Effect of sowing date on grain yield (kg ha^{-1}) of the malting barley variety Holkr at Sheno, 1981 to 1983.

Sowing date	1981	1982	1983	Mean
May 14	939	2863	-	1901
May 31	1146	2667	2246	2020
June 15	877	2781	3067	2242
July 2	1268	2675	2775	2239
Mean	1058	2747	2696	

- no harvest due to severe early drought

Source: (11)

Table 2. Effect of sowing date on grain yield (kg ha^{-1}) of malting barley varieties at Sinana, 1989.

Sowing date	Holkr	Beka	HB-120	Mean
March 30	2818	2586	2303	2569
April 9	2298	1959	1682	1980
April 19	2029	1975	1878	1961
April 29	1803	1790	1992	1862
Mean	2237	2078	1964	

Source: (12)

SEED RATES

Seed rates of 40, 60, 80, 100 and 120 kg ha^{-1} were studied using broadcasting in combination with oxen-drawn local plow and a tractor-drawn spike-tooth harrow seed covering methods in 1968 on red soil at Holetta (7). The seed covering methods did not show significant grain yield difference on the variety Proctor (Table 3). For both seed covering methods, sowing 80 kg ha^{-1} seed was the optimum rate. Plant stands one month after sowing showed loss of viable seeds due to seed covering using oxen-drawn local plow at 25%. Although the effect was not reflected in grain yield, it was recommended that seed rates for local plow should be more than the seed rate for a tractor-drawn spike-tooth harrow by 15% (7).

Table 3. Effect of seed rate (kg ha^{-1}) and seed covering methods on grain yield (kg ha^{-1}) of malting barley (var. Proctor) at Holetta, 1969.

Seed rate	Local plow	Spike-tooth harrow	Mean
40	382	494	438
60	686	669	678
80	861	1037	949
100	652	1097	875
120	715	862	789
Mean	659	832	

Seed rate LSD (0.05) 224 kg ha^{-1}

Source: (7)

Seed rate studies in 1971 and 1972 compared various rates for malting barley varieties based on seed size such as Kenya Research (large-seeded), and Aurore and Beka (small seeded) (9,10). For the large-seeded varieties, 100 to 125 kg ha^{-1} with broadcast on red soil and 100-kg ha^{-1} with drilling on black soil were optimum. For the small-seeded varieties, 75 kg ha^{-1} was the optimum on red soil for broadcasting and on black soil for drilling (9, 10). Trials conducted at Sheno from 1981 to 1983 (11) and at Holetta from 1985 to 1987 (6) examined four seed rates. At Sheno the lowest seed rate, 75 kg ha^{-1} gave comparable grain yield to that of highest seed rate, 150 kg ha^{-1} (Table 4). At Holetta, no grain yield difference due to seed rates was found (Table 5). Therefore, these results indicate that seed rate is flexible for malting barley production in the central highlands of Ethiopia.

Table 4. Effect of seed rate (kg ha^{-1}) on grain yield (kg ha^{-1}) of malting barley (var. Holkr) at Sheno, 1981-1983.

Seed rate	1981	1982	1983	Mean
75	1011	2739	2037	1929
100	1075	2842	1715	1877
125	1149	2683	1945	1926
150	996	2723	2192	1970
Mean	1058	2747	1972	

Source: (11)

Table 5. Effect of seed rate (kg ha^{-1}) and covering methods on grain yield (kg ha^{-1}) of malting barley varieties at Holetta, 1985-1987.

Seed rate	Local plow	Spike-tooth harrow	Mean
75	3000	3033	3017
100	3233	3333	3283
125	3400	3500	3450
150	3200	3267	3234
Mean	3208	3283	

Source: (6)

A seed rate trial conducted in 1989 using the variety Beka at Kulumsa indicated that seed rates of 150, 175 and 200 kg ha^{-1} gave better grain yields. However, seed rate of 125 kg ha^{-1} was considered optimum (3).

Different seed rates were examined by the AADE at Garadella, Lole, Dixis and Goffer farms from 1981 to 1983. Three levels of seed rates (100, 125 and 150 kg ha^{-1}) and three levels of N/P_2O_5 (0/20, 18/20 and 64/20 kg ha^{-1}) were used. Grain yield was enhanced significantly by applying N/P_2O_5, but in most locations 18/20 kg ha^{-1} of N/P_2O_5 gave the best yield. Seed rates of 100 and 125-kg ha^{-1} with 18/20 kg ha^{-1} of N/P_2O_5 were recommended for drilling and broadcast methods of sowing, respectively (AADE unpublished data).

Crop Rotation

Seven different cropping sequences were compared with continuous cropping of malting barley from 1984 to 1991 at Bekoji using the variety Holkr (1). Three sequences consisted of malting barley grown in one year out of two and the other three sequences of malting barley grown in two years out of three. The precursor crops were faba bean, rapeseed and oat/vetch forage mixtures. The oat/vetch mixtures were replaced by wheat in 1990 because of the poor performance of vetch in 1986-1988 crop cycles and the lack of a fodder mixture in the surrounding farming system. N/P_2O_5 rates consisting of 0/0, 0/30, 14/15, 41/30 and 55/30 kg ha^{-1} were used in this study.

Cropping sequence had a significant impact on malting barley grain yield only in one of the five seasons. In general, the first year malting barley after faba bean and rapeseed out-yielded continuous malting barley by 37%, while second year malting barley after faba bean and rapeseed was higher by 17% yield (1).

Grain yield was significantly affected by fertilizer. In 1984 and 1990 the highest level of N reduced grain yield because of lodging. Grain yield increased by 19.7 to 61.4% at the highest fertilizer rate of 55 kg N and 30 kg P_2O_5 ha^{-1} as compared to no fertilizer. Cropping sequence by fertilizer interaction was marginally significant ($P<0.10$) in 1986. Response of barley to N was lower in barley following faba bean than in any other combinations (1).

Continuous barley cropping resulted in a lower pH at one time sampling, while N reduced pH in two sampling regions (at 20-40 cm pre-planting and at 0-20 cm post-harvest in 1991). In both sampling depths, the two year cycles had higher soil P (9.9 and 10.3 units) than the three year cycles (7.1 and 6.4 units) which were higher than under continuous barley (5.6 and 6.2 units). Soil organic matter was affected by cropping sequence only at 0-20 cm depth in the 1991 pre-planting sample out of five sampling regions conducted in 1989 and 1991. Organic matter diminished in two-year cycle (5.7%), in three-year cycle (5.0%) and in continuous barley (4.2%) (1).

Economic analysis of the rotations indicated that the three-year cycle with faba bean combined with two crops of malting barley gave 16.5% more net benefit over the continuous malting barley (1).

Vertisol Management

One experiment conducted in 1970 compared the effect of seedbed preparation methods and N/P_2O_5 fertilizer levels for grain yield using variety Atlas 57 on waterlogged Vertisols at Sheno (8,14). Seedbed preparation methods were local plow, disc plow, disc-plowed narrow camber bed (6 m), and disc plowed wide camber bed (13 m). N/P_2O_5 levels of 0/0, 30/13, 30/26, 60/13 and 60/26 kg ha^{-1} were used. Disc plow or disc plow cambering gave significantly higher yields as compared to the local plow (Table 6). Yield differences because of fertilizer were highly significant with a high level of interaction between seedbed preparation methods and N/P_2O_5 fertilizer levels. High yield was obtained by applying 60 kg N and 13 kg P_2O_5 ha^{-1}. Disc-plowed camber bed of 6 m wide with the application of 60 kg N and 13 kg P_2O_5 ha^{-1} gave the highest grain yield of malting barley. The results of this experiment indicated that grain yield of malting barley on waterlogged Vertisols of the highlands can be substantially increased by improved surface drainage together with fertilization.

Table 6. Effect of seedbed preparation methods and N/P_2O_5 fertilizer (kg ha^{-1}) on grain yield (kg ha^{-1}) of malting barley (var. Atlas 57) at Sheno.

Seedbed preparation	0/0	30/13	30/26	60/13	60/26	Mean
Local plow	461	755	531	812	585	628
Disc plow	840	1174	1054	1472	1227	1153
Disc-plowed camber (6 m)	1432	1760	1417	2568	2087	1853
Disc-plowed camber (13 m)	1000	1359	1683	1966	1705	1543
Mean	933	1262	1171	1705	1401	

LSD (0.05): SB - 586, FL - 175, Interaction - 350
Source: (8, 14)

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Soil Fertility Management in Barley

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Abstract

This paper presents an overview of several fertilizer trials that have been conducted in different parts of the country with the aim of improving the soil nutrient balance and availability and finding out the optimum level of N and P fertilizer for barley

Results at Holetta showed that the responses of food and malt barley to N and P and N/P interaction was significant on the Nitosols and Vertisols, which are the two major soil types in the area. The best levels of N and P on both soil type were 60 and 26 kg ha^{-1} of N and P respectively

The application of lime significantly increased the grain yield of barley by almost tenfold at Chencha.

After a series of investigations at Sheno it was found out that soil burning could be replaced by deep ploughing or camber-beds and the use of fertilizers.

It was established that sources of phosphate such as bone meal, basic slag and rock phosphate can effectively be used to increase yield of barley

The results of EPID fertilizer trials showed that N/P response at the level of 41 kg N and 20 kg P was economical than other levels tested. More recently ADD and NFIU revised the recommendation based on soil color, region and crop.

With the objective of finding out optimum levels of N and P and to improve other soil-related constraints in barley, several field experiments were conducted in different parts of the country by different institutions. A brief review of the studies is presented in this paper.

NITROGEN AND PHOSPHORUS

At Holetta 4 rates of N (0, 30, 60 and 90 kg ha^{-1}) and P (0, 13.2, 26.4 and 39.6 kg ha^{-1}) were tested on black and red soils to establish the optimum rates of malting and food barley.

N and P had significant effect on yield of food barley, although the response on black soil was lower than on red soils. On both soil types the highest yield was obtained with 60 kg N and 26.4 kg P ha^{-1}. The response of malting barley to N and P was also significant on both soils at Holetta. In another fertilizer trial with food barley on red soils at Holetta, it was found out that phosphorus was more limiting than nitrogen.

In the Bedi area, N and P fertilizers were tested for restoring the fertility status of the soil and create a possibility of growing barley continuously. There was no significant response to either N or P, although there was a tendency for barley yields to increase with an increase in the level of N and P. Placing fertilizers in rows was not advantageous over broadcasting.

A study on the effects of time and split application of nitrogen on barley, where the treatments consisting of application of N in a single dose at sowing, at tillering and at heading did not show a significant response either to splitting or time of application of nitrogen fertilizer.

In Gojam a field experiment was conducted on producers' co-operatives fields on Nitosols in 1988 and 1989 at six sites (Sheba, Kore, Woreb, Meshenti, Enguti and Debre Mewi). Both N and P fertilizer application increased grain yield significantly. Response to 46 kg N and 20 kg P ha^{-1} was stable and was recommended to farmers in the Bahr Dar, Mecha, Achefer and Adet areas. Farmers could also profitably apply 46 kg N ha^{-1} alone.

At Illala, Quiha, and Maimekden several trials were conducted both on research station and on farmers' fields, to establish optimum N/P/K rates for barley. A significant yield response to N and P application was present at all locations except at Illala.

LIME

Barley performs better than other crops on poor sites such as Chencha and Bedi, but yields are low (less than 5 q ha^{-1}). Low yields at both Chencha and Bedi are mainly associated with the strongly acidic nature of the soils. The very humid conditions and steep topography has resulted in low pH, low exchangeable bases and low base saturations of the soils. High iron and aluminum contents fix both applied and inherent phosphate in forms unavailable to plants. Experiments were conducted at these locations for seven years to study the effect of liming with and without N and P fertilizations. At Chencha the effects of lime and phosphate on the yield of local barley was studied using four rates of lime (0, 3, 6, 9 t ha^{-1}) and four rates of phosphate (0, 20.2, 30.3 and 40.4 kg ha^{-1}).

Application of lime and phosphate significantly increased grain yield of barley at one site. Applying 3 t lime ha^{-1} and 30.3 kg P ha^{-1} was recommended. On another site the effect of lime and the interactions with phosphate was not found significant. There were no residual effects both to P and lime at both sites. The absence of residual effect was attributed to the high phosphate fixing capacity of the soil. In addition, the high rainfall at Chencha was believed to contribute to the loss of some calcium that has been applied as lime. A small dressing of lime each year was thought to be beneficial.

A trial was conducted to find out if lime can increase the effectiveness of farmyard manure (FYM). Results showed that there was a significant interaction between lime and FYM and the highest grain yield was obtained with the application of 3 t lime ha^{-1} and 12 t FYM ha^{-1} (Table 1).

Table 1. Grain yield of barley (kg ha^{-1} at 12.5% moisture) due to application of FYM and lime

FYM rates (t ha^{-1})	Lime rate (t ha^{-1}) 0	3	6	Average effect of FYM
0	18.7	331.7	889.7	416.7
6	112.0	565.4	894.5	524.0
12	591.5	1335.4	1189.9	1038.9
Average effect of lime	240.7	744.2	994.7	
LSD (5%)	310.2			

Source: IAR (1979)

At Bedi rates of lime (0, 1.5, 3.0 and 4.5 t ha^{-1}) and N/P (0/0, 30/13, 60/26, and 90/39 kg ha^{-1}) were tested from 1978 to 1981. Application of both lime and N/P fertilizer significantly increased the grain yield of barley in all four years. Mean grain yield varied from 7.1 to 13.4 q ha^{-1} for the check and from 11.4 to 19.6 q ha^{-1} for the lime and N/P treatment over four years. The largest yield increment was obtained with 3 t ha^{-1} lime, and 60 kg N and 26 kg P ha^{-1} for most years.

The residual effect from liming was generally small throughout the three years. Maximum yield obtained after application of lime for two successive years was 2.15 q ha^{-1} with 3 t lime ha^{-1}. Liming had increased soil pH, exchangeable Ca and Mg. Studies on the effect of liming, Mg and Zn were conducted at Bedi. There were no increase either due to Mg or Zn application. Soil tests indicated 156 to 192 ppm Mg and 11.5 ppm Zn. The availability of both elements was adequate for grain production.

SOIL BURNING

Yield of barley in the highlands of north Shewa region is usually very low (< 5 q ha^{-1}). Water logging, low nutrient availability and poor workability are the main soil problems limiting crop production.

Farmers around Sheno practice soil burning (guie) to increase their crop production. Usually in the first and second year good yields of barley between 12 and 18 q ha^{-1} are obtained, but there after the yield declines (Mesfin 1981, Mesfin 1982, Sahlemedhin and Westphal 1987, Taye 1986). Although soil heating results in a substantial yield increase, it was found to be a destructive and tedious exercise. Research was conducted for many years at Sheno to find alternative to soil burning.

Trials on different seed bed preparation methods showed that camber beds gave higher yields without fertilizer followed by the ridge and furrow, and straight moldboard plow. The use of fertilizer promoted the expression of yield of both crops under all treatments. The ridge and furrow, and mold board plow were also good (Mesfin 1982, Taye 1986).

In a three year trial the one time effect of soil burning was demonstrated. During the first year, the guie plot with N and P fertilizer application gave more than a two-fold yield increase over the non-guie field. The following year yield of barley in the guie field was equal to that of the non guied field with the highest fertilizer rate, 15.1 q ha^{-1} and 15.5 q ha^{-1}, respectively (Taye 1986). In another 6-year trial, it was concluded that applications of N/P fertilizer is more critical for barley production than the method of land preparation. Results at Sheno have shown that the practice of soil burning could be replaced by seeding on cambered beds with application of 60 kg N and 26 kg P ha^{-1}.

EFFICIENCY OF NITROGEN FERTILIZERS

An experiment was conducted under green house conditions to examine the effect of mixing different sources of nitrogen with phosphate fertilizers, on the amount of phosphate released to barley. $(NH_4)_2$ SO_4, $Ca(NH_2)_2$ Urea, $Ca(NO_3)_2$ and blood meal were used as N sources and Moscow rock phosphate (MRP) and Monocalcium phosphate (MCP) as P sources. Acid soils from Holetta and Jima were used in the experiment. The different sources of N had different effects on the soil reaction when N was applied as $(NH_4)_2$ SO_4 together with either MRP or MCP. Marked pH decreases on all soils were observed. Unlike the other N-sources Ca $(NO_3)_2$ increased the pH of each of the soils when applied with either P sources.

The form of N-fertilizer has also marked influence on plant uptake of P from rock phosphate rocks. When the sparsely soluble P sources (MRP) was used, application of $(NH_4)_2$ SO_4 gave the highest dry matter yields.

ALTERNATIVE FERTILIZERS

Because of the high cost of commercial fertilizers, it becomes often essential to generate information on the use of low-cost materials. Some research work, has been carried out in the past on farmyard, green manure, rock phosphate, basic slug and bone meal.

Green manuring

Barley yields were doubled by using vetch and faba bean as green manuring and percussor crops, respectively (Table 2). Within the legume treatments barley yields were doubled by applying 60 kg N and 26 kg P ha^{-1}.

Table 2. Effect of green manuring on the yield (q ha^{-1}) of barley

N-P (Kg ha^{-1})	Fallow	Field pea	Faba bean	Vetch	Mean N-P
0-0	9.87	10.31	15.38	17.83	13.34
30-13	15.77	19.36	22.68	23.80	20.40
60-26	19.11	29.02	39.49	25.78	28.35
90-40	27.91	26.62	29.20	30.22	28.49
Mean	18.17	21.33	26.69	24.41	

Table 3. Effect of FYM and mineral fertilizer on yield (q ha^{-1}) of barley.

N-P	FYM (q ha^{-1})					N-P
(kg ha^{-1})	0	30	40	50	60	mean
0-0	9.7	17.8	18.7	16.7	20.3	16.6
23-10	10.7	19.7	16.1	18.3	20.3	17.0
46-20	15.2	19.8	18.2	16.9	22.9	18.6
69-30	12.3	19.8	21.2	18.6	17.7	17.9
FYM mean	12.0	19.3	18.6	17.6	20.3	

Source: IAR (1983)

Farmyard manure

At Mekele an experiment was conducted to evaluate the influence of different rates of N/P fertilizers and FYM on yield of barley. Yields were increased by applying both fertilizer and FYM (Table 3).

Rock phosphate, basic slag and bone meal

The effect of bone meal, blood, horn and hoof meal on yield of cereal crops including barley was studied at Holetta. The results showed that crops vary in their abilities of using plant nutrients from these sources. Barley was most effective with 65-89% efficiency of that of N/P fertilizers (Asnakew 1989). In addition it was also found that application of bone meal and blood meal gave grain yields equivalent to that of the recommended N/P fertilizer rate. A trial was conducted at Holetta to examine the efficiencies of rock phosphate (RP), basic slag, bone meal, triple super phosphate on yield of barley. The results obtained at Holetta showed that all sources of P with the exception of Ethiopian rock phosphate supplied adequate amount of phosphorus for barley (Taye 1993).

FERTILIZER ADAPTIVE RESEARCH

The FAO fertilizer program under the Freedom From Hunger Campaign (FFHC) was launched in Ethiopia in 1967. The main purpose of the program was to increase crop production through the efficient use of mineral fertilizers. During 1967-1969 180 on-farm trials were done on barley and satisfactory results were obtained (FAO 1979, NFIU 1988).

In the 1971 cropping season EPID conducted 173 fertilizer trials with barley using different levels of N, P, N/P and also one level of N/P/K (NFIU 1987, FAO 1979). The trials were unreplicated and the first design was a 3 x 3 factorial N/P while the second design was a 4 x 4 partial factorial. The results of these trials were similar to those of the results of the FFHC. In the 1972/73 cropping season the first design of the fertilizer trial was modified in such a way that all the single nutrients (N and P) were replaced by combinations of N and P. At the end of 1973/74 cropping season 109 trials were conducted under the second design. The results showed 11.4 kg grain per kg fertilizer at the level of 46 kg N and 46 kg P_2O_5 ha^{-1} (FAO 1979, NFIU 1987).

Based on these results, EPID made a general recommendation for all major cereal to use 100 kg DAP ha^{-1} and 50 kg urea ha^{-1} (41 kg N, 46 kg P_2O_5 and 0 kg K_2O ha^{-1}) (FAO 1979, IAR/ADD 1982, NFIU 1987). However, this recommendation was criticized as being too crude. Because of this argument, the IAR/EPID joint research program was established in 1974 (IAR/ADD 1982). The joint program continued until 1976-77. From 1978 to 1980 a strong resolution was passed by the participants of the National Crop Improvement Conference that IAR and the Agricultural Development Department (ADD) should form a strong linkage so that research results could reach the peasant farmers. Accordingly the IAR/ADD joint research program commenced with better co-ordination and stronger linkage on eleven sites.

Fertilizer rate determination

Since 1986, on 2.5 ha field trial sites four levels of N and P_2O_5 (0, 30, 60 and 90 kg ha^{-1}) were being used as standard design and conducted as factorial trials. In addition, the same treatments were compared in partial factorial trials in the 0.5 ha trial sites. An extra treatment of 60-60-30 kg ha^{-1} of N-P_2O_5-K_2O was added. Since 1988 the same treatments are being tested on farmers' fields.

Trials in Arsi, Shewa and Bale showed the highest N/P economic optimum rate at 21 kg N and 44 kg P_2O_5 ha^{-1} on red soils (yield increase of 851 kg ha^{-1}) and 29 kg N and 36 kg P_2O_5 ha^{-1} on brown soils (yield increase of 686 kg ha^{-1}). Across the country the highest N/P economic optimum rate was 20 kg

N and 45 kg P_2O_5 ha^{-1} for red soils (ADD/NFIU, 1989). Based on these results revised fertilizer recommendations have been made depending upon soil type and region (Table 4).

Table 4. Revised barley fertilizer recommendations (kg ha^{-1} of N-P_2O_5) by NFIU

Soil type/soil color	Regions (Arsi, Shewa and Bale)	Across the Country
Nitosols	25-45	30-45
Black soils	20-55	20-40
Red soils	20-45	20-45
Brown soils	30-35	25-30

Phosphate sources determination

The phosphate sources trial was conducted to examine the direct and residual effects of rock phosphate (RP) bone meal (BN) and triple super phosphate (TSP) on barley yield.

A total of 19 phosphate sources trials for barley were tested in sites across the country from 1986-1991. The response to phosphate was very good and the difference in yield increases was high between TSP and bone meal at the same levels of phosphate application. (ADD/NFIU 1989).

The productivity indices of phosphate in the form of TSP were 19.6, 17.0 and 9.4 kg grain/kg P_2O_5 at the levels of 23, 46 and 92 kg P_2O_5 ha^{-1} respectively. The productivity indices in the form of bone meal, however, were only 9.2, 8.5 and 5.1 at the levels of 25, 50 and 100 kg P_2O_5 ha^{-1}.

Yield response curves showed that the maximum yield increase of 524 kg ha^{-1} obtained by applying 90 kg ha^{-1} in bone meal was equivalent to 26 kg ha^{-1} P_2O_5 in TSP. Therefore, efficiency of bone meal is very low as compared with TSP. On the average a yield increase of 128 kg ha^{-1} was obtained by applying bone meal, but lower yield than this was observed from rock phosphate. Results also showed that the residual effects of both rock phosphate and bone meal were similar.

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Weed Control Research in Barley

Fasil Reda

Abstract

Multi-locational testing on yield loss assessment revealed that weeds can cause about 17% yield reduction in barley Weed competition was most critical during the first 30 days of crop establishment.

Timing of manual weeding was found important and the proper time for this operation being 30-35 days after planting. Barley gave highest yield when weeded early compared to mid and late season weeding.

Among the herbicides tested 2, 4-D and Linuron (both at the rate of 1 liter product ha^{-1}), Mecoprop (3 liter product ha^{-1}), Brittox (2.5 liter) and Chlorsulfuron (20 g) were effective on broad leaf weeds. Carbyne 2 (1 liter product ha^{-1}) performed better against wild oat. Dichlofop methyl (3.5 liter prod. ha^{-1}) and fenoxaprop-p ethyl (1 liter ha^{-1}) were similarly effective on important grass weeds such as *Snowdenia polystachia*, *Setaria pumila* and *Phalaris paradoxa*. Dichlofop methyl, however, showed weaker performance against *Phalaris paradoxa*.

It has been shown that there is a considerable advantage of using weed free seeds during planting. A yield difference of 17% was observed between clean and unclean seed treatments.

Weeds are significant production constraints in barley. Despite the importance of weeds, however, weed research has not received adequate attention and consequently there is a paucity of information on weeds and weed control in barley. This paper attempts to give an overview of weed control research activities carried out on barley.

Survey

Extensive weed surveys have been conducted in the major barley growing regions to collect and identify dominant weed species. Most common weeds were early maturing broad leaf species (Table 1). Representative collection of all important species in barley is placed in the Holetta Research Center Herbarium, which now contains more than 500 specimens.

Crop loss assessment and hand weeding trials

Average yield reduction of 17% was shown in experiments conducted over several years at Holetta and several other locations (Rezene 1985). There was a considerable variation among years and locations. Weed competition was most critical during the first 30 days of crop establishment.

Yield loss in barley from weed competition is caused by reduction in number of barley tillers, although in few cases competition could lead to smaller and fewer seeds per spike (Blandridge et al. 1985).

The most common weed control practice in Ethiopia is hand weeding. The proper time of hand weeding in barley is during the early crop establishment period.

Trials at Kulumsa and Holetta showed that yield increases obtained from an intensified weeding can off-set any additional labor costs (Rezene 1985). Earlier trials have also shown that herbicide use was far more cheaper than hand labor for weed control at 7 Birr ha^{-1} for MCPA (1.2 kg a.i. ha^{-1}) vs. 838 Birr ha^{-1} for labor on black soils and 40-60 Birr ha^{-1} on red soils (IAR, 1972/73).

HERBICIDE TRIALS

Usually barley displayed sensitive reaction to the test chemicals but, recovery was satisfactory as shown by yield.

Among the tested herbicides, Flourodifan, Maloran, and Basanor were consistently effective in the earlier trials of the 1970s (IAR 1971/72 and IAR 1972/73). Flourodifan was particularly effective in controlling broad leaf weeds and gave the best result on *Phalaris paradox,* although it was not so effective on *Snowdenia polystachia*. Other herbicides which gave promising results were Terbutrin and Linuron. Terbutrin showed superior performance in terms of weed control and yield increase during 1978 and 1979. However, this chemical did not control *Plantago lanceolata* late in the season (IAR 1978/79).

During 1980 to 1983 Linuron at 1.0 kg a.i. ha^{-1} (pre-emergence), MCPA at 0.7 kg a.i. ha^{-1} were highly effective (IAR 1980/81-82/83).

Most of the common broad leaf weed species were susceptible to 2, 4-D and MCPA. 2, 4-D is still by far the most widely used herbicide in Ethiopia, but it is rarely realized that timing of application is critical. Cereals have two periods of sensitivity to 2, 4-D, between germination and tiller stage and during the early boot stage (Muzik 1970).

Some important weed species were later found tolerant to 2, 4-D and MCPA. Following further tests Mecoprop and Brittox gave wide spectrum control (IAR 1984/85 and IAR 1986). Mecoprop particularly offered a good control of *Polygonum nepalense*, but was less effective against *Galium spurium*. The mixture of Dicamba plus Mecoprop at the rate of 2.07 kg a.i. ha^{-1} and Brittox at 0.7 kg a.i. ha^{-1} were effective on *Galium spurium*. Control of *Corrigiolla capensis* by Mecoprop was improved by mixing with Bromofenoxim in Faneron p650 F. Bromofenoxim clearly helped to overcome the weaknesses of Mecoprop on this weed, but not noticeably on others.

Because of its wide spectrum activity and safety to the crop Brittox was widely used as a standard broad leaf herbicide until the late 1980s, when it was restricted for human health reasons. New broad leaf herbicides were then evaluated for their potential to replace Brittox. A mix of Mecoprop and 2, 4-D at 1.5 liter and 1 liter ha^{-1}, respectively and Chlorsulfuron at 20 g ha^{-1} were highly effective and comparable to Brittox (IAR 1991).

Herbicide experiments were carried out to control wild oats in different IAR and ARDU sites. Carbyne 2E (1 kg ha^{-1}) applied at 4-5 leaf stage was found safe to the test crop and most effective against *Avena* spp. (Rezene 1985). Fenoxaprop-p-ethyl at 0.18, Pendimenthalin at 1.5, Linuron at 1.0, and Terbutryn at 2.0 (all kg a.i. ha^{-1}) offered good control of a range of grass weed species including *Snowdenia polystachia*, *Phalaris paradox* and *Setaria pumila* (IAR 1989/90). Diclofop-methyl was also found effective on most dominant grass species, though it was less satisfactory on *Phalaris paradox*. Glyphosate was found useful in areas infested with perennial weeds such as *Digitaria* and *Cynodon spp*. Glyphosate also appears the best in zero tillage systems.

Barely is sensitive to many herbicides and considerations of its tolerance to a given herbicide is required. Moreover, a herbicide may severely damage some cultivars and not others (Fryer and Makepeace 1978, Blandridge et al 1985). An experiment carried out at Holetta in 1991 and 1992 cropping seasons has shown that there was a clear difference in sensitivity between barley cultivars and some herbicides. All test entries responded favorably to fenoxaprop-p-ethyl, but declofop-methyl negatively affected seed yield of HB 32 and HB 523. Similarly, Linuron considerable reduced seed weight of HB 42, ARDU 12-60B, HB 99 and Beka (IAR 1991 and IAR 1992).

USE OF CLEAN SEEDS

The advantage of using clean seed was proved in an experiment, where a yield difference of 17% was obtained between pure and impure seed treatments (Rezene 1985). Use of clean seed in barley is particularly important for preventing the spread of noxious grass weed species such as wild oats, which has similar seed size and shape to barley.

CONCLUSION

Several herbicides effective against the major weed species in barley are available. However, herbicide research has to continue in line with the rapidly growing population and an increased pressure on land. New chemicals will continue to be required for future weed problems which are certain to arise with further changes in agricultural practices, land and water management.

The weed flora will be in continuous change due to increased fertilizer, herbicide usage, changes in cropping pattern which would favor some weeds at the expense of others.

The effective use of control measures, whether cultural or chemical, requires an appreciation of the biological characteristics of weeds. Types of weeds, life cycle, germination time, depth of emergence are some important factors that need to be understood.

It is also important to note that in farming, weed control measures seldom work in isolation and that many other factors influence the success of control measures and weed populations. Therefore, all the factors that may influence weed control practices should be considered.

Mostly, while trying to solve a given weed problem, considering complementary measures is important for better results. All control and husbandry measures should be employed to create an environment which favors barley and disfavors weeds.

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Table 1. Dominant barley weeds in Ethiopia

Botanical name	Family
Hygrophile auriculate	Acanthaceae
Amaranthus spp.	Amaranthaceae
Cerastium octandrum	Caryophylaceae
Corrigrola capensis	Caryophylaceae
Sclerannthus annus	Caryophylaceae
Spergula arvensis	Caryophylaceae
Chenopodium spp.	Chenopodiaceae
Cyanotis barbata	Commelinaceae
Bidenns spp.	Compositae
Carduus spp.	Compositae
Cersium vulggare	Compositae
Cotula abyssinica	Compositae
Echinops macrochantus	Compositae
Galinsoga parvitlora	Compositae
Gnaphalium unions	Compositae
Guizotia scabra	Compositae
Erucastrum arabicum	Crucifereae
Cyperus spp.	Cyperaceae
Euphorbia spp.	Euphorbiaceae
Agrostis spp.	Graminae
Andropogon spp.	Graminae
Avena spp.	Graminae
Bromus spp.	Graminae
Cynodon spp.	Graminae
Digitaria spp.	Graminae
Eragrostis spp.	Graminae
Hyparrhenia spp.	Graminae
Pennisetum spp.	Graminae
Phalaris spp.	Graminae
Poa spp.	Graminae
Setara pumila	Graminae
Snowdenia polystachya	Graminae
Leucas spp.	Labiateae
Medicago spp.	Leguminaceae
Trifolium spp.	Leguminaceae
Oxalis spp.	Oxalidaceae
Plantago spp.	Plantaginaceae
Polygonum aviculare	Polyggonaceae
Polygnum nepalense	Polyggonaceae
Rumlex spp.	Polyggonaceae
Anagallis arvensis	Primulaceae
Galium spurium	Rubiaceae

Disease Surveys and Loss Assessment Studies on Barley

Yitbarek Semeane, Bekele Hundie, Getaneh Woldeab and Dereje Tadesse

Abstract

In Ethiopia 23 fungi, 2 bacteria, 2 viruses and 9 nematodes have been found on barley Early surveys identified smuts and rusts as the most important barley diseases and blotches of potential importance. Currently blotches are the most threatening diseases of the crop. Viral diseases were less frequent, currently up to 5 serotypes of BYDV are reported. Host range studies are limited to leaf rust. Inoculation tests in glass house using uredospores from grass and broad leaf weeds resulted in a non pathogenic response. Therefore, the rust was pathogenic only on the reported host as observed in the field.

Studies on pathogen variability are limited to rusts and scald. So far four races are reported for *Puccinia graminis* and two races for *P hordei*. In *Rhychosporium secalis* about 19 pathotypes are recognized. Scald and netblotch cause a yield loss of up to 67% and 34%, respectively

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Early research on barley diseases emphasized surveys and documentation of diseases, establishing the economic importance of most frequently observed diseases and development of control measures.

SURVEY AND IDENTIFICATION

Surveys on the incidence and importance of infectious agents on barley were initiated in the early 1960s. These activities lacked continuity and the information is scanty and inconclusive. So far, 23 fungi, 2 bacteria, 2 virus and 9 nematodes are recorded (Table 1). Out of these 11 fungi, 1 bacterium and all nematodes were reported by Stewart and Dagnachew in 1967 (38).

Disease surveys during 1968 to 1972 in the Arsi region reported 8 diseases (5,7,9). Among these leaf rust, scald, spot blotch, covered and loose smuts were listed as important.

An observation was made to estimate the distribution of covered smut in 6 locations of the Arsi region (9). The disease was well distributed in all locations with 33 to 70% smut infected seed.

Surveys carried by the Scientific Phytopathological Laboratory (now PPRC) during 1975 to 1978, indicated scald and barley stripe as the most severe diseases in Shewa, Arsi, Bale, Welega, Sidamo and Harerge. Powdery mildew with an incidence of about 60% was observed in Harerge (27). About

10-15% loose smut was recorded in the major barley growing regions during 1975 (27), in contrast to 25% in Gasobilay region of Welo (30,32). Up to 40% leaf rust incidence was recorded in some fields in Arsi, Welega, Gojam and Shewa (30,32). Epidemics of leaf rust were recorded in Ambo, Shashemene and Jima in 1982 (33). Both loose and covered smuts were severe in Arsi and Shewa regions during the same year. In addition blotches were severe while scald was slight in western Shewa.

Between 1980 and 1983, surveys were made to document the distribution and importance of the three helminthosporium leaf diseases. Spot blotch was found to be the most widely distributed disease of barley in the Arsi, Bale and Shewa regions (16,17). Although the distribution of net blotch was limited in some locations of the above regions, it occurred in severe condition in others. More recent work showed that net blotch was the most widely distributed and important disease of barley in the Arsi and Bale regions (40).

After a severe epidemic of ergotism in the western Welo region in 1980 a study was initiated to know the distribution of the disease, to identify focuses of infection and to come up with recommendations on control (31). The conidial stage of ergot was recorded on wild oat. Sclerotia were found in barley seeds from several places in western Welo, around Ambo and in areas of Arsi and Bale. Level of infection in the field varied from 10-80% (honey dew) and 2-10% sclerotia. Subsequent surveys in production fields of Arsi and Bale showed 5-60% infestation by wild oats (39).

Surveys to quantify barley diseases in the Shewa region showed that scald and net blotch followed by leaf rust were the major diseases (Table 2). Out of 189 fields sampled between 1988 and 1992, scald was observed on 131 fields with a mean incidence and severity of 64 and 31%, respectively. Net blotch was observed on many fields with incidence and severity of 71 and 33%, respectively. Scald was more evident at research centers and on locations from Holetta to Gohatsion, while net blotch and leaf rust were dominating from Holetta to Gedo.

Similar work in the northwestern regions of Ethiopia reported 11 fungal diseases on barley (6,20) (Table 3). Scald followed by spot blotch, net blotch and loose smut were the most widely distributed barley diseases. Out of the 186 fields sampled, scald was observed on 148 fields. Incidence and severity of scald ranged from 5 to 100% and 3 to 61%, with a mean of 13.7 and 47.6%, respectively. Moreover, root rot (*Sclerotium rolfsii*) was observed as an important disease of barley grown on residual moisture . *Septoria* spp. (*Septoria nodorum* and *Septoria passerinii*) and powdery mildew were observed as minor problems in the region.

During disease surveys from 1988 to 1993 in the Bale highlands 14 fungal and 1 viral diseases were identified (18, 22). Net blotch, spot blotch, leaf rust and scald were the most widely distributed, in order of importance.

Incidence and severity of net blotch, leaf rust and severity of scald showed considerable variation between seasons in the central region (Table 4). The incidence and severity of scald and net blotch did not vary considerably between locations but rust did. Attempts were made to observe the relationship between environmental factors and the incidence and severity of the above diseases (Table 5). Scald was significantly influenced by farm type, topography, growth stage of plants and number of tillers. Net blotch was influenced by topography, growth stage of plants and field size. Leaf rust was influenced by altitude, drainage and plant number.

Surveys to record the distribution of bacterial stripe were conducted at experiment and production fields in Gojam, Gonder, Shewa, Bale, Arsi and Welega regions (36, 37). Infections were between 10 and 20%. Studies on culturing, morphological, biochemical and pathogenicity properties led to the identification of *Xantomonas campestris pv. translucens*. In a cross inoculation test the organism was pathogenic to wheat, sesame, tomato and cabbage. A new disease with a maceration symptom on the pedicle was observed during the 1986 and 1987 crop seasons at Holetta Research Center with an infection level of 3-5%. A bacterium, *Pseudomonas* was identified as its cause.

Prevalence of barley yellow dwarf virus (BYDV) was surveyed from 1984 to 1986 in major cereal growing regions (3,34,35,36). Positive ELISA reaction with antibodies to PAV and MAV isolates of BYDV were obtained from wheat and barley samples from Bekoji and Herero, while samples from Gofer possibly contained only PAV related virus. None of the samples displayed a positive ELISA value to RPV. The incidence of the disease was higher in 1986 than 1985, where typical yellow patches covered up to 40-50% of farmers' fields in locations along the highlands of the Shewa and Welega regions (4,36). The symptoms were more evident at higher altitudes (2700 to 2900 m), although it was observed at Kulumsa (2200 m) with an incidence of 7-15%.

Similar attempts were made in 1985-86 and 1988-89 growing seasons in the highlands of Arsi, Bale, Shewa, Gojam, Gonder, Harerge and Welega (42). BYDV was prevalent between 1800 and 3000 m altitude on wheat, barley and oats in Shewa, Arsi and Bale regions. This was confirmed by direct and indirect ELISA tests using antibodies against the PAV and MAV isolates of BYDV. Although it was not confirmed serologically, symptoms of the virus were observed on cereals in Gojam, Gonder, Harerge and Welega.

Subsequent work in the Arsi and Bale highlands suggested the presence of a range of serotypes of BYDV. Out of 88 samples collected from seven locations of wheat, barley, oats and triticale, PAV was found to be the most dominant serotype. In contrast to the previous studies all the five serotypes of BYDV (PAV, MAV, RMV, RPV and SGV) were found on barley.

PATHOGEN VARIABILITY

Studies on pathogen variability were started in the early 1960s. Four races, 11, 34, 53 and 117, were identified from *Puccinia graminis* samples collected near Holetta. Similar work on *Puccinia hordei* samples from Finote Selam, Debre Zeit, Addis Abeba, Fiche and Holetta showed the presence of races 77 and 184. For the first time race 184 was isolated from Finote Selam and Holetta samples.

Attempts were made to identify inoculum sources of rust (28, 29). Based on observations during the off-season, it was assumed that the year-round presence of host-plants is a potential source of inoculum for all rusts.

Variability in the pathogen population of *Rhynchosporium secalis* was assessed using differentials and commercial varieties in the field. Variability existed between locations as well as seasons (Table 6). All the differentials showed infection toward the end of the season in one or more locations. Study on isolate variability of *Rhynchosporium secalis* indicated presence of variation among isolates (23). Twenty-four isolates from Arsi, Bale and Shewa were tested on 10 differentials yielding 19 pathotypes. Among these, pathotype 6 was the most frequent at most locations. The most complex pathotypes were obtained from research stations, while the least complex were from farmers' fields. Variation was present among isolates from the same field and from the same geographical locations.

HOST RANGE

Attempts were made to examine the host range of barley leaf rust in the country. In 1987 a grass weed (*Snowdenia polystachya*) and a broad leaf weed (*Rumex* spp.) were infected with rust collected from these weed species in Gojam and Bale (37). No symptoms were found on either weeds on barley seedlings. On the other hand , the same set of seedlings inoculated with uredospores of a barley leaf rust population from Ambo showed no infection on the weed species. Therefore, it can be concluded that the rusts found a both species were not the same as barley leaf rust and that these weeds are not hosts to *Puccinia hordei*.

LOSS ASSESSMENTS

Studies on yield losses of barley due to some important fungal agents were carried out for the past 15 years. Among the diseases scald caused a yield reduction of 21-67% for different seasons and cultivars (12, 14, 15, 17). Net blotch caused up to 34% yield loss (41).

A preliminary loss assessment study due to eye spot at Holetta indicated that loss could range from 0.6 to 8.5% depending on year and cultivar (11). Losses due to leaf and stripe rust ranged from 2.4 to 21.8%, respectively (6, 14, 17). Results on rusts were not conclusive because of interference by other leaf diseases. Studies at state farms on scald and net blotch using the variety Proctor showed a loss at Herero (Bale) of 8.1% in grain yield and of 21.1% in grain weight (MSFD unpublished). At Lole (Arsi) loss ranged from 10.1 to 28.4% in grain yield and 11.3 to 20% in thousand grain weight for different years.

CONCLUSION

Although work on barley disease surveys and loss assessments is relatively recent in Ethiopia, very useful results have been achieved. A large number of pathogens are reported. Moreover, shifts in importance of diseases has also been demonstrated. Efforts to determine the economic importance of diseases have been limited. Threshold levels for any diseases have not been determined. More studies on variability within pathogens populations are necessary to refine the breeding of barley for higher levels of disease resistance.

Table 1. Barley diseases recorded in Ethiopia.

Pathogen	Disease	Ref
Seed and weakly pathogenic fungi		
Alternaria alternata (Fr.) Keissler		1
Cladosporium cladosporoides (Frensen) de Vries		38
Cochliobolus sativus (Ito & Kuribayashi)		1
Drechslera sorokiniana (Sacc.) Subram & Jain		1
Epicoccum purpurascens Ehrenb. ex Schlecht		1
Hendersonia culmicola Sacc. Var. Minor Sacc.		1
Mildews		
Erisyphe graminis DC (f.sp. hordei)	Powdery mildew	38
Blotches and blights		
Helminthosporium gramineum Rabh. (conidial *Pyrenophora graminea* Ito & Kurib)	Stripe disease	2,38
Helminthosporium sativum Pam., King & Bakke (conidial *Cochliobolus sativus* (Ito & Kurib.)	Spot blotch	2,38
Helminthosporium teres Sacc (conidial *Pyrenophora teres* Drechs.)	Net blotch	2,38
Rhynchosporium secalis (Oud.) J.J. Davis	Scald	38
Septoria graminum Desm.	Leaf spot	38
Septoria passerinii Sacc.,	Speckled leaf blotch	38
Root or crown diseases		
Rhizoctonia solani (Kuehn)	Sharp eyespot	?
Pseudocercosporella herpotrichoides (Fron)	Dei Eye spot	14
Sclerotium rolfisii Sacc.	Root rot	38
Rusts		
Puccinia graminis Pers.	Stem rust	38
Puccinia hordei Otth	Leaf rust	38
Puccinia striiformis West	Stripe rust	38
Smuts and head diseases		
Fusarium hetrosporium Noes & ex Fr.	Head blight	1
Ustilago hordei (Pers.) Lagerh.	Covered smut	2,38
Ustilago nigra Tapke	Loose smut	2
Ustilago nuda (Jens.) Rostr.	Loose smut	2,38
Bacterial Diseases		
Pseudomonas sp.		36,37
Xanthomonas translucens (L.R. Jones, A.G. Johnson, and Reddy) Dows.	Bacterial blight	2,38
Viral diseases		
Stripe mosaic virus		38
Yellow dwarf virus	Yellow dwarf	38
Nematode diseases		
Helicotylenchus spp.		24,26
Longidours sp.		24
Pratylenchoides spp.		26
Pratylenchus spp.		24,26
Rotylenchulus spp.		24,26
Scutellonema sp.		24
Trophurus sp.		24
Tylenchorhynchus spp.		24,26
Tylenchus spp.		24

Table 2. Major barley diseases observed in Shewa region during 1988-1992 crop season.

Diseases	No. of fields infected	Number of fields with disease on route*				Average	
		1	2	3	4	incidence	severity
Scald	131	76	30	23	2	64.3	31.2
Netblotch	130	60	47	22	1	70.5	32.9
Leaf rust	90	42	36	11	1	68.4	22.1
Covered smut	40	21	9	10	-	2.1	
Spot blotch	35	28	5	2	-	53.3	10.3
Loose smut	22	12	7	3	-	7.5	
Barley stripe	16	15	1	-	-	6.9	

Source: Holetta Research Center (unpublished)

*Routes: 1. between Holetta and Gohatsion, 2. between Holetta and Gedo/Woliso, 3. between Holetta and Debresina and 4. Holetta Research Center

Table 3. Major barley diseases observed during 1988-1992 in Northwestern Ethiopia.

Disease	No. of fields infected	Percent fields infected	Mean percent incidence	Mean percent severity
Scald	148	79.6	47.6	13.7
Spot blotch	123	66.1	37.2	7.1
Net blotch	92	49.5	47.2	6.0
Leaf rust	72	38.7	22.0	6.0
Loose smut	73	39.2	8.5	8.5
Covered smut	54	29.0	3.3	3.3
Barley stripe 33	17.7	8.8	8.8	

Source: Adet Research Center (unpublished)

Table 4. Effect of season and location on the incidence and severity of some important diseases of barley in Shewa region

	Scald		Net blotch		Leaf rust	
	Inc.	Sever.	Inc.	Sever.	Inc.	Sever.
Year						
1988	66.8	27.7ab*	62.3a	21.4a	72.7bc	28.8b
1989	68.8	31.7abc	67.5ab	20.7a	66.3b	19.8ab
1990	43.8	50.1c	91.0b	68.1b	89.1c	27.3b
1991	50.6	17.5a	53.3a	10.8a	33.3a	6.3a
1992	78.6	40.0ba	83.1b	54.6b	64.7b	18.6ab
Location**						
1	58.9	26.4	66.1	30.6	62.8ab	14.7ab
2	66.5	35.2	71.5	24.9	80.0abc	30.9bc
3	76.5	39.5	80.9	56.6	55.4ab	23.4abc
4	100.0	55.0	60.0	10.0	50.0a	5.0a

Source: Holetta Research Center (unpublished)

* Means followed by the same letter within a column of a factor are not significantly ($P=0.05$) different as determined by LSD. ** Locations: 1. between Holetta and Gohatsion, 2. between Holetta and Gedo/Weliso, 3. between Holetta and Debresina and 4. Holetta Research Center

Table 5. Correlation between some environmental factors and incidence and severity of some important diseases in Shewa region 1988 to 1992

Scald	Net blotch		Spot blotch		Leaf rust		Barley stripe	Loose smut	Covered smut
	Inc.	Sev.	Inc.	Sev.	Inc.	Sev.	Inc.	Inc.	Inc.
Altitude(m)	0.06	-0.05	-0.13	0.07	-0.46**	-0.07	-0.26*	-0.31**	-0.15
Farm type	0.14	0.22*	-0.00	-0.01	0.04	0.09	0.11	0.02	
Topography	-0.14	-0.25**	-0.19**	-0.25**	-0.07	-0.23	-0.2	0.08	-0.06
Drainage	0.05	0.09	-0.00	0.02	-0.26	0.23	0.16	0.22*	0.08
Field size	0.12	0.09	-0.19*	-0.11	-0.10	0.29	0.03	-0.03	0.27
Growth stage	0.07	0.17*	0.35**	0.26**	0.45**	0.25	0.19	0.20	0.06
Plant number	-0.15	-0.24*	0.12	-0.01	-0.06	-0.09	0.07	0.28**	-0.40**

Source: Holetta Research Center (unpublished)

* and ** are significant at P=0.05 and P=0.01, respectively

Note:

1. Farm type:	1 - Farmers,	2 - Research station	
2. Topography:	1 - Level,	2 - Gentle slope,	3 - >10%
3. Drainage:	1 - Poor,	2 - Well,	3 - Good

Table 6. Reaction of barley differentials to scald during 1990 and 1992 crop seasons.

Differentials or Cultivars	1990 Holetta	1990 Adet	1990 Enjibara	1990 Bekoji	1992 Holetta	1992 Adet	1992 Enjibara	1992 Bekoji	1992 Debre Tabor
Gebrel	0	0	5	51	11	02	51	N	
Pirate	42	10	4	51	13	0	35	41	N
Tipper	31	5	5	42	22	2	20	32	N
Pipkin	21	2	10	43	32	0	10	32	N
Astrix	52	5	6	41	21	3	10	41	N
Athene	0	4	4	41	21	1	5	41N	
Igri	0	2	0	0	21	0	0	21	N
Hoppel	0	5	3	0	11	1	40	N	N
Osiris	0	0	0	0	11	0	0	51	N
Digger	62	20	30	61	95	5	3	87	0
Maris Mink	85	30	35	76	88	30	35	96	30
La Mesita	88	25	30	89	98	10	50	96	40
Armella	88	10	8	67	88	35	40	95	10
Trebi	88	30	35	72	94	20	40	94	15
Jet	84	20	15	61	94	5	20	93	5
Kitchin	84	25	20	51	96	10	30	83	0
Steudelli	99	35	4	72	98	2	30	97	0
Bay	88	30	10	97	88	2	25	83	0
Atlas 46	88	25	5	98	97	5	20	96	0
Modac	87	20	20	82	85	4	50	82	5
Forrajera	72	5	5	0	64	15	30	81	0
Nijrinudum	85	15	10	62	84	4	30	92	3
Turk	51	10	5	73	21	0	10	82	5
Ardu-12 -8c(check)	99	30	35	88	98	20	50	97	25
HB 42	0	0	0	0	21	0	0	71	0
Ardu-12-60B	52	0	0	0	11	0	20	61	0
Proctor	88	30	45	78	94	40	60	40	

Source: IAR (1992); Mehariw Genet (1993)

Disease rating at Holetta and Bekoji was on 0-9 double digit

but at Adet and Enjibara was on percent infection

N - Not planted

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Barley Disease Management Research

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Abstract

Different planting dates aimed at reducing the severity of scald and effect of seed sources on the incidence of barley stripe and loose smut were studied.

Seed dressing fungicides such as Vitavax 200 WP, Thiram 25/BHC25, Vincit, Baytan universal and Prelude universal effectively reduced seed borne diseases, while Tilt 250 EC, Sportak sigma and Sportak 45% EC controlled foliar diseases.

From disease screening trials on local and exotic barley germplasm/lines several lines were found resistant to scald.

The earliest barley disease management trial in Ethiopia was on seed dressing fungicides conducted at CADU in 1969. Later, many similar activities were carried out by different research centers and the Ministry of State Farms Development. Trials on foliar fungicides were conducted at Holetta, some State Farms and Sinana Research Center. A few experiments were also done on cultural disease control and host resistance. Results of several barley disease management research are reviewed in this paper.

DISEASE CONTROL

Planting dates

Among the different planting dates tested to reduce the incidence of scald at Holetta, planting susceptible cultivars until mid June resulted in severe incidence and high yield losses. Yield losses were 31% for 12 June planting and 43% for 15 June planting, while minimum losses were recorded on cultivars planted on 27-30 June (5, 6).

Seasonal effect on infected seed sources

Barley seeds harvested in the off-season and grown during the main season reduced the incidence of barley stripe by 91.3% and loose smut by 99.5% as compared to seeds produced in the main season in 1990 and 1992. Planting off-season produced-seed during the main season also increased yield by 2.7 q ha^{-1}.

Chemical control

The fungicides Benlate WP, Denosal WP, Brassicol 75 WP, Vitavax 200 WP and Thiram 25/BHC were studied to control seed micro flora under laboratory condition (MAFD unpublished). Mean percentage of barley seeds with fungus growth were significantly reduced in all treatments compared to the check. Vitavax 20 WP and Thiram 25/BHC were better than other treatments, but had some phytotoxic effect on seedling growth.

Seed dressing fungicides; Vitavax/prochloraz, Vincit, Baytan universal, Prelude universal and Agrosan "H" applied at 3 different dates before planting were assessed against loose smut and leaf stripe at Adet. All fungicides except, Agrosan controlled loose smut by 82-99% and barley stripe more than 98% at 10,30 and 90 days of seed dressing before planting. The efficacy of Agrosan was also high on barley stripe and low on loose smut. All fungicides except Baytan universal at 90 days before planting stimulated the growth of seedlings.

In 1992, Tilt 250 EC was sprayed to control helminthosporium leaf blotch at a rate of 0.5 l ha^{-1} at different plant growth stages at Sinana. The result revealed that one application at stem elongation and another at ear emergence controlled the disease and gave a yield of 51.3 q ha^{-1} (12).

Out of 8 foliar fungicides tested against net blotch at Herero and Lole state farms, Tilt 250 EC, Sportak sigma, Sportak 45% EC and Alto 100 SL lowered disease severity and increased yield and kernel weight significantly as compared to the check (Table 1) (13).

Effective fungicides screened between 1969 and 1983 for controlling seed-borne and foliar diseases are presented in Table 2.

Host resistance

Among the 500 entries evaluated for resistance to scald HB-114, HB-115 and HB-116 were resistant (9, 10, 14). In a different set of study, EH/538/F-12-6-2, Beka, EH 270 B/F-4B-11-5B-5, HB-7 and 2 other lines were found tolerant to scald (Table 3) (9, 10, 14, 15). In another experiment, 150 entries consisting of landraces and some commercial food and malting barley varieties were tested at 8 locations. Across the test sites entries were infested 90% by leaf rust, 61% by spot blotch, 62% by scald and 53% by net blotch. Adet and Lole were the most favorable areas for the development and spread of these diseases (11). Although most of the varieties and landraces were susceptible to different diseases, some of them were resistant to leaf rust (Table 4) and others to scald and net blotch (Table 5).

CONCLUSION

The vast majority of farmers are still using local varieties, and have no means to increase input. To increase barley yield emphasis should be given to cultural control measures as they are cheaper than fungicides. Research should also focus to identify resistant and low input requiring varieties.

Table 1. Effect of fungicide treatment on net blotch at Herero and Lole state farms during 1988-1989.

Treatment	Rate (kg/lt ha^{-1})	Severity (%)	1000 kwt (g)	Yield (q ha^{-1})
Impact 12.5% SL	1.0	30.5	31.0	27.6
Bayfidan 850 EC	0.5	33.3	31.0	33.1
Sportak sigma	1.0	9.7	32.8	42.4
Bravo carb	2.0	50.0	30.0	26.3
Alto 100 SL	0.8	22.2	31.8	40.9
Sumi 8	2.0	27.8	33.0	38.6
Tilt 250 EC	0.5	13.9	33.8	41.7
Sportak 45% EC	1.0	12.5	31.5	43.7
Control	-	58.3	27.5	29.4
Mean	-	28.7	31.6	36.0
SE ±	4.3	0.8	2.4	
LSD 05	12.5	3.5	6.9	
CV %	29.8	5.3	13.6	

Source: (13)

Table 2. Effective seed dressing and spray fungicides against major seed-borne and foliar diseases, 1969–1983.

Product	Type(s)	Disease(s)	References
Thiram	Seed dressing	Covered smut	1,2,3
Mercury	Seed dressing	Covered smut	1,2,3,
Quintozene	Seed dressing	Covered smut	1,2,3,
Voroniz	Seed dressing	Covered smut	1,2,3,
Carboxin	Seed dressing	Loose smut	3,4,
Etem (maneb)	Foliar spray	Scald	5
Tridemorph (calixin)	Foliar spray	Scald + Helm.	7
Benlate 50	Foliar spray	Leaf diseases	7
Tridemorph + Benlate	Foliar spray + seed dressing	Leaf diseases	8,9
Benlate + Agrosan	Foliar spray + seed dressing	Leaf diseases	8,9
Propiconazole (tilt) 250 EC	Foliar spray	Scald	8,9
Triadimefon (bayleton)		Foliar spray	Scald8,9
Chlorothalonil (bravo 500)	Foliar spray	Scald	8,9
Flutriafol (impact)	Foliar spray	Spot blotch	8,9

Table 3. Development of scald as AUDPC at middle plant part and yield of cultivars at three sites, 1990.

	AUDPC			Yield (q ha-1)		
Cultivar	Holetta	Bekoji	Adet	Holetta	Bekoji	Adet
Proctor	3255b	2813a	1525a	18.2e	34.3ef	14.9efg
Beka/s	0e	0f	224efg	18.4e	34.4ef	23.3bcd
Holkr	217e	141ef	282def	29.9abcd	44.0abcd	27.6ab
HB-52	1076d	1555b	724c	23.5de	37.9cdef	22.2bcd
Balkr	240e	25f	265def	30.2abcd	37.9cdef	22.7bcd
HB-68	1864c	558cd	952b	20.4e	38.9cdef	13.3fg
AHOR 880/61	2e	62ef	52g	31.8abc	38.0cdef	9.3g
ARDU-12-60B	0e	0f	343def	19.6e	49.9a	25.8abc
ARDU-12-9C	7e	0f	435de	31.8abc	41.6bcde	20.7cd
IAR/H/485	1856c	16f	942b	23.8cde	43.1abcd	21.5cd
HB-7	0e	635c	349def	25.8bcde	39.9bcdef	29.3a
HB-15	12e	0f	224efg	24.3cde	36.6def	23.9bcd
HB-42	0e	312de	211fg	29.9abcd	47.9ab	23.3bcd
HB-100	157e	319e	461d	33.4ab	45.8abc	22.4bcd
HB-99	0e	231ef	413def	36.6b	38.7cdef	18.9de
ARDU-12-8C	3862a	2785a	1463a	7.4f	32.1f	13.3fg

Means in column followed by the same letter are not different (0.05) as determined by Duncan's Multiple Range Test

AUDPC – Area under disease progress curve

Source: PPRC (unpublished)

Table 4. Reaction of barley varieties and accessions to leaf rust in 1989

Variety	Location and altitude (m) Ambo 2225	Adet 2240	Herero 2350	Sinana 2400	Holetta 2450	Lole 2480	Diksis 2650	Sheno 2700	Max.infection (%)
Composite 29	20S	10MR	80s	5MS	5s	20MS	10MS	5MR	80S
ARDU-12-60B	0	tR	30Ms	0	5MS	10MR	5MS	0	30MS
HB-100	5MS	5MR	40Ms	5R	5MR	10MS	5MS	0	40s
Sheno-bulk	80s	tr	60s	10MS	0e	20MS	10MS	5MS	80MS
Beka	10Ms	tr	40s	5MR	5MS	5MR	0	5MR	40s
Proctor	5MR	tr	60s	5R	0	5MS	5MS	0	60s
Holkr	tr	tr	30MS	5R	0e	5MR	tMS	0	30MS
Balkr	5s	tr	20MS	tR	0e	5MR	0	0	20MS
HB-122	5MR	10MB	0	0	0	0	5MR	10MS	10MS
IAR/H/485	30s	10MR	60s	5MR	10MS	10MS	20MS	5MS	30s
PGRC/E accessions									
202536	30s	tr	20s	5MR	0e	10MS	5MS	5R	30s
202602	10s	tr	30s	5MS	5MS	10MS	40MS	5MS	40MS
202603	tR	tr	40s	5MR	5MS	10MR	10MS	5MS	40s
202611	30s	20MR	0	5MS	5MS	5MS	40S	5MS	40s
202626	10MS	tr	40s	5MR	5MS	10s	30S	5MR	30s
202627	5MS	5MR	20s	10MS	5MS	10MS	20MS	5R	20MS
202652	30s	tr	0	0	0	0	5R	0	30s
202636	5MR	tr	40s	5R	0e	10MS	40MS	tR	40MS

Source: (11)

Table 5. Reaction of food and malting barley varieties to blotches and scald, 1989

Variety	Ambo SB	Ambo NB	Ambo SC	Adet SB	Adet NB	Adet SC	Herero SB	Herero NB	Herero SC	Sinana SB	Sinana NB	Sinana SC	Holetta SB	Holetta NB	Holetta SC	Lole SB	Lole NB	Lole SC	Diksis SB	Diksis NB	Diksis SC	Sheno SB	Sheno NB	Sheno SC	Max. infection 0-9 scale SB	Max. infection 0-9 scale NB	Max. infection 0-9 scale SC
Composite 29	6	2	0	9	9	0	2	3	0	2	0	0	1	0	4	7	2	0	2	0	2	1	1	0	9	9	4
ARDU-12-60B	7	0	0	9	9	0	1	3	0	1	0	0	1	0	1	5	2	0	4	1	0	1	1	1	9	9	1
HB-100	6	0	0	9	8	0	2	2	0	1	1	0	1	0	1	6	1	0	2	1	0	1	1	5	9	8	5
Sheno-bulk	3	0	0	9	9	9	1	3	0	2	1	0	0	0	5	6	2	0	2	1	0	1	2	3	9	9	9
Beka	5	0	0	9	9	0	1	1	0	1	1	0	1	0	1	6	2	0	4	1	0	1	0	1	9	9	1
Proctor	8	0	0	9	5	9	2	1	6	1	0	0	0	0	7	5	1	3	2	1	2	0	0	4	9	5	9
Holkr	7	0	0	7	9	0	1	2	0	2	1	0	1	0	6	5	1	0	3	1	1	1	1	1	7	9	6
Balkr	6	0	0	9	9	0	2	2	0	2	2	0	2	0	5	4	1	0	3	1	0	0	0	1	9	9	5
HB-122	**-	-	-	9	8	4	4	2	0	-	-	-	1	0	4	7	2	0	3	0	0	0	0	1	9	8	4
IAR/H/485	6	0	0	9	9	0	1	4	0	1	1	0	0	1	2	6	3	0	2	2	0	1	1	2	9	9	2

* SB = spot blotch, NB = net blotch and SC = scald

** = missing

Source: PPRC unpublished

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Use of barley landraces in breeding and selection program aimed at low input environments: the Syrian experience

Joop van Leur, Stefania Grando and Salvatore Ceccarelli

Abstract

Most farmers in Syria and other west Asian countries, north Africa and Ethiopia are cultivating barley landraces using minimal levels of inputs. Improved germplasm must be developed, to realize full profit from production inputs invested by the farmer Because better plant development is positively associated with disease development, new germplasm needs greater disease resistance than landraces presently grown by farmers. Lines may be selected from the local germplasm that have adequate disease resistance and are adapted both to local climate and to improved practices. What is most important is that, the use of homogeneous lines should be avoided.

BARLEY CULTIVATION AND STATUS OF BARLEY DISEASES IN SYRIA

Barley was domesticated in West Asia and has been of primary importance since the advent of settled agriculture. In West Asia and North Africa barley, grain and straw, is mainly used as cattle feed. Nearly all barley cultivated in the Syrian Arab Republic (SAR) is rainfed. The recent increase of the barley production (Table 1) is mainly caused by sowing barley in steppe lands that were formerly used for grazing. Previous decline in barley yields can partly be explained by the unfavorable growing conditions of recently cultivated lands. Drought and cold are also main yield limiting factors. Because of the high probability of crop failure, farmers hesitate to invest in fertilizer or other inputs that may increase production (Cooper et al. 1988). Except mechanized field preparation and harvesting, most farming practices have not changed much over several centuries. Many farmers save their own seed and improved varieties occupy a negligible part of the total area.

Farmers' fields are rarely free of diseases. Among the leaf pathogens scald *(Rhynchosporium secalis)* and powdery mildew *(Erysiphe graminis)* may reduce yields, especially in areas or seasons with high rainfall. Net blotch *(Pyrenophora teres)* is rarely a problem. First infections of leaf rust *(Puccinia hordei)* usually appear too late in the season to cause a significant damage. Dryland root rot caused by *Cochliobolus sativus* and *Fusarium spp.*, is present throughout the barley growing areas, but are only important in the drier zones. Seed-borne diseases like covered smut *(Ustilago hordei)* and barley leaf stripe *(Pyrenophora graminea)* are common in barley fields, as farmers do not use fungicides to dress barley seed.

Severity of the different diseases are seldom high enough to cause yield losses. This is partly because of unfavorable environment, especially for leaf diseases that require a high humidity and/or mild temperatures. This can be explained partly by the poor nutrient status of the soil. The effect of disease resistance of the landrace populations has been underestimated, but became obvious after new varieties with inferior resistance were tested on large scale trials.

Barley landraces and disease resistance

Perhaps the most important factor in the sustainability of traditional farming systems are the local varieties that were selected over many generations under different stresses. Certain authors recognize that: "Landraces will yield something despite biotic and abiotic stress factors, have an excellent general fitness for local conditions and wide spectrum resistance to diseases in the region" (Harlan 1976). Others view landraces as susceptible to diseases and see this characteristic as one of the factors that limits the potential yield (Ruttan 1989).

ICARDA's barley project began to systematically evaluate barley landraces from Syria and Jordan in 1984. Single head progenies from collections of different sites were evaluated for agronomic characteristics (Ceccarelli et al. 1987) and for disease resistance (van Leur et al. 1989). High diversity in all characteristics studied was found among and within collection sites. Certain characteristics showed differences between regions, which could be related to differences in the local environment. Field tests were conducted during the 1989-90 seasons to investigate local differences with a large number of lines. A total of 25 collection sites, each represented by 20 single head progenies were evaluated. The collection sites were from five regions with distinct environmental characteristics. Winter temperatures decrease from southern Jordan towards northeastern Syria. Rainfall is higher in western Syria and lower towards the center of the country. A relationship between environmental conditions of the collection sites and level of disease resistance of the germplasm collected was demonstrated for powdery mildew and scald (Figure 1). Powdery mildew resistance was more frequent in materials collected in the warmer areas of Jordan and southern Syria, where the pathogen is more frequent. More scald resistance was found in lines originating from northern Syria. Our survey data show that scald pathogen occurs more frequently in the northern part of the sampled area. A large difference for all diseases existed among lines within collection sites.

Field tests with mixtures of isolates cannot detect differences in specific resistance genes. Preliminary results of seedling tests under controlled conditions with genetically homogeneous strains of the scald fungus confirmed the resistance detected in field tests and indicated that the resistance is effective against highly virulent strains (van Leur unpublished data). From the southern part of the sampled area, landrace lines with resistance to highly virulent powdery mildew strains were identified (Jorgensen pers. comm.). These results suggested that the resistance of the Syrian and Jordanian lines to specific diseases is based on a number of genes. However, combined resistance to more than one disease is rare.

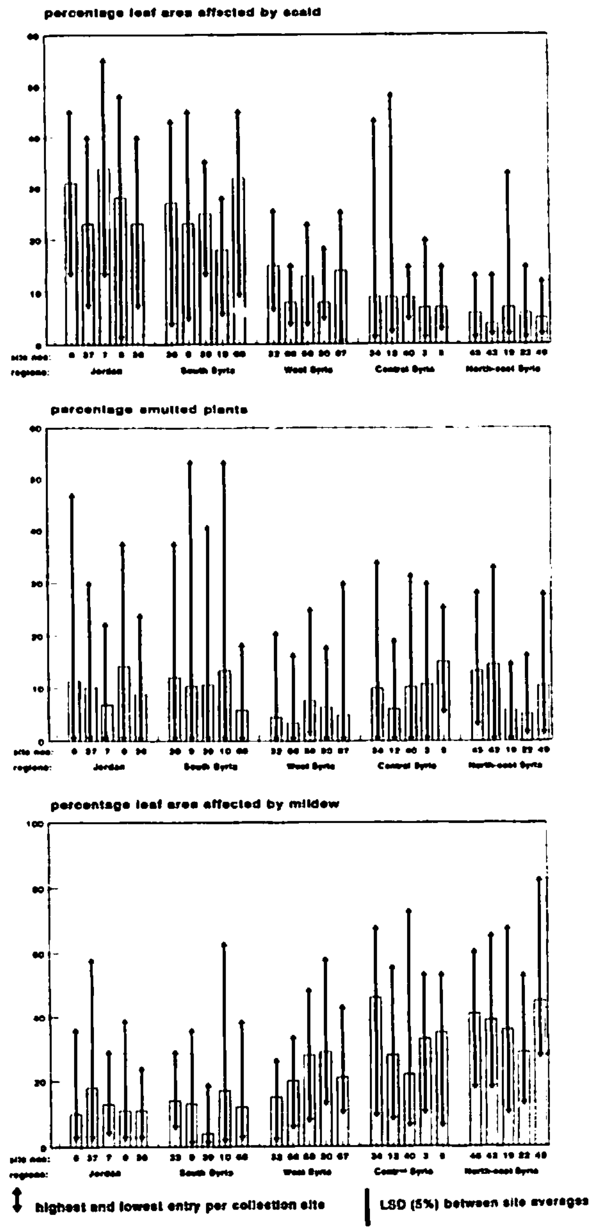

Figure 1. Relationship between environmental conditions and level of disease resistance of germplasms

Use of barley landraces in a selection program

Improved germplasm is likely to benefit from high inputs and to resist high disease pressure. The introduction of improved, often exotic, germplasm has been an important part of improved packages in the past, especially in areas with high production potential, as local material did not respond to high levels of fertilizer or irrigation. However, yield increase in the rainfed barley systems in Syria will be relatively small compared to irrigated systems and drought stress will remain the main abiotic stress factor.

The advantages of basing a selection program on local barley germplasm as compared to exotic material are obvious; not only is the material already adapted to growing conditions and stress factors in the target environment, but it could also meet specific demands of producers and consumers, be it straw quality, grain color or dough strength. These demands should not be underestimated, several examples exist where farmers continue to grow their traditional varieties, even though higher yielding improved lines are available. Rapid progress may be expected by selecting within landraces. Although local germplasm may be well adapted, no pure selection or crossing program should be undertaken without an extensive testing of the pure lines. Results presented here and ongoing work with other barley pathogens, like *Pyrenophora teres* and *P. graminea*, show clearly that a significant part of the landrace population consists of lines that have a high susceptibility to one or more pathogens. Therefore, before any crosses are made with landraces, a careful examination of the purified line for its resistance to major and minor pathogens is necessary.

Pure lines versus varietal mixtures

Growing large areas of genetically homogeneous barley varieties is a feature of improved farming systems. This threatens the durability of disease resistance, as new pathogen strains with higher levels of virulence can develop rapidly. Provided that varieties can be replaced in time this does not necessarily lead to yield instability (Plucknett et al. 1987). Unfortunately, the infra-structure needed to continuously breed new varieties with different resistance genes and to distribute the seed timely to farmers is lacking in most developing countries. Durability of disease resistance is, therefore, essential for germplasm meant for low-input environments. The use of landraces for pure line selections or parental material is not a guarantee that the resulting material will have durable disease resistance. Apart from providing useful genes, landraces teach us a lesson by showing that heterogeneity is a positive trait for long-term stability.

Table 1. Yearly average production of barley in the Syrian Arab Republic during two five-year periods.

Period	Area (1000 ha)	Production (1000 t)	Yield (kg ha⁻¹)
1968-72	701	453	646
1983-87	1449	732	505

Source: Annual Agricultural Statistical Abstracts, Ministry of Agriculture and Agrarian Reform, SAR

CONCLUSIONS

The work with local barley germplasm revealed a high variability for disease resistance within landraces. Therefore, a meaningful evaluation of germplasm collections can be made by extracting and testing a representative sample of pure lines. This type of evaluation has led to the following major conclusions: it is possible to identify, within landraces, individual genotypes with a combination of useful characters; the heterogeneity for morphological and agronomic traits as well as for disease resistance is likely to assist in the stability of performance in stressful (both biotic and abiotic) environments; local germplasm could be used to develop new germplasm, which has both stable performance and adequate resistance, even to higher disease pressure in the future farming systems. It is not well-known how much of this variability contributes to yield stability and disease control. However, the durability of resistance is likely to increase by maintaining level of variability in barley.

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Barley Entomology Research

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Abstract

The major insect pests on barley in Ethiopia are the barley shootfly (*Delia arambourgi*) and the Russian wheat aphid (*Diuraphis noxia*). Work on management of these pests has been carried out for years. Host preference, bionomics, crop resistance, effect of sowing date and chemical control have been studied. Results of these studies are reviewed in this paper

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Insects inflict heavy damage on barley in Ethiopia. To collect, identify and document the important insects pests, study their biology and bionomics, estimate the crop losses they incur and device control methods research was conducted in the past three decades. The results are reviewed in this paper.

Survey of Insect Pests

Entomological surveys identified many field and storage insect pests as well as natural enemies of a few pests (Table la-lc). Barley shoot fly *(Delia arambourgi)*, Russian wheat aphid *(Diuraphis noxia)* and Epliachna beetles were observed in several regions.

Barley shootfly is a widely distributed pest of barley in Tigray, Gonder, Gojam, Shewa and Bale regions. Infestations up to 100% have been recorded in research fields and state farms in Bale, while on farmers' fields the damage was lower (3). Improved cultivars were found more susceptible than farmers' cultivars. This may be due to early planting of improved varieties, which resulted in high incidence of barley shootfly. The fly incidence was 8-15% in the off-season and 85-100% in the main season. The lack of crop-free period in this region may favor the fly.

Russian Wheat Aphid (RWA) is widely distributed in Tigray, Welo, Shewa, Gonder and Bale regions (1). In Shewa, particularly in areas between Sheno and Debre Birhan, there has been a persistent and high level of infestation both in 'belg' and 'meher' seasons. High infestation by RWA is associated with shortage of rainfall and warm temperature (1,2).

The importance of Epilachna beetles (*Epilachna spp.*) has recently increased. The beetles were found around Debre Birhan, Mojo, Bale and Gojam damaging crops by feeding on their leaves. Both the larvae and the adult beetle skeletonize the leaves by scraping chlorophyll (4).

The most recently recorded pests are beetles (*Nematocerus spp.* and

Mesoleurus spp.) and the African bollworm (*Helicoverpa armigera*). The shiny cereal beetles were found boring into the collar region of the plant and killing seedlings. Grubs of the weevil of *Mesoleurus* sp. caused complete loss of the crop at Sheno Research Center during the 1993 season.

STUDIES ON BARLEY SHOOTFLY

Host range

Surveys have been made at Holetta, Sheno, Kulumsa and other barley growing areas to identify alternative hosts. Ten plant species, all in the grass family, were identified as hosting the fly. Host preference of the fly suggested that tef and barley were most liked, followed by wheat and wild oats (1).

Population dynamics

Barley shootfly monitoring has been conducted at Holetta using yellow plastic bowls filled with water and a few drops of detergent to catch adult flies daily. Trapping started in mid-June and ended in mid-August. The highest catch was in June and the second peak was at the end of July (6).

Germplasm screening

Seven varieties were evaluated at Holetta in 1971 (6). Among these Compound 14/20 and 17373 Turkey showed 36% and 16% seedling damage, respectively. At Sinana, where barley shoot fly pressure was high and consistent, 23 advanced accessions were tested. A high variability among accessions to fly damage was observed. The susceptible lines showed wider difference in number of heads between treated and untreated plots (Table 2).

Sowing date

Studies on population dynamics of barley shootfly at Holetta indicated population peaks in mid June (6). Late June and early July sown barley were, therefore, attacked more than the late sown ones (7). At Kulumsa no significant difference among the four sowing dates, starting from 26 June in a two-week interval, was observed (1). In the Bale highlands, farmers plant barley from late August to early September to escape the fly attack. Sowing date trials conducted at Sinana, using variety AHOR, showed that barley planted on August 2 had a mean infestation of 97% and yield of only 2.0 q ha^{-1}. The August 12 and August 22 plantings had 54 and 20% infestation and yielded 15.3 and 18.3 q ha^{-1}, respectively (15).

Chemical control

Non-phytotoxic insecticides were evaluated for their efficacy against the fly. All reduced fly damage and gave better yield than the check (Table 3).

Four systemic insecticides: trichlorophon, demeton-methyl and phosphamidon (spray formulations) and disulphoton (granule) were tested. Trichlorophon and phosphamidon resulted in a higher proportion of dead larvae. These two chemicals as well as discalphoton resulted in a higher number of live shoots (Table 4).

Cumulative results of many years indicated that a seed treatment with Aldrin 40% wp, (at 500 g q^{-1}) was the most effective (8). However, lately Aldrin was abandoned due to its toxicity. Six different insecticides were compared with Aldrin at Holetta. Effective control was obtained with Furadan 30% ST (2). At Sinana three seed dressing chemicals were also compared to Aldrin. None of them was better than Aldrin, but imidacloprid as NTH 33893 Fs and Gaucho 70% resulted in more number of plants and fertile heads than the other insecticides (15).

STUDIES ON RWA

Host range

Sixteen species of plants in the grass family were reported as hosts. Field and pot experiments at Holetta with three *Graminae* species and four cultivated and wild grasses showed that RWA preferred Bromus grass barley and bread wheat (Table 5).

Population dynamics

Studies on population fluctuations of RWA were conducted at Chacha for two seasons by planting barley in early May. Infestation started fifteen days after planting. Counting was made seven times at a fifteen-day interval. The two years average count showed that the peak was in late May and low in late August and September. In addition the aphid population showed variations over seasons. Though RWA was dominant, other species of aphids (*Rhopalosiphum maidis, Metaplophium dirhodom* and *Sitobion sp.*) were also recorded (11, 12).

Germplasm screening

Breeding lines of barley landraces were evaluated for their resistance to the RWA at Holetta using irrigation for two seasons. They were evaluated based on the degree of leaf rolling and chlorosis using a 0-9 scale. Out of 640 lines, 19 lines were selected.

Sowing date

Importance of RWA was studied in five different sowing dates ranging from early May to early July using variety Sheno local. Spray with dimethoate (30% EC at the rate of 400 ml ai ha^{-1}) was compared with unsprayed plots. Highest infestation was found in the earliest sown plots, followed by the second sowing date. No infestation was found in the other plots. Yields between sprayed and unsprayed plots were not significantly different. Best yields were obtained from the May and mid-June sown plots (Table 6).

Effect of fertilizer

Comparison of aphid population between fertilized and unfertilized conditions was made for two seasons at Chacha. In the fertilized plots, DAP and urea were used separately and in combination. Aphid counting was made by sampling ten plants per plot. Aphid infestations were recorded in all the treatments, but the differences were not significant (12, 13).

Chemical control

Carbofuran 50% SD, Furadan 1-5% SD and Diazinan 50% SD were evaluated against RWA for six consecutive years at Chacha. In this experiment, best yields were obtained from the two highest rates of Furadan SD (Table 7).

Earlier application of the two highest levels of Furadan, Pirimicarb 50% WP and Chlorophyriphos 48% EC were compared. Effective control was obtained by the two rates of Furadan followed by Pirimicarb 50% WP (14).

CONCLUSION

The major pests are already identified and arrays of control measures have been developed. However, they were not transferred to farmers. Chemical insecticides have not been pushed, due to their unavailability and high cost. Since the production of barley is predominantly by subsistence farmers, control measures should emphasize cultural methods and germplasm with resistance or tolerance to the two major pest of barley.

Table 1a. Field insect pests of barley reported in Ethiopia

Scientific name	Common name	Pest status
Agrotist insilon	Greasy cutworm	Uncertain
Atlopus simulartix	Glay grasshopper	Sporadic
Chrysodeixis acuta	Plusie worm	Minor
Decticoides brevipennis	Welo bush-cricket	Sporadic
Delia arambourgi	Barley fly	Major
Diuraphis noxius	Russian wheat aphid	Major
Epilachna similus	Tefepilachna	Common
Hemosepilachnna vegintipunctata	Tefepilachna	Uncertain
Gnatocerus cornutus	Broad horned flourbettle	Uncertain
Gonoephalum simplex	Dust brown bettle	Minor
Grullus bimaculatus	Two spotted cricket	Minor
Hysteroneura setareae	Rust plum aphid	Minor
Locusta migratoria migratorioides	Migrtory locust	Sporadic
Macrotermes	Mendi termite	Minor
Metapologhium dirhodum	Grain aphid	Minor
Macrosiphum avenae	English Grain Aphiid	Minor
Cedaleus senegalensis	Sand Grasshopper	Sporadic
Phymateus asgratus	Bust locust	Uncertain
Phymateus pulcherrimus	Bust locust	Uncertain
Rhopalosiphum maidis	Maize aphid	Minor
Rhopalosiphum padi	Oat aphid	Minor
Ruspolia differeens	Edible bush cricket	Uncertain
Schistocerca gregaria	Desert locust	Sporadic
Schizaphis graminum	Wheat aphid	Minor
Sesamia epunctifera	Stalk borer	Uncertain
Sitobion fragariae		Uncertain
Spodoptera exempta	Army worm	Sporadic
Tenebroides mouritanious	Cadella	Minor
Troderma granarium Everts	Khapa beetle	Minor
Zonocerus variegatus	Veriegated grasshopper	Minor

Source: (1)

Table 1b. Storage insect pests of barley reported in Ethiopia

Scientific name	Common name	Pest status
Rhizopertha dominica	Lesser Grain Weevil	Minor
Sitophilus granarius	Grain Weevil	Common
S. Oryzae	Rice Weevil	Common
Sitotroga cerealella	Augoumois Grain Moth	Minor
Tribolium confusum	Red flour beetle	Minor
T. destructor	Flour beetle	Minor

Source: (1)

Table 1c. Natural enemies (predators) of Russian wheat aphid *(D. noxia)* reported in Ethiopia

Order	Species name
Coleoptera	*Adonia variegata*
	Lioadaliia signifera
	L. sexarata
	L. Intermedia
	Lioadalia spp.
	Cheilomenes intermedia
	C. lunata
	C. Littrata
	Scumunus spp.
Diptera	*Sphaerophoria rueppelli*
	Aphids hortensis
	A. colemani
	A. setiger

Source: (1)

Table 2. Results on evaluation of advanced barley germplasm against barley fly (*D. arambourgi*) at Sinana during 1991 meher season.

Acc No.	Mean of infestation (%) Treated	Mean of infestation (%) Untreated	Mean number of heads/plot Total	Mean number of heads/plot Untreated	Rank*
3378	30.0	93.8	24.5	2.3	S
3302	22.5	90.0	26.8	0.0	S
3550	9.3	76.3	257.5	58.5	LT
1766	20.0	88.8	25.3	1.0	S
1618	13.8	78.8	777.0	18.0	S
3289	15.0	78.8	167.0	40.5	LT
1694	8.8	75.0	199.8	61.5	LT
3383	20.0	83.8	77.8	8.0	S
1659	15.0	81.3	80.5	22.5	S
1617	20.0	87.5	56.8	5.0	S
3369	20.0	85.0	50.8	6.8	S
1829	17.5	78.8	96.8	25.0	S
3380	20.0	85.0	86.8	6.5	S
3363	14.5	73.8	267.5	93.8	LT
1730	18.8	87.5	90.5	1.3	S
3364	8.3	72.5	260.8	114.0	T
3367	8.3	71.3	299.3	111.3	T
3382	16.3	83.8	75.3	6.0	S
1641	27.5	91.3	26.0	4.0	S
1764	26.3	87.5	105.0	16.8	S
Klon 57/85	47.5	99.0	18.0	0.0	S
3368	17.5	77.5	266.8	85.0	T
Holker	21.3	93.3	119.8	0.0	S

*S - Susceptible, LT - Less tolerant and T - Tolerant
Source: (15)

Table 3. Effect of insecticide treatments on barley shootfly (*D. aramburgi*) damage and yield of barley.

Treatment	Application (ai ha^{-1})	Damage count	Plant height (cm)	Days to heading	Yield (q ha^{-1})
Aldrin 40% WP	0.24	15.7	96	59	16
Dursban 30% ST	0.24	11.3	81	57	19
Carbary1 5% G	0.05	20.3	89	56	16
Seedox 80% WP	0.40	12.7	82	56	17
Carbofuran 75% SP	0.75	8.3	88	57	18
Dystox 5% G	0.05	13.7	80	69	18
Dursban 5% G	0.05	13.7	80	69	18
Control	0.05	26.7	70	61	13

Source: (2)

Table 4. Effect of some systemic insecticides on infestation of barley shootfly *(D. arambourgi)*.

Treatment	Dead larvae (%)	No. of live hearts per plot	No. of heads at beginning of heading	No. of heads per plot in mid Oct.	Yield (g plot⁻¹)
Check	14.3	62.8	1	131.7	215.4
Trichlorphon 80% SP	48.7	107.7	31	214.0	318.0
Disulphotin 5% GR	20.0	93.4	21	190.3	250.5
Demetonmethyl 25% EC	20.2	71.8	2	137.4	234.8
Phosphamidon 50% Sol.	56.0	106.6	25	189.5	308.6

Source:(5).

Table 5. Host plant preference of the RWA *(D. noxia)*.

Host plant	1st	2nd	3rd	Mean
Barley	10	204	25	80
Bromus grass	5	207	150	142
Cultivated oats	1	3	6	6
Wild oats	2	9	6	6
Tef	8	0	0	3
Bread wheat	11	209	95	105

Sources: (10, 11, 12)

Table 6. Effect of sowing date on RWA (*D. noxia*) population.

Sowing date	Aphid count											
	Treated					Untreated plots					Yield (q ha⁻¹)	
	1st	2nd	3rd	4th	Mean	1st	2nd	3rd	4th	Mean	Treated	Untreated
11 May	7	14	1	0	5	14	109	4	0	32	42.3	39.4
26 May	0	3	0	0	1	0	37	1	0	9	48.3	34.4
12 June	0	0	0	0	0	0	0	0	0	0	40.4	40.2
27 June	0	0	0	0	0	0	0	0	0	0	25.7	23.4
3 July	0	0	0	0	0	0	0	0	23	7	10.9	

Source: (13)

Table 7. Evaluation of different seed dressing chemicals on RWA *(D. noxia)* population.

Chemical None	Rate (ai ml ha^{-1})	1st	2nd	Yield (q ha^{-1})
Furadan 1% SD	10	11	34	16.9
Furadan 2% SD	20	8	18	16.8
Furadan 3% SD	30	8	25	18.0
Furadan 4% SD	40	6	16	20.0
Furadan 5% SD	50	6	14	20.7
Carbofuran 50% SD	815	11	37	15.1
Diazinan 50% SD	250	12	35	16.0
Control	-	18	48	13.6

Sources: (9, 11, 12, 13)

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Smallholder Barley Production Practices and Constraints

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Asmare Yalew

Abstract

In most areas barley is grown in the main season (meher). However, in Welo, north Shewa and Bale barley is also grown in the short rainy season (belg). In Adet, Bahir Dar and Debre Tabor barley is sometimes double cropped when rainfall is conducive. In Debre Tabor, Dabat and Debark farmers grow mixtures of wheat and barley.

Planting in the main season is usually done from mid May to end of July. In areas where double cropping is practiced the second crop is planted during August through October.

Farmers' weed management practice involves a number of operations: frequent plowing, use of high seed rates and hand pulling of the major weeds late in the season after the critical stage of weed competition.

A number of barley cultivars are grown in the survey areas most of which are unimproved local varieties. In some of the survey areas about nine different barley varieties are being cultivated.

The proportion of farmers applying fertilizer on barley ranges from zero in Debre Tabor to 100 percent around Kulumsa. The most common fertilizer used is di-amonium phosphate. Urea is generally not applied on barley.

Barley production constraints include low soil fertility, weeds, diseases and pests, frost and hail, waterlogging, seasonal labor shortage, seasonal food shortage, shortage of arable land, shortage and late delivery of fertilizer, and shortage of draft power.

Barley in Ethiopia is grown by subsistence farmers. It is mainly produced for consumption and sold for cash in small quantities. It is the main staple food in major growing areas and also used for making local drinks. Barley straw is the second preferred animal feed next to tef straw. Stem stubs of barley are also used for thatching.

PRODUCTION PRACTICES

Barley production varies from one area to another and mostly grown in the main season. However, in areas like Bale, north Shewa and south Welo barley is mainly grown in the short rainy season (belg). In Adet, Bahir Dar and Debre Tabor barley is sometimes double cropped when the rainfall is conducive. An early-maturing barley cultivar planted in May and harvested in September may be followed by a second barley crop. Near Debre Tabor farmers plant mixtures of wheat and barley at equal amount of seed and harvested at the same time. This practice is also common in Dabat and Debark. Farmers claim that this practice reduces weeds and gives higher yield than sole cropping barley. Intercropping of barley with noug or lupin is also practiced in the highlands of Debre Tabor.

Land preparation

Land preparation for barley usually commences immediately after the onset of rain. In some areas, farmers start plowing just after the preceding crop is harvested and before the soil becomes dry. Plowing frequency varies depending on availability of oxen, soil type, preceding crop and weed management practices. Farmers who do not adequately weed their barley fields plow more frequently than others. Barley fields on average are plowed three to four times before planting (Table 1).

Planting time

Planting time of barley is dictated by altitude, soil and variety. It also varies depending on th onset and distribution of rainfall. Main seaseo planting is done from mid May to the end of July. In areas where double cropping is practiced the second crop is planted from August to October.

Table 1. Barley production practices in Ethiopia.

Location	No. of plowing	Weeding method	Weeding frequency	Percent weeding
Holetta	2-5	HW, HB	one	
Sheno	2-5	HW, HB	one	
Kulumsa	4-5	HW, HB	one	
Sinana	3-4	HW	one	
Genale	3-4	HW	one	
Adet	2-8	HW	one	36
Bahar Dar	2-10	HW	one	52
Deber Tabor	3-4	HW	one	

HW - hand weeding and HB - herbicide

Source: Aleligne and Franzel, 1987; Aleligne, 1988; Aleligne and Regassa, 1992; Aleligne *et al.*, 1992; Alemayehu and Franzel, 1987; Chilot *et al.*, 1989; Hailu and Mohammed, 1986.

Weed management

Although weeds are one of the major constraints in barley cultivation in most of the survey areas, less priority is given to weed control as compared to wheat and tef. This is mainly due to labor shortage caused by overlapping of operations and the farmers' belief that barley competes well with weeds. Around Holetta the critical period for weed control coincides with land preparation and planting of tef and weeding of wheat and faba bean. Similarly, in Adet and Bahir Dar it overlaps with maize cultivation, preparing land for tef and planting faba bean, field pea, millet and oil seeds. As a result farmers use the following combinations of weed control methods in barley:

- plowing their fields as thoroughly as possible to control early emerging weeds,
- using higher seed rates than recommended in order to suppress weed competition as well as to compensate for the low germination rate of their seed,
- hand pulling of major weeds only, and
- applying 2,4-D when available, but at less than the recommended rate.

In Mota and Ennese 82% of interviewees practice a single hand weeding and 16% weeding twice. In Debre Tabor farmers weed their barley field twice, at early tillering stage and at jointing stage. Seed rates ranged from 100-300 (Table 2) kg ha^{-1}. Lower seed rates are used when fertilizer is applied or when short season varieties are used because of their higher seed viability and high tillering capacity.

Table 2. Seed rates for barley

Area	Range (kg ha^{-1})
Holetta	168-256
Kulumsa	100-250
Sinana	120-160
Genale	100-300
Bahir Dar	200-240
Debre Tabor	120-200

Source: Aleligne and Franzel, 1987; Aleligne, 1988; Aleligne and Regassa, 1992; Aleligne *et al.*, 1992; Alemayehu and Franzel, 1987; Chilot *et al.*, 1989; Hailu and Mohammed, 1986.

Cultivars

Mostly unimproved local cultivars are grown in the survey areas (Table 3). In the Ennese farming zone farmers reported eight cultivars, in Dabat and Debark nine cultivars. Improved varieties such as ARDU-12-60B (food barley), Beka and Holkr (malting barley) are also grown along with the local cultivars. The use of improved barley varieties was indicated only at Holetta, Kulumsa, Sinana and the Genale survey areas.

In the Debre Tabor area farmers prefer early maturing cultivars in order to escape dry spells and frost at the end of the season, to alleviate food shortage, for convenience of double cropping, and in case of a reasonable yield, the harvest can be sold to hire labor for weeding tef.

Table 3. Barley types and varieties grown in Ethiopia

Survey area	Types	Varieties
Holetta	Food	Baleme, AHOR 880/61, HB-42
Kulumsa	Food	Aruso, Burtigi, Muga, ARDU-12-60B
	Malting	Beka
Sinana	Food	Aruso (Balticha), Burtuji, Barsedet
Genale	Food	Aruso, Unitan, Felibaye, Muga, Kesele, Akelat, Senef kolo, ARDU 12–60B
	Malting	Holkr, Beka
Adet	Food	Semereta, Gofer
Bahir Dar	Food	Aleme, Semereta, Gofer Semereta
Debre Tabor	Food	Tsebel Gebes, Awra Gebes, Senef kolo, Zembeleta, Bule and Bule Gagre

Sources: Aleligne and Franzel, 1987; Aleligne, 1988; Aleligne and Regassa, 1992; Aleligne *et al.*, 1992; Alemayehu and Franzel, 1987; Chilot *et al.*, 1989; Hailu and Mohammed, 1986.

Fertilizer use

Low soil fertility is reported as a major problem in barley production. Table 4 shows the proportion of farmers applying fertilizer and the rate used in barley production. The proportion of farmers applying fertilizer on barley ranges from zero in Debre Tabor to 100 percent around Kulumsa. The most common fertilizer used is DAP. Urea is not applied on barley. Farmers apply at a rate of 24 up to 100 kg ha^{-1}, which is below the recommended rate.

Diseases and pests

Pest and diseases are common on barley (Table 5). Aphids are the most important insect pests in five of the eight survey areas. Farmers plant early in the main season escape frost damage. Other pests reported by farmers are shoot fly, grubs and vertebrate pests (birds and rodents).

Diseases such as leaf blotch, smut and rust are reported hindering barley production in different parts of the country. Farmers in northwestern Ethiopia have developed a strategy for controlling the incidence of loose smut and stripe on barley. They use seed from off-season planting locally known as *Mesno gebs* for main season planting locally known as *Abat gebs*. The efficacy of this technique was later confirmed by researchers at Adet Research Center. Seeds harvested from the off-season and main season crops were planted during the main season of 1990 and the incidence and severity of loose smut and leaf stripe were assessed. Leaf stripe and loose smut were reduced by 86% and 99%, respectively.

Table 4. Fertilizer use on barley

Area	Farmers using (%)	Rate range (kg ha^{-1})
Holetta	30	24-50
Kulumsa	100	50-100
Sinana	80	25-50
Genale	80	25-100
Adet	38	50-100
Bahar Dar	60	53

Sources: Aleligne and Franzel, 1987; Aleligne, 1988; Aleligne and Regassa, 1992; Aleligne *et al.*, 1992; Alemayehu and Franzel, 1987; Chilot *et al.*, 1989; Hailu and Mohammed, 1986.

Harvesting and threshing

Barley harvest extends from August to December depending on cultivars used, sowing date and soil type. In northwestern Ethiopia, the commonly grown early maturing barley varieties are harvested from late August to early October, while the late maturing cultivars are harvested in early November. In most barley growing areas, the main season barley is harvested from October to December. Harvesting is usually done manually with a sickle. The harvested barley is piled until threshing. Threshing is usually done by animal trampling on a small threshing ground plastered with cow dung.

SOCIO-ECONOMIC CONSTRAINTS

Socio-economic constraints include unavailability of improved inputs, seasonal labor shortage, shortage of draft power and shortage of land.

Table 5. Major pests and diseases on barley reported by farmers

Survey area	Pests	diseases
Holetta	barley fly	rust
Kulumsa	grubs, aphids	smut
Sinana	aphid, cutworm	
Genalle	aphid, shoot fly	leaf blotch, leaf rust
Adet		smut, rust
Bahar Dar	birds, termites white grub hoppers	leaf blotch, leaf rust
Debre Tabor	aphids, birds and rodents	smut

Sources: Aleligne and Franzel, 1987; Aleligne, 1988; Aleligne and Regassa, 1992; Aleligne *et al.* 1992; Alemayehu and Franzel, 1987; Chilot *et al.*, 1989; Hailu and Mohammed, 1986.

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Economics of Smallholder Barley Production and Technologies Tested On-Farm

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Abstract

Most of the research efforts on barley emphasized improved production packages. The major evaluation criterion has been biological yield. The inclusion of economic criteria to derive research recommendations has not been sufficiently considered. Only few studies were initiated to assess the feasibility of barley production under smallholder conditions. Technologies meant to improve production and economic return of food barley were evaluated on various sites including farmers' fields in different regions of the country. The trials focused on varieties, fertilizer, weed control methods, planting time, seeding rate and surface drainage.

Much of the research effort on barley has been on producing improved production packages that could give superior yields compared to the traditional farmers practice. The major evaluation criterion has been biological yield. The economics of barley production and the inclusion of economic criteria to derive research recommendations have been largely ignored. So far only limited studies were initiated to assess the feasibility of barley production and to derive fertilizer recommendations based on input and output prices for the smallholder. On-farm verification trials were conducted to evaluate on-station research results. This paper reviews the economics of smallholder barley production and results of on-farm trials.

ECONOMICS OF SMALLHOLDER BARLEY PRODUCTION

Information on the economic efficiency of barley production in Ethiopia is limited. Profitability studies have been undertaken by different individuals and organizations at different times. Among these efforts the ones done by Food and Agricultural Organization (FAO), Alemaya University of Agriculture (AUA) and Institute of Agricultural Research (IAR) are summarized as follows.

In their investigations of farming systems and farm management practices of the smallholder in Harerge highlands, Storck *et al.* (1991) have done gross margin analysis of barley both for belg and meher seasons and other small cereals (Table 1). Higher revenue was obtained from the belg barley. Average barley price for meher season in the reference period was

15% less than that of the 'belg' season. This variation further increased gross returns gap of barley between the seasons by approximately 500 Birr ha^{-1} for the belg crop, i.e., more than double of the 'meher' crop.

In the economic analysis of land use, crop production was evaluated using data on area, production, yield and cost of inputs generated from the agricultural sample surveys conducted during 1974/75 and 1977/78 (FAO 1986). Gross return could be used as a criterion for deciding the maximization of benefits for the community in terms of output from a given set of input. The net returns reflected the maximization of benefits from a particular enterprise for a farmer. The distribution of cost of production for the years is shown in Table 2. In 1974/75 material costs were in higher proportion to the total cost, while in 1977/78 work force was in the highest proportion. The reasons for such a shift in distribution of cost components are not clear.

Enterprise budgets were developed for Adet and Holetta mixed farming zones to figure out private financial profitability using average technical coefficients for each zone (Table 3). The technical coefficients are representative of the average practices of the smallholder in the two zones. Private profitability is used by farmers to assess and compare alternative plans for exploiting resources at their market prices.

Table 1. Returns of barley and other small cereals in Harerge highlands, 1987.

Item (Birr ha^{-1})	Barley (meher)	Barley (belg)	Wheat	tef
	% of Cases			
Gross revenue				
<100	36.0	2.0	14.3	20.4
100-200	16.0	12.2	14.3	9.2
200-300	16.0	20.4	14.3	13.0
300-400	16.0	22.4	8.2	22.2
400-500	4.0	4.1	12.2	5.6
500-700	8.0	14.3	16.3	7.5
700-1000	4.0	18.4	4.0	16.7
>1000	0.0	8.2	4.1	11.1
Average gross revenue	212.0	508.0	496.0	424.0
Average gross margin	168.0	436.0	457.0	364.0

Source: Storck *et al.*, 1991.

Table 2. Distribution of production cost components of barley and other small cereals

Cost Components	Barley 1974/75	Barley 1977/78	Wheat 1974/75	Wheat 1977/78	Tef 1974/75	Tef 1977/78
Birr ha⁻¹						
Work force	22.7	52.4	23.1	50.8	16.7	57.3
Traction	31.1	31.7	37.2	32.5	32.0	34.3
Materials	46.2	15.9	39.7	16.7	51.3	8.4
Total	100	100	100	100	100	100
Birr q⁻¹)						
Manpower	10.5	18.1	7.6	18.0	10	16.6
Traction	7.1	10.9	7.1	11.5	6.2	10.0
Materials	5.2	5.5	4.4	5.9	3.3	2.3
Total	22.8	34.5	19.0	35.3	19.5	28.9

Source: FAO (1986)

Small-scale farmers in Ethiopia use traditional tools and implements of limited value for land preparation, cultivation and other activities (Storck *et al.*, 1991; Adet Research Center unpubl. data). Therefore, the average value accounting for depreciation of all implements owned by the smallholder is low. For instance, it was 35 Birr for Harerge highlands (Storck *et al.*, 1991) and 34-40 Birr in Bahir Dar (Adet Research Center unpubl. data). Thus, capital is less important for the smallholder. Apart from draft animals, production is based on land and labor. Therefore, the analysis employed here is gross margin analysis, where only variable costs are considered.

Gross return to barley production per hectare in mixed farming zone of Adet is slightly better than Holetta. However, the reverse is true when per hectare gross margin is considered.

ON-FARM VERIFICATIONS

On-farm trials in IAR/ADD and farmers' fields were undertaken to address priority problems of food barley identified through diagnostic surveys. The trials were on varieties, planting time, seeding rate, fertilizer, weed control and surface drainage.

Table 3. Barley enterprise budgets for Holetta and Adet

Item	Holetta	Adet
Yield (kg ha⁻¹)	1451.00	952.00
Gross returns (Birr ha⁻¹)	1227.26	1257.64
Variable costs		
seed	152.75	199.71
fertilizer	69.56	52.65
herbicide	10.25	–
imputed family labor (Birr ha⁻¹)	134.70	175.20
Total variable cost	367.30	427.60
Gross margin (Birr ha⁻¹)	860.00	830.10
Family labor required (md ha⁻¹)		
land preparation	10.25	20.40
sowing	0.72	0.72
weeding	18.30	–
harvesting	9.25	17.58
threshing and winnowing	6.37	9.31
guarding	–	16.88
Total family labor	44.89	64.89
Imputed family labor (Birr ha⁻¹)	134.70	175.20
Gross margin excluding family labor	1092.56	1082.44

Source: Adet Research Center (unpubl. data) and report of Holetta Research Center Agr. Econ. division, Holetta (unpublished)

Variety verifications

During the 1976 to 1981 cropping seasons ten improved varieties and local cultivars were compared in Shewa, Gojam, Welega, Gonder, Tigray and Gamo Gofa regions on sites of the Ministry of Agriculture, Agricultural Development Department (MOA-ADD). Although the results of variety trials were not consistent in grain yield, different improved varieties gave better yields in most of the regions (Table 4). The variety IAR-H-485 gave the highest yield in Welega, Gonder, Gamo Gofa and Tigray. Variety AHOR 880/61 was better than local cultivars in Shewa, Gonder and Gamo Gofa.

IAR has been cooperating with MoA-ADD in providing improved varieties of barley for 14 field trial sites in 1989. The results of these trials were also not consistent in grain yield. The mean grain yields suggest that HB-100, HB-42 and ARDU 12-60B performed better in three consecutive cropping seasons (ADD 1991, 1992)

Since 1980 improved barley varieties with recommended package were tested on farmer's fields. In Wolmera, the variety IAR/H/485 was tested from 1980 to 1985, giving an average yield over five years of 1960 kg ha^{-1}. During

1985 to 1992 crop seasons the varieties HB-7, HB-37, HB-42, HB-52, HB-100, AHOR 880/61, ARDU 12-60B, Beka and the local cultivar Baleme were tested under improved and farmers' managements. The improved management included recommended practices of fertilizer and weed control. Most of the improved varieties gave significantly higher yield than the local cultivar under improved management (Table 5). The results suggested that improved varieties should only be grown under better management, while the local cultivar can be grown under less favorable conditions.

Table 4. Mean grain yields (kg ha^{-1}) of improved barley varieties as compared to local cultivars in six regions, 1976-81

Variety	Shewa	Gojam	Welega	Gonder	Tigray	Gomo Gofa	Mean
Local	1580	1600	1280	1460	1530	2580	1670
C-63	1210	1325	-	1820	-	1550	1475
Kenya Res.	1545	1500	1090	1920	1410	1760	1540
Beka	1330	1095	1170	1330	1710	2650	1545
Comp. 29	1715	1170	-	-	-	-	1440
IAR-H-485	1420	1430	1600	2050	2200	4190	2150
Bedi Black	1645	-	-	-	-	1645	1645
Kulumsa	-	-	-	-	-	1670	1670
EH-11-F3AT-BL	1500	3220	1380	-	-	2900	2250
AHOR 880/61	1635	1350	-	1620	750	3440	1760
Holkr	-	-	-	1330	-	1800	1565

Sources: ADD (1991, 1992)

On-farm weed control trials

The economics of controlling weeds by hand weeding or by herbicides was studied at Holetta and Bahir Dar. At Bahir Dar, the herbicides were Britox 52.5% (1312 g ha^{-1} a.i.), 2,4-D (720 g ha^{-1} a.i.) and Britox + Illoxan 36 EC (900 g ha^{-1} a.i.). Other treatments included were one hand weeding (25-30 days after emergence) and farmer's practice (no or selective hand weeding). The highest yield was obtained by applying Britox (Table 6). Britox gave 25% higher yield than farmer's practice (Regassa *et al.*, 1990). It also gave the highest MRR of 321%. However, Britox was not recommended because of negative effects. Other herbicides or hand weedings were not economical at the time of the study.

At Holetta, one on-station and one on-farm verification trial were conducted to determine economical weed control practice. On the station variety Holkr was used with five treatments, i.e., one hand weeding (HW), twice hand weeding, Afalon (2 l ha^{-1}) + HW, CMPP (3 l ha^{-1}) + HW and Afalon + CMPP. Afalon with supplementary hand weeding gave 25% higher yield than one hand weeding (Table 7), however, grain yield differences were not statistically significant.

Table 5. Mean yield (kg ha^{-1}) of barley varieties, Holetta, 1985-92

Variety	Improved management	Farmers' management	Difference
Local	2090	1375	715
HB-7	1995	905	1090
HB-37	2230	930	1300
HB-42	2580	1520	1060
AHOR 880/61	2385	1235	1150
HB-100	3240	2105	1135

Source: Unpublished Report, Holetta Research Center
Agricultural Economics Division

Table 6. Yield increase over control for different weed control practices on barley, 1988 and 1989, Bahir Dar.

Treatments	Yield (kg ha^{-1})	increase (%)
Farmer's practice	1007	-
One hand weeding	1184	18
2,4-D	1110	10
Britox	1254	25
Britox + Illoxan	1145	14

Source: Regassa et al 1990

Table 7. Yield increase of different weed control practices on grain yield of barley, 1986-1987, Holetta.

Treatment	Yield (kg ha^{-1})	increase (%)
One hand weeding (1 HW)	2320	-
Two hand weeding	2460	6
Afalon + 1 HW	2850	23
CMPP + 1 HW	2505	8
Afalon + CMPP	2155	-

Source: Unpublished reports of Agricultural Economics Division, Holetta Research Center

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Barley Technology Transfer

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Abstract

Barley technology transfer has been conducted through demonstrations by FFHC, CADU, EPID and MOA/IAR since 1967. Several food and malting barley varieties have been demonstrated in many areas. Currently, five varieties are under production. The earlier fertilizer demonstration trials showed a value cost ratio for application of 100 kg ha^{-1} di-ammonium-phosphate ranged from 1.9 to 3.8.

Transfer of barley technology has been conducted since the late 1960s mainly by FFHC, CADU, EPID and IAR/MOA. Currently, barley technology demonstration is carried out by MOA and IAR/MOA. This paper reviews some barley technologies transferred during this period.

Fertilizer Demonstration

Fertilizer demonstration had been conducted by CADU in Arsi region at Dighelu, Asela, Eteya and Huruta in 1968 and 1969 (3,4). The demonstrations were carried out at 3 sites in 1968 and at 6 sites in 1969. K gave no response, while N gave a yield increase of 20%. P gave an increase of 43.6%. The highest yield was obtained by applying 40/40 kg N/P_2O_5 ha^{-1} with an increase of 71% (Table 1). However, the highest value cost ratio (VCR) of 1.77 was obtained with P only (Table 2).

Table 1. The effect of fertilizers on the yield of barley in Arsi region, CADU, 1968-69.

Treatment (kg ha^{-1})			Yield (q ha^{-1})		Mean Yield	Yield increase	
N	P	K	1968	1969	(q ha^{-1})	(q ha^{-1})	(%)
0	0	0	15.30	10.60	12.95	-	-
40	0	0	19.10	12.00	15.55	2.60	20.10
0	40	0	20.50	16.70	18.60	5.65	43.60
40	40	0	23.50	20.80	22.15	9.20	71.04
40	40	40	23.45	18.80	21.13	8.20	63.32

Source: (3)

Table 2. Economic evaluation of fertilizer on barley in Arsi region, CADU, 1968-69.

Treatment (kg ha^{-1}) N	P	K	Yield (q ha^{-1})	Value of yield Increase (Birr ha^{-1})	Cost of fertilizer (Birr ha^{-1})	VCR
0	0	0	12.95	-	-	
40	0	0	15.55	26.00	33.00	0.79
0	40	0	18.60	57.50	32.00	1.77
40	40	0	22.15	92.00	65.00	1.42
40	40	40	21.13	82.00	97.00	0.85

Source: (3)

Demonstration of soil burning (guie) vs. fertilizer was conducted by CADU from 1968 to 1969. In 1968 yield increases of 181 and 128% were obtained by applying 100 kg each of triple-super-phosphate (TSP) and urea over soil burning at Sagure and Asela areas, respectively (Table 3). VCRs of 2.1 and 1.5 were obtained at Sagure and Asela (3). The average for all the demonstrations showed about the same yield increase for soil burning and 100 kg of each TSP and urea. A good benefit was obtained with 100 kg TSP and 50 kg urea in 1969. The 1969 demonstration of using 100 kg of TSP or 100 kg di-ammonium-phosphate (DAP) instead of 100 kg each of TSP and urea showed similar results (3).

Table 3. Mean grain yield (q ha^{-1}) of barley on soil burning vs. fertilization at farmers' field in Arsi, 1968--69.

Year	Locations	Control	Soil burning	NP_2O_5 (Kg ha^{-1}) 46/46	92/92
1968	Sagure	8.55	18.30	24.05	29.40
	Asela	8.85	27.05	20.15	28.75
Mean		8.70	22.70	22.10	29.10
				NP_2O_5 (Kg ha^{-1}) 23/46	46/92
1969	Sagure	7.50	18.75	19.95	25.25
	Asela	1.50	18.50	12.50	11.00
	Dighelu	12.50	16.00	9.50	15.00
Mean		1.17	17.75	13.98	17.08

Source: (4)

Fertilizer demonstrations were also conducted by EPID throughout the country except in Arsi A VCR of 0.95 to 3.75 was realized in the demonstrations (5,6,7). The lowest VCR (0.95) was obtained at 46 N fertilization in 1974 and the highest VCR (3.75) was obtained in 1973 with 100 Kg ha^{-1} DAP A 100 kg DAP ha^{-1} gave consistent VCR of 1.88, 2.75 and 3.75 in 1971, 1972, 1973, respectively.

VARIETY DEMONSTRATION

In 1968-71 the yield of local barley under unfertilized condition was 11.8, 16.4, 17.4 and 17.5 q ha^{-1} at Huruta, Gonde and northern Asela, respectively, while it was 13.4, 14.9 and 15.3 q ha^{-1}, in southern Asela, Sagure and Digelu, respectively. This continuous yield increase was due to better farm management such as earlier planting, better weeding, seed cleaning, soil preparation, seed covering and increased use of manure.

In CADU's demonstrations of food barley varieties during 1977-85 improved varieties out yielded local cultivars (Table 4). The yield advantage ranged between 5.6 q ha^{-1} at Guna, Arba Guna and 17.2 q ha^{-1} at Egu, Munessa. Based on these results varieties IAR/H/485, ARDU-74-10C, AHOR 880/61 for Arbagugu highlands; IAR/H/485, ARDU-12-10C, HB-42 and EH163/F3.17.11 for Chilalo highlands and IAR/H/485 for Chilalo mid altitude areas of the Arsi region were considered for production (8).

PACKAGE DEMONSTRATION

A total of 97 demonstrations of improved barley varieties with their production packages were conducted during 1986-1992 in major barley growing areas of the central zone. The demonstrations compared the improved method which included improved varieties, recommended, seed rate of 125 kg ha^{-1}, 60 kg N and 60 kg P_2O_5 ha^{-1}, and two hand weedings with the farmers' traditional barley production practice. The plot size of the demonstration was 0.25 ha for each method. HB 42 gave a yield of 27.5 q ha^{-1} at Wolmera, while ARDU 12 gave 26.7 q ha^{-1} at Ada Berga, and AHOR 880/61 gave 23.5 q ha^{-1} at Selale (Table 5).

Table 4. Average yield increase of improved food barley varieties evaluated in the Arsi region during 1977-85

Locations	Altitude (m)	Varieties	Yield advantage (q ha⁻¹)	Increase (%)
Bolo jeju	2560	IAR/H/485	7.1	38
Arba Gugu		ARDU 74-10 C	6.6	30
Gube Cholle	2760	IAR/H/485	17.0	51
Arba Gugu		ARDU 74-10 C	16.2	49
		EH/163/F3 17/11	8.4	43
		AHOR 880/61	12.5	40
Guna	2700	ARDU 74-10 C	8.5	29
Arba Gugu		IAR/H/485	5.9	20
		AHOR 880/61	5.6	19
Egu, Munessa	2580	HB-42	7.0	35
		EH/163/F3 17/11	17.2	83
Gedeb, Kofele	2520	ARDU 74-10 C	16.5	74
Chilalo		IAR/H/485	13.1	63
Gobessa, Shirka Chilalo	2400	IAR/H/485	10.0	25
Kofele, Chilalo	2660	ARDU 74-10 C	9.5	41

Source: (3)

Table 5. Mean yield of demonstration trial in barley growing areas of the central zone, 1986-92.

Location	No. of Demon	Yield (q ha⁻¹)				Increase (%)		
		Local	HB-42	ARDU-12 608	AHOR 880/61	HB-42	ARDU-12 60B	AHOR 880/61
Wolmera	47	12.8	27.5	24.4	19.5	115	91	53
Ada Berga	19	12.5	22.6	26.7	21.6	87	113	72
Addis Alem	9	13.3	21.6	18.6	21.4	63	36	62
Selalie	13	11.6	23.9	21.8	23.5	106	88	102
Dandie	4	12.0	22.1	21.1	19.8	84	75	65
Gedo	2	15.0	23.6	-	-	57	-	-
Jibatna Mecha	3	13.0	24.1	22.5	-	85	73	-
Mean		12.9	23.6	21.5	21.2	83	67	64

Source: Holetta Research Center (unpublished)

SEED MULTIPLICATION AND DISTRIBUTION

Starting from 1967 seeds of improved barley varieties were distributed by CADU (2). In 1969, EPID in collaboration with CADU, demonstrated improved varieties to farmers and attempted to distribute improved seeds. Later, seed distribution was carried out by different organizations such as the Agricultural Inputs and Marketing Supply (AIMS), Agricultural Marketing Corporation (AMC) and Agricultural

Inputs Supply Corporation (AISCO) which has over 600 seed distributing centers in the country (1). The Relief and Rehabilitation (RRC) and the Ministry of Agriculture (MOA) were also involved in the production and distribution of barley seed. Since its establishment in 1979 the Ethiopian Seed Enterprise (ESE) has produced over 18,600 tons of food and malting barley seed (Table 6). The Institute of Agricultural Research has also produced 69.7 tons of basic seeds and distributed to the ESE and others (Table 7).

Table 6. Multiplication and distribution of barley (q) by ESE to different organizations, 1979/80 - 1991/92

Year	Total Produce	Distribution to		
		MSFD	MOA	Others
1979/80	2,558	2,414	44	-
1980/81	7,441	2,868	2,150	1,423
1981/82	2,873	2,207	594	72
1982/83	8,653	7,313	1,233	106
1983/84	16,476	15,271	1,205	-
1984/85	17,223	13,548	3,639	36
1985/86	21,075	16,263	-	1,812
1986/87	20,421	15,192	92	1,137
1987/88	41,228	23,171	23	18,034
1989/90	8,893	7,966	-	4,873
1990/91	12,368	10,114	1,826	428
1991/92	12,296	-	7,599	4,696
Total	186,343	125,023	18,405	42,914

Source: ESE (unpublished)

Table 7. Multiplication and distribution of barley seeds (q) by IAR, 1984-1992.

Year	Multiplied	Distribution to			
		ESE	Research	Farmers	Others
1984	21.0	10.0	5.0	-	60.0
1985	58.0	21.0	7.0	1.3	2.0
1986	7.0	-	4.0	1.2	0.7
1987	24.0	12.0	6.0	3.0	2.0
1988	42.0	18.4	13.0	6.3	4.0
1989	52.0	22.0	18.0	5.0	12.0
1990	35.0	5.0	11.0	5.6	14.0
1991	176.5	-	24.9	6.5	51.0
1992	281.6	-	5.24	21.4	104.0
Total	697.1	88.4	141.3	50.3	249.7

Source: Holetta Research Center (unpublished)

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Utilization of Barley for Development of Low Cost Supplementary and Weaning foods

Asrat Wondimu

Abstract

Optimal conditions for malted barley were standardized and different trials were also carried out on popping of barley which was used in the formulation of the weaning food.

The blend consists of barley and chickpea in a ratio of 2:1. Barley and chickpea have been germinated for 48 and 24 hrs to produce a weaning food of good nutritive value, low paste viscosity and high calorie density Popped and roller dried weaning foods were also formulated on the same basic ration and 5% malted barley flour was added to reduce the paste viscosity and enhance the calorie density of the foods.

Nutritional qualities of all the formulations fall within the recommended levels given by ISI. The protein content ranged from 14.8 to 15.6%, fat 1.85 to 3.8%, carbohydrates 60.5 to 66.7%, and caloric 338.6 to 344.2. The essential amino acid contents were also satisfactory Protein efficiency ratio was 2.59.

The most common traditional weaning food in many parts of Ethiopia is a gruel prepared from cereal grains, which is poor nutritionally. Beyond its poor nutritional contribution, it also exhibits high viscosity since it absorbs large amount of water on cooking. Malting of cereals and legumes to produce cereal-legume blends was found one of the best solutions as a means of reducing dietary bulk (Malleshi and Desikachar 1982). During the process of germination, biochemical changes take place and some constituents increase where as others decrease. The rapid synthesis of pro-vitamin A, B-complex vitamins and vitamin C in germinating seeds have been reported by Chen, et al. (1975). Besides, the availability of minerals may be increased due to a decrease of phytic acid content in germinated seeds. Anti-nutritional factors could also be reduced depending on the extent of germination and type of grains. There is also an improvement in protein and starch digestibility.

Materials and Methods

Barley grains purchased from market were mechanically cleaned to remove foreign matter. The clean grains were washed with a tap water, steeped for 16 hr., germinated for 48 hr and sun-dried to about 12% moisture (Malleshi and Deskachr 1982). Pearling was carried out in a horizontal emery polisher and the husk was separated by aspiration. The pearled barley grains were roasted in an electrical roaster at 75°C for 45 min., pulverized in a plate mill and sieved through a 60-mesh sieve.

Samples were evaluated for malting loss, kernel weight and volume. Density and hardness viscosity were measured according to Brandtzael et al. (1981) and alpha-amylase activity was determined by the method of Bernfeld (1955). Popping was carried out in a sand medium heated at 24°C for 25 sec. The optimal popping conditions were standardized according to Daodu (1986). The weaning food blend was mixed with water at a ratio of 30:70 (w/v). The resulting slurry was homogenized in a wet grinder (prima mill) to eliminate lumps and roller dried on a twin roller system (Malleshi et al. 1989).

The formulation was within the recommended pattern of FAO/WHO (1976). Depending on the type of the process, the weaning foods were named malted weaning food (MWF), popped weaning food (PWF) and roller dried weaning food (RDWF). The proximate composition was determined by AACC (1986) procedures and dietary fiber was determined according to Asp et al. (1983). Carbohydrate was calculated by difference and total energy (calorie) was calculated by the standard method.

For protein efficiency ratio (PER) determination freshly weaned male albino rats (Wistar strain) with an average weight of 38 g were distributed into 7 groups (10 rats per group) in a randomized block design (Pellett and Young 1980). In the study 10% protein diets were used. The diets also contained 1% vitaminized oil, 1% vitaminized starch and 4% salt mixture. Food and water were given ad libitum and water was provided separately through clean bottles.

RESULTS AND DISCUSSION

Steeping

The moisture uptake of rats was rapid at initial stages of steeping, while the increase became slow and constant afterwards. At room temperature on 16 hr steeping the moisture content was 44%. Prolonged steeping time did not significantly increase germination; instead it increased the losses because of leaching (Fig 1).

Malting loss

Malting loss varied between 8% and 22% from the first to fifth of malting (Fig 2).

Physic-chemical changes during malting

Changes in 1000 kernel wt., 1000-kernel volume, density and hardness are presented in Table 1. The decrease in weight and volume indicated a utilization of endosperm in the grain without much effect on seed structure. There was a gradual decrease in hardness during the first 5 days of germination. During germination biochemical changes took place due to partial hydrolysis of cell wall.

Kilning

Temperature and time of kilning influenced alpha-amylase activity and paste viscosity of the sample (Table 2). When kilning temperature was increased to 80°C, paste viscosity increased, due to the decrease in alpha-amylase activity. Prolonged kilning produces a brown color and unacceptable aroma. Kilning at 70-75°C for 45 min. was sufficient for an optimum paste viscosity and an acceptable aroma. Kilning reduced microbial load of the product (Daodu 1980, Livingstone et al. 1991).

Effect of germination on viscosity

A drastic decrease in paste viscosity of barley malt was observed during germination. The paste viscosity (15% w/v) was 100 cp for control, and 94 cp and 65 cp after 1 and 2 days germination, respectively. This suggested that prolonged germination of barley could produce a very low paste viscosity and a high alpha-amylase activity. However, as the germination periods increased there could be tremendous loss of dry matter, development of high microbial load and spoilage. A two-day germination was found sufficient to reduce the paste viscosity consistently.

Table 1. Effect of germination on density and hardness of barley.

	Germination (days)					
	0	1	2	3	4	5
1000-seed wt.(g)	40	34	32	30.5	29	27
1000-seed volume (ml)	47	41	40	38.5	37	36
Density (g ml^{-1})	0.8	0.8	0.8	0.7	0.7	0.7
Hardness (B.U.)	21	15	11	9	6	6

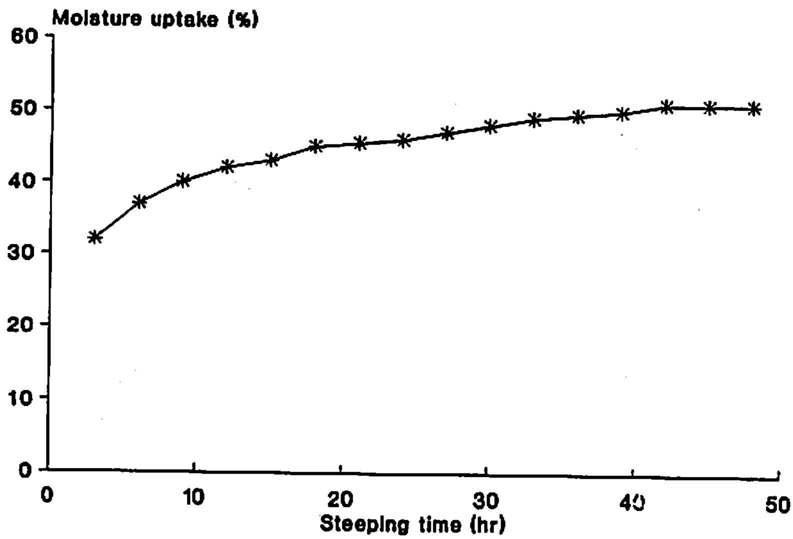

Fig. 1. Effect of steeping on moisture up take of barley

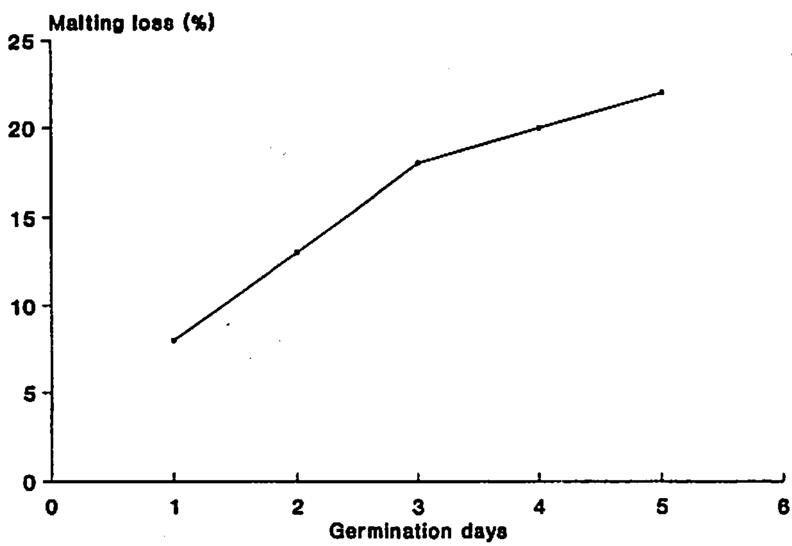

Fig. 2. Malting loss in barley

Table 2. Effect of kilning on the viscosity of barley malt.

Kilning conditions		20% slurry
Temp.(°c)	Time (min)	viscosity (cp)
-	-	120*
60	45	130
70	45	156*
80	45	200
70	30	140
70	45	156
70	60	315
70	80	380

* Without Kilning, good flavor development

Effect of germination on alpha-amylase activity

The effect of progressive germination on development of alpha-amylase activity is given in Fig. 3. There was an increase in alpha-amylase from 2922 (maltose unit/g) in the second day of germination to 4756 (maltose unit/g) in the third day of germination. Increase in alpha–amylase activity has positively affected viscosity reduction, reduced bulk density and raised calorie food. The commercial malt flour sample had an alpha amylase activity of 6400 maltose unit/g but 13000 maltose units/g was reported by Malleshi and Desikachar (1988). The variation could be due to varietal differences.

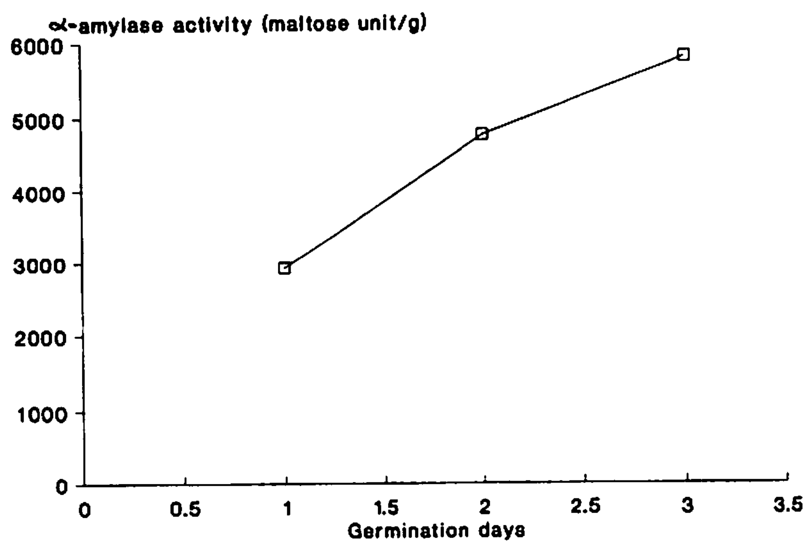

Fig. 3. Effect of germination on α amylase activity of barley

Viscosity of weaning foods

Pooped and roller-dried weaning foods (without malt) exhibited a high viscosity, which is disadvantageous in terms of calorie density (Fig. 4). At 15% (w/t) slurry concentration the paste viscosity for popped and roller dried weaning foods was 12 400 and 12 800 cp respectively. Malted weaning food (MWF) had a lower paste viscosity (980 cp) even at 25% (w/v) concentration. To produce a low consistency and high calorie density weaning food, barley malt at 1-5% was added to RDWF and PWF. There was a progressive lowering in viscosity with increasing level of barley malt (Fig. 5). Similarly Malleshi and Desikachar (1988) and Mosha and Svanbery (1983) indicated that the preparation of germinated flour is time-consuming operation, so it would be practical to use it as an additive to liquify prepared gruel, as it has to be prepared less often.

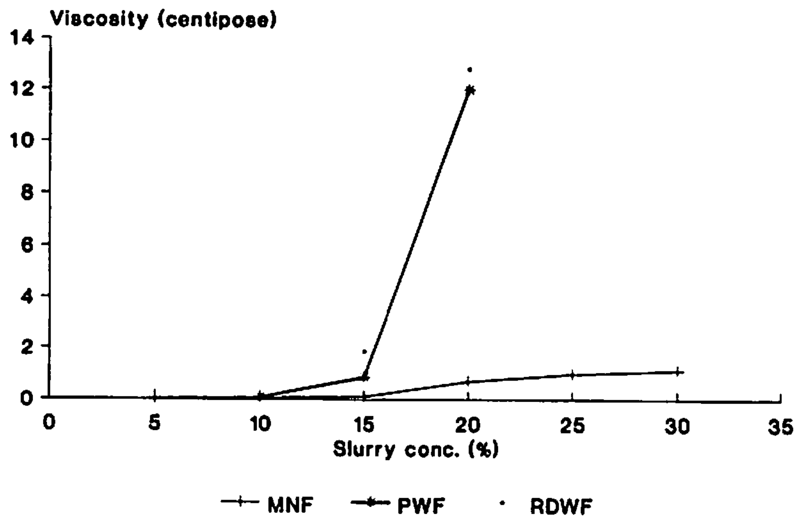

Fig. 4. Viscosity measurement of weaning foods

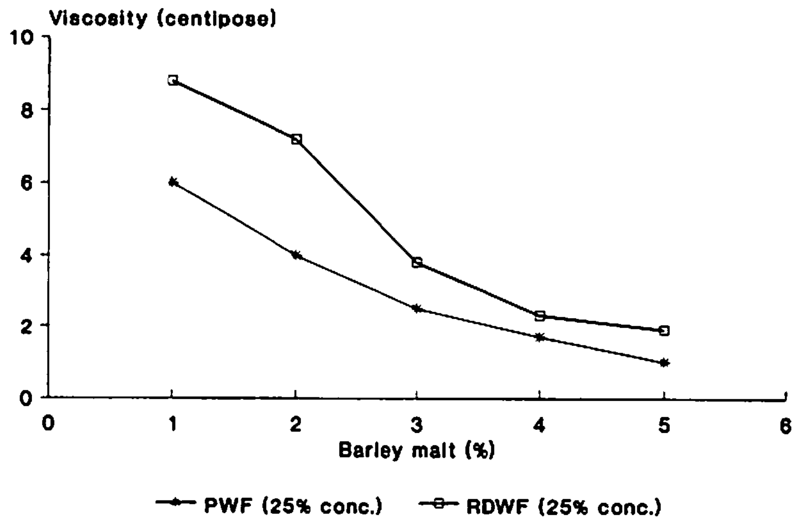

Fig. 5. Effect of addition of barley malt on viscosity of the weaning food

Optimal composition of weaning food formulations

The weaning food blend of 60% barley, 30% chickpea, 5% skim milk powder and 5% sugar was found optimum. The addition of skim milk powder helped to supplement essential nutrients. The quality of the product was as recommended by ISI (1969). MWF had a moisture content of 6.5% followed by PWFM (4.9%) and RDFM (3.5%). Protein content ranged from 14.8 to 15.6%, which is in line with FAO/WHO (1976) recommendations for "International Standards of Infant Foods (Table 3).

Table 3. Proximate composition of weaning foods formulation (100 g sample)

	MWF	PWFM	RDFM	ISI recomm mended (1969)
Moisture (g)	3.0	4.9	3.5	Max. 10.0
Protein (g) (N x 6.25)	15.6	14.8	15.2	Min. 14.0
Ether extractive (g)	3.8	3.8	1.85	Max. 7.5
Total ash (g)	2.2	2.0	2.2	Max. 5.0
Dietary fiber (1 and 2)				
Insoluble (g)1	7.8	9.6	7.7	-
Soluble (g)2	3.8	3.2	2.9	-
Total (g)	11.6	12.8	10.6	-
*Carbohydrates (g)	60.5	61.7	66.7	Min. 45
Calcium (mg)	138	131.4	131.0	Max. 1000
Phosphorous (mg)	358	275.4	283.0	-
Iron	10.2	10.7	11.3	Min. 10.0
Energy (K.cals)	338.6	340.2	344.2	-

*by difference

CONCLUSIONS AND RECOMMENDATIONS

Although barley is appropriate for a wide variety of food, its consumption is limited because of difficulties in removing its husk and bran. Barley must be pearled in order to make it palatable. Traditionally barley is pearled manually at household level which is a tedious and time-consuming task. Therefore, a simple dehulling machine should be introduced for rural as well as urban communities. Milling characteristics of barley varieties should be studied for flour yield and quality. Improved ways of germination should be developed to minimize microbial contamination.

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Barley Utilization

Maaza Kerssie and Lakech Goitom

Abstract

An experiment on barley composite flour for five types of Ethiopian traditional food showed that a mixture of 10-50% barley with tef and wheat is satisfactory for injera, dabo and anebabero. A mixture of 10-90% barley with wheat and sorghum is satisfactory for kita and genfo. When the mixture of barley flour to wheat flour exceeds 50%, the bread quality is affected.

Barley accounts for over 60% of the food for the inhabitants of the Ethiopian highlands. Barley is used in many traditional foods and in making local beverages. Pearled barley is used as a soup thickener, in making stews and dressings. Barley flour is used to make injera, baby foods and gruel and porridge. The malt is used in brewing beverages and malt extracts. In addition the malt syrup is used in baking industries, candy making, malted milk, yeast and vinegar.

CHEMICAL COMPOSITION

Barley is mainly used as a source of carbohydrate, though the protein content is also important. Table 1 compares the nutrient composition of barley to other cereals. Barley protein is composed of 19 amino acids, but low in lysine and methionine (1). Therefore, it is necessary to consume barley with legumes or animal products to supplement the deficient amino acids.

Table 1. Chemical composition of some cereals.

Cereals	Energy (Cal)	Moisture (%)	Protein (g)	Fat (g)	Carbohydrate (g)	Fiber (g)	Ash (g)	Ca (mg)	P (mg)	Iron (mg)
Barley	334	11.3	9.3	1.9	75.4	3.7	2.0	47	325	10.2
Wheat	339	10.8	10.3	1.9	71.9	3.0	1.5	49	276	7.5
Tef	336	11.1	10.5	2.7	73.1	3.5	3.1	157	348	58.9
Maize	356	12.4	8.3	4.6	73.4	2.2	1.3	6	276	4.2
Sorghum	338	12.1	7.1	2.8	76.5	2.3	1.6	30	282	7.8
Millet	326	12.1	7.2	1.4	77.1	5.6	3.3	386	220	85.1

Source: (4)

Traditional foods and drinks

Barley in Ethiopia is traditionally used in various forms of foods such as injera, dabo, kita, anebabero, porridge, and drinks like areki and tella. Barley food such as kolo, beso, chiko are convenient to carry and store and therefore used by travellers and as a military ration during war times. Genfo made from barley is preferred over that made from other cereals. The main food and drinks prepared from barley are presented in Table 2.

Traditional processing of barley grain

Cereals such as barley, wheat, maize and sorghum are dehulled manually, usually by women using mortar and pestle. The process involves cleaning the grain to remove stones and dirt, and soaking in hot water for 10-15 min. Excess water is removed by draining, the grain is pounded to loosen the bran and after that spread on a mat to dry in the sun. Separation of the bran from the grain is done by winnowing. The pearled grain is used for human consumption, while the bran is used for animal feed.

The clean grain is milled into flour using 'wefcho' and 'mej', a traditional mill made from a flat, grooved stone. The flour after sifting is used to make injera, dabo and kita. The roasted grain is used to make kolo or milled into besso and chiko.

Barley in composite flour

To decrease dependency on tef and to diversify eating habits, attempts have been made to develop composite flour recipes (Table 3). Good to acceptable quality barley/tef injera could be prepared in 90/10 percent combination. Quality bread cannot be made by barley alone, because it lacks gluten. Bread made from barley flour becomes darker (2). Barley flour should not exceed 50% for bread making. Good quality kita and anebabero can be made with barley alone or in combination with other cereals. Personal preference plays a major role in selecting the type of cereals for making kita and anebabero. Genfo is usually prepared from barley alone or in combination with other cereals in different proportions. Barley kolo can be served alone or in combination with roasted legumes and oil seeds, such as chickpea and sunflower. In some areas it is served with a mixture of butter and chili powder or honey to enhance the flavor.

Table 2. Main types of foods and drinks made from barley.

Local	Description	Kind of Materials	Preferred grain quality
Foods			
Budena/Injera	thin spongy bread	fine flour (leavened)	large grains
Dabo	thick bread	fin flour (leavened)	White kernels
Kita/Torosho	thin dehydrated bread	fine flour (unleavened)	
Merga/Genfo	Soft porridge	fine flour	
Kinche	hard porridge	coarse flour	hull-less
Atmit	Soup-like (gruel)	fine flour	
Besso	fine flour moistened with water or fat	grains roasted and ground into fine flour	
Chiko	fine flour softened with butter	grains roasted and ground into fine flour	
Kolo	Roasted grains	grains roasted and pounded or thumped	partially naked large
Enkuto	Spikes roasted over flame	handful of dried spikes	large grains
Eshet	grains roasted or row over flame	green/unripe/spikes	
Drinks			
Zurbegonie	besso-water mix	the same as besso	
Bequre	thin, unfermented or slightly fermented	besso flour plus malt	
Borde	thick little fermented	flour plus malt	
Tela	fermented (undistilled)	coarse flour of roasted grains plus malt	
Areqe	Distilled	the same as tella	

Source: (3)

Table 3. Minimum and maximum amount of barley flour for formulating composite flours

Traditional food	Composite flours	Barley (%)	
		Minimum	Maximum
Injera	Barley-Tef	10	50
	Barley-Wheat	10	50
	Barley-Wheat-Tef	10	50
Dabo	Barley-Wheat	10	50
Anebabero	Barley-Wheat	10	50
Kita	Barley-Wheat	10	90
Genfo	Barley-Wheat	10	90
	Barley-Sorghum	10	90

Source: (5)

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Improvement and Utilization of Barley Straw

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Abstract

Out of 6.5 million tons of crop residues produced each year in the country over a million tons of straw comes from barley There is substantial under utilization of barley straw as animal feed. The major constraints on the use of barley straw as animal feed are low nutrient content, low voluntary intake, poor digestibility use of straw for other purposes and unavailability of storage facility The low nutritive value could be upgraded to support increased animal production. There are several factors that affect the quality of barley straw This paper presents review of previous research work on barley straw quality improvement and utilization in the country

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The major methods to improve the feeding value of cereal straws are physical and chemical treatments, supplementation for deficient nutrients and mix with legume straw.

There are several factors that affect the quality of barley straw. Some of these factors are: varietal differences, environmental conditions under which the crop is grown (soil, temperature), management of the crop such as weeding, fertilizer application and time of harvest and post harvest handling.

STRAW PRODUCTION AND QUALITY

Availability and nutritional characteristics

There are no actual data on the quantity of barley straw produced in Ethiopia. However, Alemu et al (1992) estimated an annual production of 1.2 million tons of barley straw based on grain production between 1982 and 1987. According to Kossila (1988) the multiplier used to convert barley grain yield to fibrous residues varies from 1.2 to 1.5 depending on the region where it is produced. For Africa a multiplier of 1.5 is recommended to arrive at the total crop residue produced and after an allowance of 0.3 kg for field losses, 1.2 kg of residue is assumed for each kg of barley grain harvested. Thus, from a total of 1,063,000 tons of barley grain produced in 1989 (CSA 1992), 1.59 million tons of barley straw could be produced of which 1.27 million tons is annually available for livestock feeding. With the inclusion rate of 50% in the diet, this quantity can comfortably support fattening of 3.7 millions heads of cattle weighing 250 kg with a daily gain of 0.5 kg per day.

The major barley producing regions are Arsi, Shewa, Welo and Gojam (CSA 1992). These regions account for 42% of ruminant production in the country and 76% of barley straw produced nationally.

Like other crop residues, barley straw is characterized by low crude protein, high fiber, and negligible amount of fat. In terms of chemical composition barley straw is superior to wheat, but inferior to tef straw (Table 1).

According to Van Soest (1965), a total fiber content of over 55% will impair feed intake while feed with a crude protein (CP) content below 7% will result in a negative N balance. The high fiber content and the low CP level in barley straw suggest the need for supplements if optimum utilization of barley straw is to be achieved. Chemical analysis of barley straw samples collected from six locations is summarized in Table 2.

Degradation characteristics of barley straw have been studied at IAR (Holetta) using ruminally fistulated steers. Barley straw was low in degradation rate and potentially degradable fraction (Table 1).

Factors affecting straw quality

Varietal differences

Among the major options in optimizing crop residue utilization, the need to exploit varietal differences has received much attention. However, the importance of varietal differences in straw quality is still controversial. Some authors have reported substantial (Nicholson 1984, Orskov 1986, Remanzin 1986) while others have reported smaller differences (Kernan et al. 1979, Pearce 1983). Under local condition, variation in nutritional quality and relationship between straw quality and grain yield were investigated using five improved varieties and one local variety of barley at two locations (Table 3). Differences in vitro dry matter digestibility (IVDMD) between varieties were not significant. The coefficient of variation varied from 2.2% at Sheno to 3.2% at Holetta.

Correlation between grain yield and IVDMD was positive at Sheno (r = 0.73), but negative at Holetta (r = -0.55). A positive association between grain yield and straw quality had been reported (Kernan et al 1979, White et al 1981, Erikson et al 1982, Tuah et al 1986, Dias-Da Silva and Guedes 1990). However, Colucci et al (1992) reported a negative relationship between grain yield and straw quality for 12 barley varieties, which is similar to the findings at Holetta.

The inconsistency of the relations at two locations (Table 3) could be due to the small number of varieties and one year data. Further studies on the relationship between grain yield and straw quality are necessary.

Environment and crop management

A study conducted in three locations to investigate location effects on grain and straw yield indicated a significant difference in grain and straw yield (Table 4). The quality of straw is affected by crop management such as fertilizer application. Work conducted on wheat (Lulseged and Jemal 1989) indicated that application of 46 kg N ha^{-1} improved leaf to stem ratio and nitrogen content of the leaves and stems. Agronomic studies carried out at Sheno suggested a marked increase on both grain and straw yield due to N and P applications (Table 5). The stage at which the residue is harvested will also affect the quality of the residue. This is clearly indicated in Table 2 where the nitrogen content of barley straw decreased from 1.2% (at vegetative stage) to 0.6% (at full maturity).

INTEGRATION OF FORAGE CROPS IN BARLEY PRODUCTION

Intercropping barley with forage crops

In the central highlands fallowing is a common practice. The production of forages for weedy fallow in traditional cereal-fallow rotations, can considerably improve the present feed shortage as well as fertility of the land.

Barley and forage crops intercropping experiments were carried out at Holetta and Sheno with the objective to establish forage crops without adversely affecting the grain yield of barley. At Holetta the undersown forage crops established successfully and none of the species significantly affected the yield of barley (Table 6).

At Sheno forage species were undersown at two planting dates: simultaneously with barley and immediately after first weeding of barley. Those sown after weeding failed to establish in all three years due to low temperature. Similar results were reported from Ginchi (IAR 1982). Forage crops sown with barley at Sheno established successfully without significant yield reduction of barley. Barley grain, straw and forage yield at Sheno are shown in Table 7. Generally barley yields were low due to lodging. On the average 10 t ha^{-1} of barley straw and 1.7 t ha^{-1} of improved forages were harvested at Holetta (Table 6) and 3 t ha^{-1} of barley straw and 1.2 t ha^{-1} of forage yield was also obtained at Sheno from the same piece of land (Table 7).

Cropping sequence

In an experiment conducted at Sheno in 1986 and 1987 (Adamu 1991) to identify suitable preceding crops for barley, the highest grain and straw yields were obtained from barley following vetch and faba bean (Table 8).

At Quiha a similar experiment was conducted in 1973 and 1974 with wheat, fallow, oats/vetch and tef as precursor crops. Barley planted after oat/vetch yielded highest (IAR 1975). These preceding forage crops, besides increasing the yield of barley, would also alleviate the existing feed shortage and serve as a protein supplement to the barley straw.

Undersowing barley with clovers

The potential of various forage legumes to increase the productivity of crop-livestock system has been studied by ILCA (Nnadi and Haque 1988). Species within the *Trifolium* genera have received high attention for the Ethiopian highlands.

A preliminary on-farm study conducted at Holetta, Sendafa and Sululta to assess the effect of undersowing barley with clovers mixture on the grain and straw yields of barely (Abate and Jutzi 1985), showed that clovers mixture grown under barley did not cause a significant reduction of grain and straw yield. The application of P increased significantly grain and straw yields of barley during the first year. Clover establishment was better on plots applied with P, but it is likely that the barley yield increase was a direct effect of P application rather than the N-fixation activity of the clovers. Hence the authors concluded that clovers can grow with barley without adversely affecting grain yield. Similar work on wheat with clovers (Abate et al. 1992) showed significant increase in the total wheat straw yield and its quality. This can be also true for barley straw as both crops are grown in similar environmental conditions.

Multipurpose trees in barley growing regions

Tree legumes such as *Chamaecytisus palmensis* (Tagasaste) for high altitude and *Sesbania* for mid altitude highlands have considerable potential for sustaining barley-livestock system in the Ethiopian highlands.

In an on-farm trial conducted at Holetta and Deneba high leaf fodder yield was attained at Holetta after one year growth from two accessions of *Tagasaste* and one accession of *Sesbania* (Table 9). On the other hand, low leaf fodder yield was recorded at Deneba where low temperature (annual mean temperature 13.8°C) appeared to cause retarded growth during the growing period. High protein leaf fodder from multipurpose trees (Table 10) could be used as supplement to barley and other straws which are low in nutritive value (Table 11).

CONCLUSION

Feed shortage is a major factor constraining animal production in the Ethiopian highlands. Since human and livestock population are nearing the maximum carrying capacity of the Ethiopian highlands, research should concentrate on more intensive systems that produce higher yields of protein and energy. Barley straw is the main crop residue produced in the highlands and it is an integral part of the ruminant diets during the dry season. There is substantial under utilization of barley straw as animal feed. Barley straw and other cereal straw, because of the stage of crop harvest, are low in protein content and digestible dry matter. The low nutritive value could be upgraded to support increased animal production. Very little work has been done on improvement of barley straw quality and its utilization as animal feed.

Most of the results presented in this document are the outcome of different experiments that require further work to make a coherent and valid conclusion. Future work should concentrate on evaluating barley straw varieties using laboratory chemical analysis and different bio-assay techniques. Agronomic practices which optimize the quality of barley straw should be conferred. Screening of forage legumes for barley growing regions and evaluating the supplementary value of these legumes to barley straw based diet is also an area which should get due attention.

Table 1. Chemical composition and rumen degradability[1] parameters of barley and other cereal straws (% DM).

Residue	CP	EE	Ash	NDF	ADF	Lignin	a	b	c
Barley	6.2	2.3	8.3	73.2	45.0	6.3	21.1	33.7	0.026
Tef	6.0	1.7	7.1	74.5	42.4	7.7	19.8	58.1	0.024
Wheat	3.9	1.6	7.2	77.2	48.2	7.9	-	-	-
Native hay	-	-	-	-	-	-	16.3	56.8	0.031

a- soluble fraction, b- insoluble but potentially digestible fraction,

c- rate of digestion

Source: Seyoum and Zinash (1989), [1] Holetta Research Center (Unpublished)

Table 2. Chemical composition (% DM) of barley straw from different locations.

Location	CP	ADF	Lignin	NDF	IVDMD	ASH
Debre Berhan	3.75	42.5	6.2	67.4	54.5	8.9
Debre Zeit	3.13	51.0	6.6	78.2	44.7	9.5
Kuriftu	3.13	50.1	6.3	75.5	35.8	8.7
Melka Werer	-	47.0	8.6	-	-	7.3
Selale (straw)	3.75	45.7	5.5	72.7	51.8	6.8
Selale (Vegetative)	7.50	34.3	4.4	53.8	63.2	9.2
Shola	3.13	52.8	7.6	80.7	-	9.9

Source: Anindo, D. (Personal communication)

Table 3. Variations in nutritional quality of different varieties of food barley straw.

Variety	NDF		IVDMD	
	Holetta	Sheno	Holetta	Sheno
HB-100	69.5	67.1	47.1	50.3
HB-99	71.6	65.7	44.3	49.9
ARDU-12-9C	72.8	66.6	44.6	48.2
HB-32	70.7	69.5	47.0	47.9
HB-42	68.1	67.1	46.7	50.3
Local	68.1	71.0	48.0	48.8
Mean	70.1	67.9	46.3	48.8

Source: IAR, 1991

Table 4. Effect of location on grain and straw yield.

Location	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Kotu	1.4b	1.8b
Dalota	2.0a	2.3a
Cheki	1.2c	1.6c

Source: Sheno progress report April 1990-March 1991

Table 5. Effect of N and P fertilizers on grain and straw yield (Sheno, meher season).

Fertilizer (kg ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
N		
0	0.7f	1.0f
23	1.0e	1.4e
46	1.3d	1.8d
60	1.6c	2.3c
90	1.9b	2.7b
150	2.1a	3.2a
P		
0	0.8e	1.3e
10	1.2d	1.8d
20	1.5c	2.1c
30	1.6b	2.2c
40	1.6b	2.3b
53	1.8a	2.6a

Source: Sheno progress report, April 1990 to March 1991

Table 6. Mean yield of barley and intercropped forage species, Holetta, 1982/83.

Intercropped species	Grain (t ha^{-1})	Straw (t ha^{-1}) (air dried)	Forage DM (t ha^{-1}) 1982/83	1983/84*
Sole barley	3.1	10.8	-	-
Phalaris 'Sirocco'	3.3	10.4	0.6	18.0
Lolium 'Kangaroo valley	3.4	9.0	3.2	7.6
Lolium 'Mt Alma'	3.1	8.2	3.6	6.1
Tall fescue	3.4	10.9	0.6	11.2
Setaria	3.3	13.2	0.3	20.4
Lolium 'Westerweldicum'	2.9	8.2	1.9	7.4
Mean	3.2	10.0	1.7	11.8
CV%	1.1	19.3	34.6	10.8
LSD (0.05)	NS	2.7	0.9	0.2

Source: IAR, Holetta (1983, 1986)
* - Three harvests

Table 7. Average yield of barley and intercropped forage species, Sheno, 1990.

Intercropped Species	Grain (t ha^{-1})	Straw (t ha^{-1}) (air dried)	Forage DM (t ha^{-1}) 1990/91	91/92	92/93
Sole barley	1.9	2.8	-	-	-
Phalaris 'Australia'	2.2	3.1	-	-	1.8
Tall fescue	1.8	3.8	1.4	0.9	2.9
Lolium 'Kangaroo valley'	2.6	4.2	1.6	4.2	1.5
Lotus corniculatus	1.6	2.5	0.3	1.2	3.5
Trifolium tembense	1.0	1.9	1.5	1.0*	
Mean	1.8	3.0	1.2	1.8	2.4
CV%	29.0	30.1	33.0	31.9	32.8
LSD (0.05)	NS	NS	0.6	1.2	NS

* The harvest was due to regeneration of dormant seeds
Source: IAR, Sheno (unpublished)

Table 8. Effect of preceding crops on grain and straw yield of barley, Sheno, 1987.

Preceding crop	Grain yield (t ha^{-1})	straw yield (t ha^{-1})
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
Oats	1.4ab	1.9b
Potatoes	1.3b	1.6b

Source: Adamu (1991)

Table 9. Mean plant height, leaf and stem yield of *Tagasaste* and *Sesbania* grown on farmers' backyards at Holetta and Deneba, 1992.

Location	Acc. no.	Height (cm)	Yield (DM kg ha^{-1})	
			Leaf	Stem
Holetta				
Tagasaste	MOA	202	1098	1296
	ILCA 15378	286	2238	2648
Sesbania	ILCA 15019	235	1956	2717
	SE	26	551	746
Deneba				
Tagasaste	MOA	159	612	601
	ILCA 15378	182	810	925
	SE	12	164	186

Source: Kahsay (1993)

Table 10. Forage yields and nutritive value of some MPTs at Debre Zeit.

Species	Forage yield (kg ha^{-1} yr^{-1})	CP (% DM)	IVDMD (% DM)	NDF (% DM)
Sesbania sesban	5026	30.0	75.6	26.3
Leucaena sp.	4807	27.2	63.6	45.7
Chamaecytisus palmensis	11037	24.4	66.9	48.5

Source: Kahsay et al. 1993

Table 11. Nutritive value (% DM) of crop residues and native pasture hay.

Crop residues	CP	IVDMD	NDF
Tef	4.1	48.5	79.6
Wheat	4.0	46.7	79.8
Barley	4.4	53.9	71.5
Sorghum	2.2	57.6	70.1
Maize	3.8	41.2	73.0
Faba bean	6.4	54.0	74.3
Field pea	6.7	-	73.6
Chickpea	5.3	50.9	50.2
Lentil	7.8	55.4	52.9
Native hay	6.6	55.3	68.8

Source: Kahsay et al. 1993

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Barley in Ethiopia: the link between botany and tradition

Zemede Asfaw

Abstract

A brief review of the general botany of barley and traditions associated with barley cultivation in Ethiopia is presented. The main groups of barley are given under the classical method of grouping as six-row, two-row and irregular types, while the hulled, hull-less and partially hulled types are treated in the formal taxonomic contexts. Characters of universal occurrence include forms with long spikes, lax spikes, hulled kernels, white kernels, black kernels, and awned lemmas with long, rough, persistent awns, while others are restricted to one or two of the main groups. Systems of barley nomenclature and classification used by farmers for ages are discussed, noting the parallelism with that of formal taxonomy. The oral tradition has been sampled as a testimony of the significance of barley to Ethiopia.

Barley has a unique place in Ethiopia, though its origin has been debated. The question of its antiquity had been an area of concern in many studies, i.e., in studies of crop domestication pattern in Africa (Porteres 1976, Purseglove 1976), interpretations of linguistic evidence (Ehret 1979) and archaeologic and historical studies (Brandt 1984). Various sources agree that it has been in cultivation for at least the past 5000 years. The first Ethiopians known to have ever cultivated barley are believed to be the Agew people, in about 3000 B.C. (Gamst 1969). In the southern part of the country barley cultivation and plough culture are said to have come simultaneously, with the additional remark that until very recently barley was looked upon as a special and sacred crop (Haberland 1963).

Archaeology has yet offered anythinn concerning barley antiquity in Ethiopia as the recovery of botanical remains has never been made its central focus, except the study of fossil pollen grains that proved to be ineffectual for the grass family. The limited archaeological studies seem to have been hampered by the fact that the traditional bee-hive shaped grass thatch and cow dung plaster are less favorable for fossilization of grains (Clark and Williams 1978).

There have been many foreign missions and crop explorations in Ethiopia in the last 400 years. Early travellers, including the Portuguese Francisco Alvares, who explored Ethiopia in the 1520s (Alvares 1961), have recorded the wide occurrence of barley. The presence of domestic varieties of barley in Ethiopia was acclaimed by many 19th century crop taxonomists including

Kornicke and Atterberg (Orlov 1929, Ciferri 1940, 1944, Vavilov 1951). Barley was also covered in the germplasm exploration studies of American and British missions (USA operation mission to Ethiopia 1954, Huffnagel 1961). Explorers were most attracted by the morphological variations and the abundance of endemic types (Orlov 1929). Though largely fragmented, early studies covered many aspects including morphology, agronomy, ecology, diversity, evolution, genetics and taxonomy.

Interest then shifted toward utilization of Ethiopia barley germplasm in the breeding and development of modern barley varieties. Harlan (1968,1969) considered Ethiopian barleys to be inferior by modern standards as cultivars, but very valuable sources of genetic material for breeding. Although this claim was based on observations made when the material was grown far away from its natural habitat and geographical range, it seems to have had an influence on the direction of barley research in Ethiopia for a long time. Other researchers acknowledged attractive character including big kernel size, high tillering capacity, high grain weight (Orlov 1929, Huffnagel 1961, Westphal 1975) and important nutritional qualities such as higher protein content and cholesterol reducing chemical factors(Anderson et al. 1991, Heen et al. 1991). The importance of Ethiopia as a source of barley germplasm was reviewed by Mulugeta (1985), providing a list of countries where larger collections are being maintained, including the USDA collection described by Moseman and Smith (1981). Ethiopian barley types have significantly contributed to understanding and improvement of the crop world-wide. More recent studies focus on the resistance of Ethiopian material to pathogens, germplasm conservation and utilization, assessment of diversity and biochemical gene markers (Alkamper 1974, Qualset 1975, Metcalfe et al 1978, Endashaw 1983, Mulugeta 1985, Engels 1986).

Morphological Variations

The cultivated taxa of *Hordeum* are a group of forms distinguished by differences in spike characters. More botanical forms with geographical and ecological races being represented by several agricultural "varieties" occur throughout the world (Bell 1965). Giessen et al. (cited in Huffnagel 1961) recognized 170 types from Ethiopia as *deficiens, distichon, hexastichon, intermedium* and *labile*

Several botanical forms and morphological groups of barley are found in Ethiopia. Botanical identification of types following barley variety identification keys gave 64 distinct types, while classification gave 42 morphological groups under five major groups (Zemede 1988). The main groups can be viewed under hulled, hull-less, partially hulled, six-row, two-row with varied spike shape, density and pigmentation. Glumes and lemma also display a wide range of variation in size, shape, color and texture, Some morphological types are reported to be endemic to Ethiopia (Orlov 1929, Harlan 1969). The possible variations in each major group (six-row, two-row and irregular types) and main attributes are shown in Table 1.

The common botanical forms of Ethiopian barley are *deficiens, pallidum, nutans* and *nigrum* types, while the pyramidal, parallel and hull-less types have restricted occurrences. The frequency of six-row types, hull-less types and those with compact and colored spikes is highest at higher altitudes.

The dominating barley types vary between fields, localities and regions. Up to 12 distinct morphotypes were recovered from a single barley field. Since morphological variations expressed under uniform ecological conditions are more likely to be genetic, the different morphotypes seen in a field are bound to be manifestations of gene differences.

A combination of agroclimatic and biological processes, some of which are indicated below, are believed to have favored the diversification of barley forms in the Ethiopian environment.

- Highly heterogenous environment is believed to have favored mutations and their subsequent fixation.
- Biological processes of natural selection are combined with breeding systems of barley that engrosses predominant selfing and limited outcrossing.
- Domestication processes, diversity of agricultural systems, agglomeration of different forms in a single field, occasional deliberate selection of lines by farmers, the diverse cultural values of social groups may have assisted the process of fixing and preserving of forms.

While the selection pressures favored the preservation of many botanical forms, they must have also disfavored other types which became less and less frequent, and even "extinct" from cultivation. The hooded type was reported as characteristic in Ethiopia (Bell 1965) and recovered from Ethiopian barley samples kept in foreign gene banks. The type is never encountered under cultivation in recent years and forms reported to be common in some regions and localities during the Vavilovian expedition are absent or rare in those areas at present.

Table 1. Morphological variations in Ethiopian barley.

Character	Six-row	Two-row *Deficiens*	Two-row *Nutans*	Irregular
Spike	dense	dense	dense	-
	lax	lax	lax	lax
	long	long	long	long
	short	-	short	-
	stout	-	-	-
Kernel	hulled	hulled	hulled	hulled
	hull-less	-	hull-less	-
	hull-partial	partial	partial	-
	white	white	white	white
	black	black	black	black
	purple	purple	purple	purple
Appendages	hood	-	-	-
	awn	awn	awn	awn
	awn long	long	long	long
	awn short	short	-	-
	awn rough	rough	rough	rough
	awn smooth	-	-	-
	awn diverging	diverging	diverging	-
	awn converging	converging	converging	-
	awn persistent	persistent	persistent	persistent
	awn brittle	-	-	-
Outer glumes	broad	broad	-	-
	narrow	narrow	narrow	narrow
	long awn	-	-	-
	short awn	short awn	short awn	short awn

Groups of Barley

The classical way of grouping barley into main morphological classes is based on spike row number. However sorting on the bases of caryopsis type provides a neat and more eloquent system, by which the following three groups are easily distinguished by Ethiopian farmers.

Hulled barley

This group is what might be called the barley proper. The husk adheres to the grain requiring arduous dehulling to make it ready for human consumption. As a group it is the largest in area, provenance and number of morphological types. Hulled and partially hulled types account for about 70% of the morphologically distinct barley types of Ethiopia. It is the most diverse major category including six-row, two-row, irregular forms, dense, lax, hooded, long awn and short awn, rough awn and smooth awn, etc. This character shows up in all major morphological groups, i.e., 6-row (dense, lax), 2-row (deficiens, nutans) and irregular types (Table 1).

Hulled barley is considered by farmers of Ethiopia to be less labor intensive and higher in yield, while it is less popular among women as it involves highly strenuous labor.

Hull-less barley

The hull-less (naked) barley is a group in which the husk falls free on threshing without adhering to the grain. Naked types are cultivated in the highlands of Shewa, Gonder and Tigray. The high lysine-high protein *(hiproly)* types are part of the Ethiopian hull-less barleys. Within this group 2-row, 6-row, lax and dense forms are found. The frequency of hull-less types is low and its distribution is restricted. Most of the types were found as rare admixtures in fields of hulled and partially hulled types. In one locality in Shewa where the highest concentration of hull-less types were found, 31 distinct barley types were identified of which 4 were of the hull-less types (Zemede 1990).

The proportion of hull-less types was calculated from records of Ciferri (1944) to be 38% for Ethiopia and from Orlov (1929) to be 36% for the Addis Abeba region. These early works show that the variation and frequency were higher and the distribution wider than that observed at present. Orlov (1929) reported a diversity of forms and claimed that the Ethiopian materials are genetically different from the Asian ones. Hull-lessness is a recessive character encountered in six-row and nutans types of two-row forms.

Recent results amplify the traditional practice of using hull-less barley for food, by confirming its superior nutritional quality with respect to proteins, fats, minerals, dietary fiber and energy (Heen and Frolish 1991).

Discussion with farmers in Shewa indicated that cultivation of hull-less barley has been declining, which is supported by a comparison of the early records and the present one. Some hull-less types, reported by Orlov (1929) and Ciferri (1944), were not found in their studied areas. Hull-less and partially hulled types are favorable by women, who pressurize their men to cultivate them, or undertake cultivation by themselves in small plots around the homestead.

Partially hulled barley

This constitutes a diverse group of 2-row barley with lax and dense forms in which the husk is easily removed upon heating. This group was encountered in many regions, but most frequently in the highlands of Shewa, Gamo Gofa, Gonder and Bale.

The partially hulled grain is more preferred for consumption in a form of roasted grain, which is easy to prepare and simple to serve, requiring light roasting and pounding (dehulling). This is evident from the local name given to this group which means lazy person's barley or simply 'lazy barley, easy going barley'.

Barley Consumption

Ethiopia ranks second only to Morocco with respect to per capita consumption of barley consumed annum (Bhatty 1992, citing FAO data of 1990). The data show 68, 19 and <1 kg, respectively, for Morocco, Ethiopia, and Europe and America. Unlike many other countries, its role as important food grain continued to the present, with about 40% of the total grain produced being used as foods (Hailu Gebre and Pinto 1977).

The highest consumption of barley takes place in highland areas where it is widely cultivated. In these areas consumption begins at around the milky stage of grain when youngsters remove awns from green unripe spikes, crush them between the palms, blow away fragments of rachis and glumes and consume the raw green grains in the field. Unripe spikes may also be roasted over fire, which burns away awns and glumes after which spikes are crushed, fragments blown away and the grains eaten. Farmers associate barley food with increased physical strength, analogous to the ancient Romans where barley was given to gladiators (Briggs 1978). Different kinds of bread, porridge, soup and gruel are made from barley in every household with some preferences of types for some category of foods (Zemede 1990).

Affinities of Ethiopian Barley

Vavilov initially considered Ethiopia as the center of origin for barley and later as a secondary center of diversification. The main reason for this reversal of opinion was the absence of wild progenitor. Other researchers acknowledged this secondary nature (Takahashi 1955, Huffnagel 1961). Some researchers argue in favor of the earlier view by referring to the diversity and endemicity of forms and the frequency of disease resistant genes. Still others emphasized the unique endemic forms and the abundance of forms with features that are generally considered most primitive in barley including covered caryopsis, bigger plants, pubescence, well-developed glumes and anthocyanic straws. Some tended to consider at least some of these features as consequential of early introduction of the barley.

The claim that Ethiopian barley evolved independently (Harlan 1968) is substantiated by experimental results of crosses between Ethiopian and non-Ethiopian barleys, resulting in sterility and reduced seed set ratios (Smith 1951, Jonassen and Munck 1981). However, a cross between *spontaneum* and an Ethiopian *vulgare* showed a high level of hybrid viability and fertility was found (Zemede and Bothmer 1990).

Popular Nomenclature and Classification

The major languages spoken in Ethiopia at present all have a specific name for barley and for the major morphological types (Table 2).

The most widely used name for barley in Ethiopia, 'Gobs' or 'Gebs' is assumed to have been derived from the term 'Gebz' or 'Gazb' which according to Ehret (1979) belongs to an extinct east cushitic language group. Gebs is widely used in central and southern Ethiopia, sometimes with slight modifications. The most commonly used form in the northern part of the country is the term 'Segam', which is the same as the Geez form. Linguistic analysts trace the terms Gebs and Segam back to the roots 'Geb' and 'Sek' of the Agew language (Ehret 1979). The Geez root for Segam is also related to the Bilen (cushitic) term 'Seakma' or 'Sekma' and the Awiya 'Simeki' (Leslau 1979). The nearest term to the Geez root Segam, which is known to antedate Gebs, from among the languages spoken in countries neighboring Ethiopia is the Nubian 'Serin' (Table 3).

Besides the diversity of vernacular names for the different cultivated barley forms the highly systematic nomenclatural system is very striking. As in the botanical system of naming the major criterion of traditional naming rested upon caryopsis type, spike row number, grain color, use, origin and adaptation. The names fall under three main categories based on being hulled, partially hulled and hull-less. The naming system can be illustrated with the following examples. In the series, 'senefgebs', 'senefnetchgebs-balekaport', three main botanical features are included in the last one, namely partially hulled character, straw, grain color and the broad outer glumes that look like an overcoat of the grain. While some vernacular names enjoy a wide provenance, the use of other types is very restricted. The integration of popular nomenclature of crops with the formal taxonomy is believed to facilitate the building up of the history of the crop and routine application.

Tables 2. Names of barley in different Ethiopian languages.

Name	Language	Source
Gebs	Argoba	Leslau 1979
Gebs	Amharic	Woldemichael 1987
Gebs	Gogot	Leslau 1979
Gebs	Soddo/Gurage	Cufodontis 1968
Gerbu	Oromo	Cufodontis 1968
Gus	Afar	Cufodontis 1968
Gos	Adere	Cufodontis 1968
Gos	Gimira	Leslau 1979, Ehret 1979
Gesso	Shinasha	Ehret 1979
Gebra	Quara	Ehret 1979
Gevera	Kemant	Ehret 1979
Geb	Agew	Ehret 1979
Gabz/Gazb	East Cushitic	Ehret 1979
Segam	Geez	Leslau 1979
Segam	Tigre	Woldemichael 1987
Seram	Beja	Ehret 1979, Woldemichael 1987
Seqo/sheko	Kefa	Ehret 1979
So-o	Hadiya	Woldemichael 1987
So-a	Kembata	Woldemichael 1987
Sek-(Sekum)	Agew	Ehret 1979
Kusa	Janjero	Ehret 1979
Banga	Welayita	Woldemichael 1987
Biota/poorta	Konso	Engels and Gottsch 1986

Table 3. Names of barley in some languages outside Ethiopia.

Name	Language	Source
Sry	Egyptian	Ehret 1979
Serin	Nubian	Ehret 1979
Sir	Semitic	Ehret 1979
Orge	French	Woldemichael 1987
Ngano	Swahili	Herbert (Per. Com.)
Sciahir	Arabic	Cufodontis 1968

ORAL TRADITIONS

There are many traditional sayings, poems, lines from songs and aphorisms on the importance of barley in the life of the Ethiopian society (Table 4).

Table 4. Traditional sayings, poems, lines from songs and the attributes of barley to which they refer.

Sayings, poems, etc., (Amharic)	Attributes
Gebs yehil nigus	Barley, the king of grains
Minim biarsu endegebs ayafsu	Reference to yield
Ayzosh nefse dereselish gebse	Early coming food
Hulegebu gebs	All purpose grain
Gebs sibesl abatun yimsel	Character transmission
Gebs yebela sew	Food quality
Gebsima doro	Reference to grain color
Gebs kitu yilbes	Planting habit
Gebsna gebs abro yinfes	Planting habit
Yegebs bizu nedo, yeteff sisu nedo	High seed yield
Yedoro ayn yemesele yegebs tella	Brewing quality
Gomen bawotaw nefs yimesegenal gebs	Early coming food

Conclusion

It has become common among contemporary barley breeders that landraces should be materials for gene banks and not to be used for breeding. However, since landraces of barley and other crops are feeding almost the entire Ethiopian population, they merit better attention. The overriding points with respect to barley in Ethiopia include the following among others.

- the contribution of barley to the general crop improvement can be raised by concentrating on indigenous material,
- the importance of barley landraces need to be backed by appropriate actions including:
- selection and breeding of better types for specific zones
- formulation and utilization of co-adapted mixtures of landraces,
- exploitation of better yielding varieties in rewarding zones, seasons and with appropriate management complements,
- improving the genetic promising landraces for specific zones and
- working in close collaboration with traditional farmers.

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