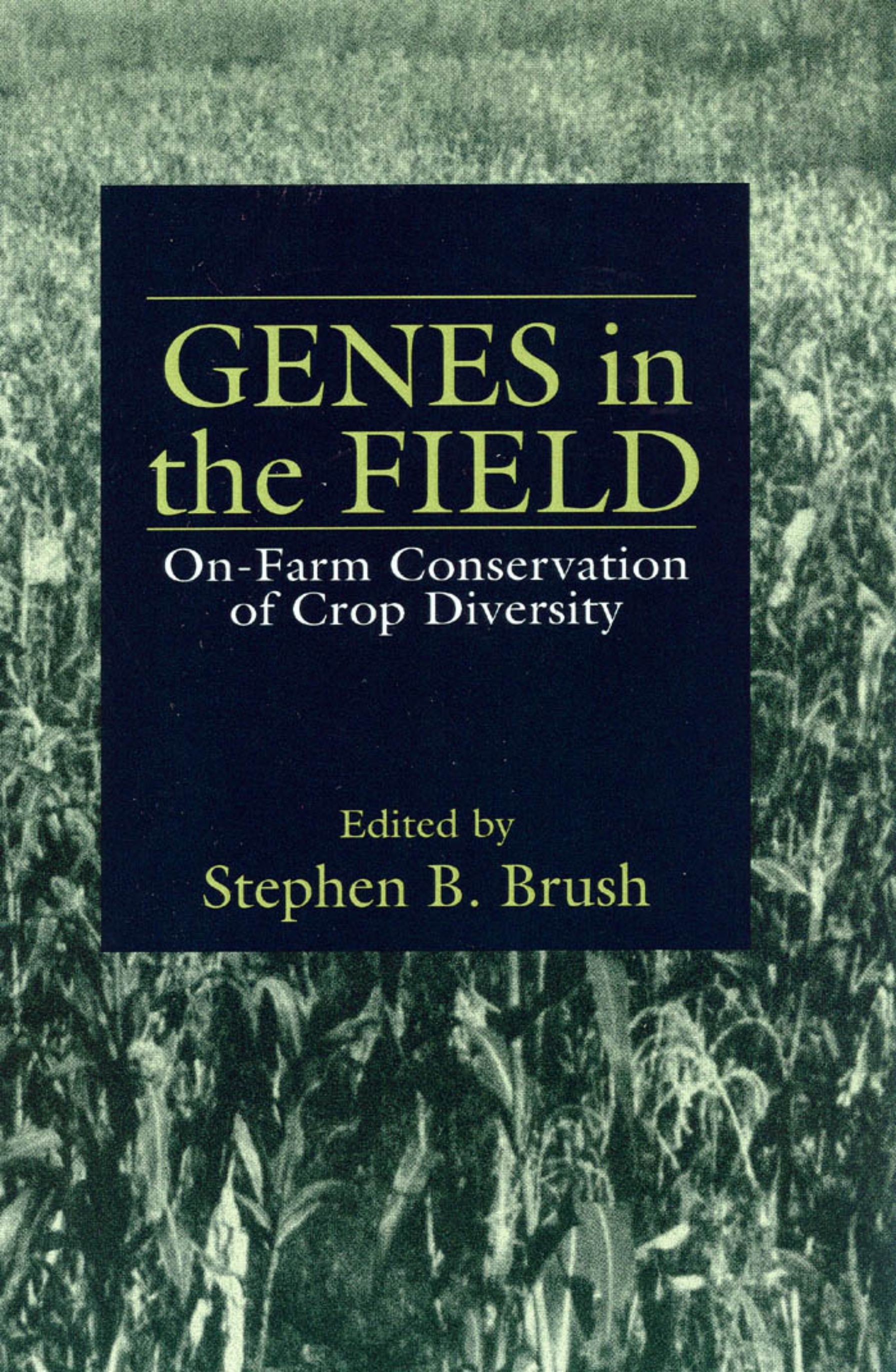

GENES in the FIELD

On-Farm Conservation of Crop Diversity

Edited by

Stephen B. Brush

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Stephen B. Brush, Ph.D.

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The barleys of Ethiopia

Zemede Asfaw

Introduction

Recognized as one of the world's most ancient food crops, barley has been an important cereal crop since the early stages of agricultural innovations 8,000 to 10,000 years ago. Throughout history, barley has undergone continuous manipulation in an effort to optimize its use for human consumption and as animal feed. Barley has been used as a model organism in experimental botany, the plant of choice because of its short life cycle and morphological, physiological, and genetic characteristics. Globally, barley ranks fourth among cereal crops in both yield and acreage, after wheat, rice, and maize (Munck 1992b). With advances in food production and agriculture, major dietary shifts from barley to rice and/ or wheat have resulted in the decline in barley consumption, with the exception of societies — particularly those relying on traditional, small-scale agricultural systems — in which its use as human food has continued to the present.

The world has now "re-discovered" barley as a food grain with desirable nutritional composition including some medicinal properties. Barley breakfast foods and snacks are increasingly available, driven by recent research findings, which show that barley fiber contains beta-glucans and tocotrinols, chemical agents known to lower serum cholesterol levels (Burger et al. 1981; Anderson et al. 1991). In Ethiopia, barley is the third most important cereal crop next to teff and maize. It is the staple food grain for Ethiopian highlanders, who manage the crop with indigenous technologies and utilize different parts of the plant for different purposes.

Efforts to improve barley have demonstrated a preference for a limited number of modern, genetically uniform cultivars suited for high input agriculture, to the neglect of the various farmers' varieties, or landraces, on which a large sector of the human population has subsisted for millennia. The trend has narrowed the genetic base of the local material, leading to the gradual replacement of landraces with modern barley cultivars or of other crops such as wheat and oats. One consequence of this replacement is the loss of indigenous knowledge associated with replaced landraces. It is noted that some earlier morphotypes of Ethiopian barley (e.g., hooded barley; Bell 1965) are no longer found in cultivation. Some Ethiopian barley types (e.g., smooth awned types, hull-less types) kept at the Gatersleben gene bank in Germany (Index Seminum 1983) are not found in the country at present. Some varieties reported as abundant during the Vavilovian expedition (many naked and some rare covered forms) (Orlov 1929) could not be found in those areas (Asfaw 1988). The global trend has been to select for a few high yielding types, thus narrowing the genetic base of a crop. This trend has influenced the direction of Ethiopia's limited barley research over the past four decades. In crop genetic resources conservation efforts, Ethiopian barley has been identified as a priority crop since the 1920s, and extensive germplasm collections have been deposited in gene banks all over the world, especially in Russia and the U.S. (Orlov 1929; Ciferri 1940, 1944; Negassa 1985). Both the usefulness of barley and its high genetic and morphological diversity have rendered barley conservation a matter of top priority. This is evidenced by a long history of conservation in gene banks around the world since the 1920s, beginning formally in Ethiopia in 1976. *Ex situ* germplasm conservation has facilitated the preservation of the diversity present at a given point in time, but does not preserve the dynamic co-evolutionary processes that take place when landraces are continuously cultivated in their natural agroecological settings. To remedy this shortcoming, the need for complementary *in situ* conservation has been recommended and is under serious consideration (Feyissa 1995; Soleri and Smith 1995; Altieri and Montecinos 1993).

Scientists are currently working to improve barley using genetic engineering and other modern techniques; they are looking forward to the formulation of barley ice cream and many other fabulous products for future markets. Another area of research concentrates on alternative approaches for sustainable use and conservation of the diversity in the barley gene pool. This approach focuses on *in situ* conservation of barley landraces — a new line of thought rooted in the traditional practices that have preserved the indigenous farmers' varieties. Traditional farming systems have the dual functions of production and conservation since the entire agroecosystems are crop germplasm repositories (Altieri and Montecinos 1993). This chapter highlights the case of barley in Ethiopia, focusing on the importance of traditional management and cultural practices associated with the landraces. Traditional farmer practices are viewed in the light of on-farm conservation activities being implemented under a new landrace on-farm conservation project, *A Dynamic Farmer-Based Approach to the Conservation of Ethiopia's Plant Genetic Resources,* supported by the Global Environment Facility and implemented by the Biodiversity Institute of Ethiopia in collaboration with other institutions.

The barley crop

General botany, phylogenetic relations, and classification

Barley belongs to the genus *Hordeum* L. in the tribe Triticeae of the family Poaceae. The genus *Hordeum* is a distinct genus in the tribe, well distinguished by three one-flowered spikelets at each rachis node. Its taxonomy and phylogeny have been studied by many scholars including Orlov and Åberg (1941), and von Bothmer et al. (1981). Believed to have differentiated from *Agropyron-Elymuss*-like ancestors (von Bothmer et al. 1981), the barley genus, *Hordeum,* is a relatively small genus with about 28 species distributed over wide geographical areas and diverse ecological habitats. Its three main centers of distribution are southern South America, western North America, and southwestern to central Asia. Species occurring in the Americas, Eurasia, the Mediterranean-Middle East, and Africa number 19, 5, 3, and 1, respectively. The greatest diversity of the genus is found in southern South America, which together with southwestern Asia constitutes the primary centers of diversity (von Bothmer et al. 1981). The two areas of its primary center are connected by a single endemic species (*Hordeum capense*) found in South Africa.

Two parallel hypotheses have been posited to explain an ancient differentiation of the genus: one proposes that ancient forms of *Hordeum* were distributed in a larger area including South America and southern and eastern Africa up to central Asia; a second hypothesis asserts that early migrations of the genus took place in one primary center, most likely South America, migrating to Asia via South Africa. The former view, which advocates a wider initial distribution of the barley genus, is considered more plausible (von Bothmer et al. 1981), based on the fact that there is at least one primitive group in each major area. According to modern treatment, *Hordeum vulgare* L. is differentiated into two subspecies: *spontaneum* and *vulgare.* The former subspecies contains all the *spontaneum* group and is the immediate ancestor of all cultivated types. All of the cultivated types are lumped into subspecies *vulgare.* The main feature distinguishing between the two subspecies is that the *spontaneum* types have brittle rachis while the *vulgare* types have tough rachis. The *spontaneum* group is believed to have been derived from the wild *Hordeum* species, *H. murinum* and *H. bulbosum,* characterized by well-developed lateral florets (von Bothmer and Jacobsen 1985). A scheme for the taxonomy and classification of the cultivated and *spontaneum* groups has been developed by Orlov and Åberg (1941). The cultivated group is frequently treated in a taxonomic scheme consisting of convarieties — multiple varieties having the same or equal taxonomic status and displaying discernible morphologies and generally recognized as distinct cultivated varieties/forms (Table 4.1). The convarity category is the botanical equivalent of cultivar groups.

Table 4.1 Infraspecific Taxonomic Groups of Barley (Grillot 1959; von Bothmer et al. 1981)

1. Convar. **Vulgare**	all rachis spikelets fertile, awns long
Var. *Vulgare*	caryopsis not naked, spike lax
f. *Vulgare*	rachis tough
f. *Agriochathon*	rachis brittle (a wild 6-row form)
Var. *Coeleste*	caryopsis naked, spike lax
f. *Coeleste*	awned
f. *Trifurcatum*	awns bifurcate
Var. *Hexastichon*	caryopsis not naked, spike compact
Var. *Revelatum*	caryopsis naked, spike compact
2. Convar. **Distichon**	fertile central spikelets, sterile or male fertile laterals
Var. *Distichon*	caryopsis not naked (covered)
Var. *Nudum*	caryopsis naked
Var. *Zoecnthon*	caryopsis not naked, spikes short and broad, awns divergent
Var. *Deficiens*	caryopsis not naked, laterals glume-like appendages
3. Convar. **Intermedium**	lax type of six row
4. Convar. **Labile**	irregular spike row number

History of cultivation and use

The earliest cultivation of barley is believed to have begun some 8,000 to 10,000 years ago in the area of the Middle East known as the Fertile Crescent (Giles and von Bothmer 1985; von Bothmer and Jacobsen 1985). This conclusion, still debated by many (e.g., Bekele 1983; Negassa 1985), is based on archaeological findings and the presence of *spontaneum* types both in the absolute wild state and as weeds in crop fields in southeast Asia. The spontaneous form also occurs as weed in North Africa, probably harvested in prehistoric times from wild stands as far south as the Nile Valley of Egypt (Wendorf et al. 1979). The crop is now grown worldwide with greater concentration in temperate areas and high altitudes of the tropics and subtropics. The greatest diversity of barley in terms of morphological types, genetic races, disease-resistant lines, and endemic morphotypes exists in Ethiopia (Orlov 1929; Huffnagel 1961).

Initially one of the dominant food grains, barley has been surpassed by rice and wheat in many countries. In traditional societies barley continues to be a very important food grain. Internationally, its importance as a feed and brewing grain has increased through the years. Recent findings on the nutritional qualities of barley have begun to make it a desirable food item even in those countries where its consumption had declined for many years (Anderson et al. 1991). It is likely that traditional barley landraces will attract the consumer society as they the tend to be more nutritionally balanced than modern varieties. With increasing consumer awareness of nutritional composition of diets, landraces are anticipated to fetch higher market prices. It may not be too long before the genotypic attributes of a crop begin to positively influence its market price. The potential for some barley landraces in this regard appears to be high (e.g., some naked and partially naked types).

Barley in Ethiopia

Antiquity and botanical affinities

The persistence of two parallel hypotheses regarding the possible origin of barley in Ethiopia has resulted in a lively debate among crop scientists. A number of studies have dealt with various aspects of the debate, including crop domestication patterns in Africa (Porteres 1976; Purseglove 1976), interpretations of linguistic evidence (Ehret 1979), and archaeological and historical documentation and analyses (Brandt 1984). Sources agree to the extent that barley has been in cultivation in Ethiopia for at least the past 5,000 years, based on evidence that it was cultivated about 3000 B.C. by the Agew people of northwest Ethiopia (Gamst 1969). In parts of southern and central Ethiopia, the history of barley cultivation is reported to have coincided with the history of the plow culture. It is said that barley was considered a sacred crop by the Oromo people of southern Ethiopia (Haberland 1963). Bekele (1983) challenged the single origin hypothesis, arguing that based on barley flavonoid data, it is highly plausible that *spontaneum* gene was introgressed and gradually swamped up into the *vulgare* gene pool in Ethiopia.

Barley researchers have long considered the Ethiopian barley stock as an isolated line that evolved independently from the mainstream of world barley evolution, posited to be around southwest Asia (Harlan 1968). Such claims were based on a limited number of experimental results that gave clues of partial sterility and reduced seed set ratios of crosses between Ethiopian barley and those from Europe and Asia (Smith 1951; Jonassen and Munck 1981). These comments prompted a major question as to how far the Ethiopian barley gene pool has differentiated from that of its wild ancestor. A reciprocate crossing experiment undertaken between *spontaneum* lines and a selection from the Ethiopian *vulgare* showed high levels of hybrid viability and fertility (Figure 4.1), assessed on the basies of pollen fertility, seed set, hybrid viability, and vigor (Asfaw 1991; Asfaw and von Bothmer 1990). Mechanisms of character inheritance were easily followed as they conformed to the known ratios, demonstrating the ease with which genes can be transferred between *spontaneum* and the Ethiopian stock. The free intercrossing of the two subspecies has been reaffirmed (von Bothmer and Seberg 1995).

History of exploration and studies

Foreign crop exploration missions began in Ethiopia 400 years ago, at which time barley was a primary crop under investigation. Early travelers, 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 registered by many 19th

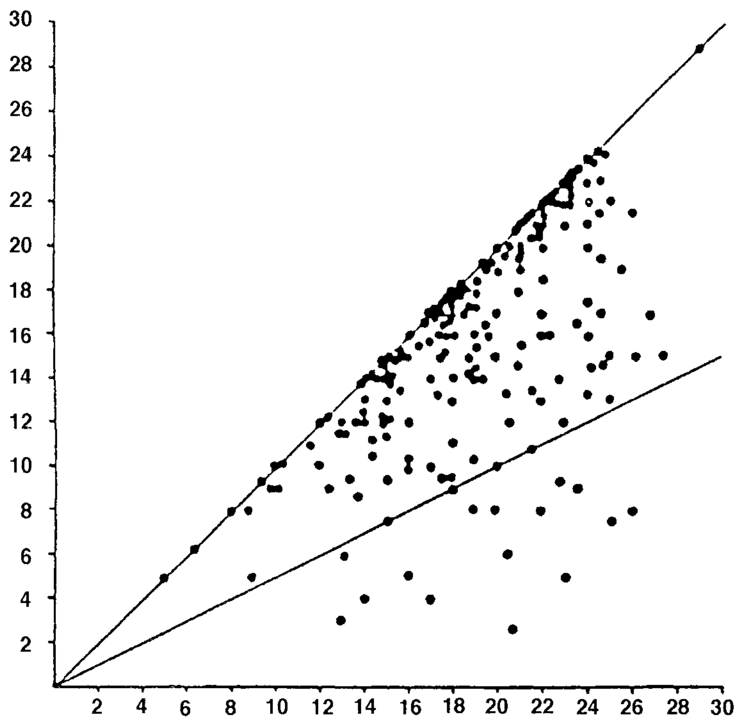

Figure 4.1 Fertility between *spontaneum* and Ethiopian barley types [Florets *(vertical), Grains (horizontal)]*. Points on the diagonal line show F2 generation plants in which all florets set seeds and the second line marks the level where half of the florets set seeds and the other half are aborted (Asfaw and von Bothmer 1990).

century crop taxonomists, including Kornicke and Atterberg (Orlov 1929), and the first scientific botanical account was given by Chiovenda (1912). Later studies noted the unique features of the barley cultigen grown in Ethiopia (Orlov 1929; Ciferri 1940, 1944; Vavilov 1951). Barley was also targeted in the germplasm exploration studies of American and British missions (U.S. Operation Mission to Ethiopia 1954; Huffnagel 1961). Judging from the content and emphasis of the descriptions produced, the early explorers appeared to have been most attracted by the morphological variation and the endemic types as reported subsequently (Orlov 1929). The early studies covered aspects of the morphology, agronomy, ecology, diversity, evolution, genetics, and taxonomy of the barley grown in Ethiopia. The more comprehensive studies were those of Russian and Italian investigators (Orlov 1929; Ciferri 1940, 1944), who made field explorations and collections in Ethiopia, as well as observations through cultivation experiments and laboratory analyses in their respective countries. The methods and results from these studies were not made available locally and not taken up by resident researchers.

As international researchers increasingly realized the potential of Ethiopia's diverse barley types, particularly for disease resistance, interest shifted toward the utilization of germplasm in the breeding and development of modern cultivars. Many reputed modern barley cultivars in Europe and the U.S. owe their resistant genes to material originally collected from Ethiopia (Hoyt 1988). Harlan (1968, 1969) publicized the view that Ethiopian barley types were not favored for improvement as modern cultivars, while emphasizing their immense value as gene donors for barley improvement. 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 influenced the direction of barley research in Ethiopia. Other researchers have fully acknowledged the attractive traits of Ethiopian landraces including large kernel size, high tillering, and large 1000-grain weight (Orlov 1929; Huffnagel 1961; Westphal 1975), and favorable nutritional qualities such as higher protein/lysine content (Munck 1992b; Jonassen and Munck 1981) and cholesterol-reducing chemical agents (Anderson et al. 1991; Heen et al. 1991). More recent studies have focused on the resistance of the Ethiopian types to known pathogens, germplasm conservation and utilization, assessment of diversity, and biological gene markers (Qualset 1975; Metcalfe et al. 1978; Bekele 1983; Negassa 1985; Engels 1986). Asfaw has shown the wide diversity in morphological characters (1988, 1990) and hordein polypeptide pattern (1989c), and the potential for wide hybridization (Asfaw and von Bothmer 1990). Demissie (1996) investigated morphological and molecular diversity markers and stressed the implications for *in situ* and *ex situ* conservation. Other studies have identified a wealth of ethnobotanical knowledge associated with barley landraces in Ethiopia (Asfaw 1990). Ethiopian barley types have contributed significantly to the understanding of barley, increasing its status as a soundly fathomed crop on a worldwide scale.

Distribution throughout Ethiopia

Barley is cultivated in every region of Ethiopia and demonstrates wide ecological plasticity and physiological amplitude throughout the country (Asfaw 1988, 1989; Lakew et al. 1996). The crop is cultivated from 1,400 to over 4,000 meters above sea level, with the greatest frequency and diversity occurring between 2,400 and 3,400 meters in the northern and central regions of Ethiopia (Figure 4.2). Diverse landraces and morphological classes of barley are adapted to specific sets of agroecological and microclimatic regimes throughout the country. The higher preponderance of some morphotypes (six-rows, naked caryopsis types, dense spikes, higher anthocyanic types) and some hordein polypeptide patterns at higher altitudes, other types (e.g., two-rows, lax types), and other hordein polypeptide patterns at lower elevations are documented (Asfaw 1988, 1989b). Differential distribution, including abundance of primitive flavonoid patterns (Bekele 1983), resistant genes (Negassa 1985), and phenotypes and diverse molecular

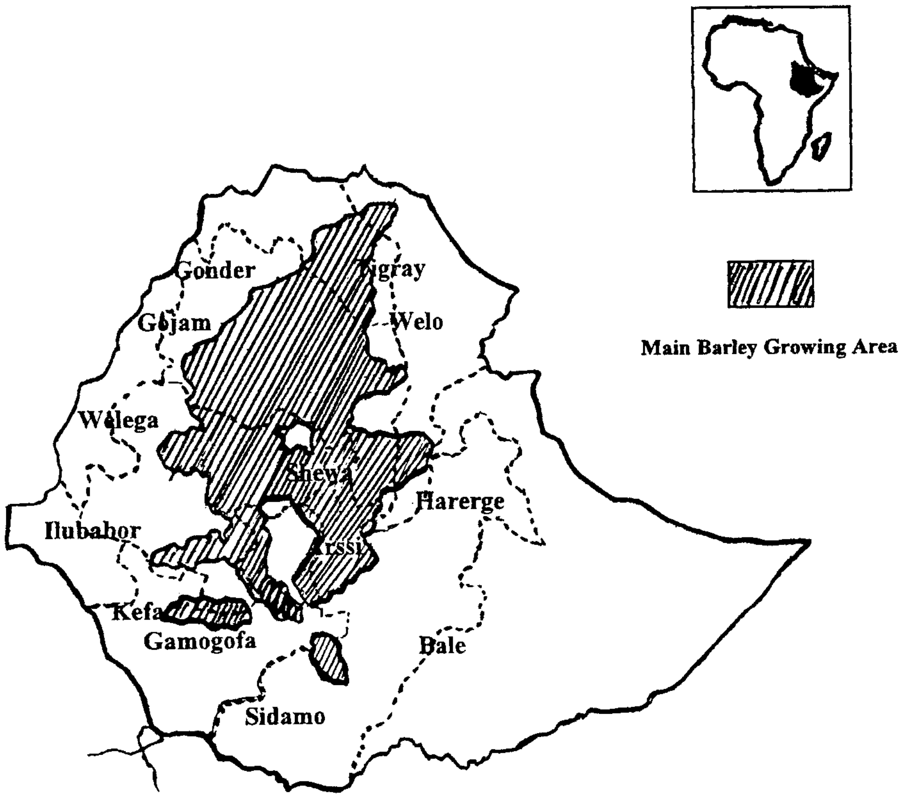

Figure 4.2 Distribution of Barley in Ethiopia.

markers have been reported (Asfaw 1988, 1989c; Demissie 1996; Demissie and Bjornstad 1996, 1997). Within the general barley growing areas and the optimal agroecologic range there are pockets in which are concentrated some morphological and chemical groups that can guide future conservation strategies. On the whole the southern and southeastern highlands harbor more morphotypes than the central and northern highlands. However, some individual localities within both zones (e.g., Kembata, Galessa-Tululencha, Chencha) are recognized as pockets of higher number of morphotypes per field, as illustrated by a study carried out in Jibat and Mecha (Asfaw 1990) revealing higher number of morphotypes per field and in the entire locality. While some barley morphotypes are widely distributed, others are restricted to narrow ranges and isolated pockets. Some types are still sheltered from the direct effects of invading modern agrotechnology such as the use of modern cultivars, inorganic fertilizers and pesticides as they are found in places not easily accessible except to the owners. Hence, Ethiopia is a promising site for both *ex situ* and *in situ* conservation of barley. Demissie and Bjornstad (1996, 1997) recommended that collection and conservation of barley germplasm in Ethiopia should take account of the differential distribution of polymorphism in phenotypes, isozymes, and hordein genotypes.

Significance and modes of consumption

As the third most important cereal crop cultivated in Ethiopia, barley is grown primarily for local food and beverage consumption. For small-scale highland farmers, barley is the predominant subsistence crop. It is typically produced two times per year, during the long and short rainy seasons that extend from June to September and from February to April, respectively. In some regions, barley is also produced three times per year, drawing on residual moisture supplemented with irrigation. While some landraces are cultivated during both primary growing seasons, others are adapted only to the-long rainy season. In terms of consumption, Ethiopia ranks second only to Morocco with respect to the number of kilograms (68 and 19, respectively) of barley consumed per person per annum (FAO 1990, in Bhatty 1992). Whereas barley consumption declined in many countries, it continued at the same level in Ethiopia, where nearly 40% of the total grain produced is used as food (Gebre and Pinto 1977).

Within Ethiopia, the highest levels of barley consumption occur in highland areas where it is widely cultivated, accounting for the bulk of the total crop harvest. In these areas barley consumption begins at the milky stage of grain maturation when youngsters remove the awns from the green unripe spikes, crush them between the palms, blow away the fragments of the rachis and glumes, and consume the tasty raw green grains in the field in limited quantities. Such unripe spikes may also be green-roasted over fire. Similarly, a sheaf of ripe barley can be roasted in the fire, crushed between the palms and the grains eaten as a supplementary or "waiting" food. Different kinds of bread, dough balls, porridge, soup, and gruel are made in every household from any barley type, but there are preferred types for different methods of preparation (Asfaw 1990). Many alcoholic and nonalcoholic local beverages are brewed in the household from barley grains for daily consumption or for holidays and celebrations. The barley straw is used in the construction of traditional huts and grain stores either as thatching or as a mud plaster (Figure 4.3). The barley crop-residue is used as fodder mainly for bovine cattle and equine. The small grains that fail to fill up and those crushed in the process of threshing and consequently mix with the chaff are kept aside for chicken feed (and sometimes small ruminants and riding horses or mules) by some families. Some barley types are purposely cultivated for their special uses (e.g., partially naked types for roasted grains) while many others are more of multipurpose types.

Special features of barley in Ethiopia

The cultivated forms of *Hordeum* are a group of interfertile lines distinguished by differences in spike characters. More than 180 botanical forms of

Figure 4.3 Barley stalks constructed in the traditional way (Shewa).

barley, represented by a larger number of agricultural "varieties," occur throughout the world (Bell 1965). A large number of botanical varieties have been recognized (e.g., Orlov 1929; Orlov and Åberg 1941; Ciferri 1944). Giessen et al. (cited in Huffnagel 1961) are reported to have identified 170 types from Ethiopia, grouped into five convarieties (viz. Convar. *Deficiens, Distichon, Hexastichon, Intermedium,* and *Labile)* (see Table 4.1). The *Deficiens* and *Labile* forms are endemic to Ethiopia. Their occurrence only in Ethiopia supports the hypothesis that a unique evolutionary reduction in the morphological characters of barley occurred in Ethiopia; in fact, the *Labile* group represents an intermediate form. This observation, together with the view that the barley genus had enjoyed a wider distribution in the geologic past, including in eastern Africa, supports the argument that barley probably originated independently in Ethiopia as well (Bekele 1983; Negassa 1985). Recent studies also brought to light the presence of a large number of botanical forms and morphological types of barley (>60) and hordein groups (>40) in the Ethiopian barley material (Asfaw 1988, 1989c; Demissie 1996).

The main groups can be classified as hulled, hull-less, and partially hulled types with six-row, two-row, and irregular morphologies, and varied spike shape, density, and pigmentation. These distinct characteristics are further combined with glume and lemma characters that display a wide range of variation in size, shape, color, and texture. The wide diversity is further accentuated by the coexistence of features considered primitive in cultivated barley, such as covered caryopsis, bigger plants, pubescence, well-developed glumes and anthocyanic straws, with more advanced features, including short awns, large grains, deficient forms, straw yellow spikes and grains, and naked types. All the convarieties, varieties, and forms listed in Table 4.1, except the form *agriochrithon,* occur in Ethiopia.

The more common botanical forms of Ethiopian barley are *Deficiens, Pallidum, Nutans,* and *Nigrum* types. Some of the morphological types are reported to be endemic to Ethiopia (Orlov 1929; Harlan 1969). The pyramidal, parallel, and hull-less types are restricted in distribution and are less abundant, although mobility between regions is a possibility as evident from some vernacular names of barley land races.

The frequency of six-row types, hull-less types and those with compact and colored spikes is highest at higher altitudes. The dominant barley types vary between fields, localities, and regions, with up to 12 distinct morphotypes present in a single barley field that averages 0.5 ha. Since morphological variations expressed under uniform ecological conditions are likely to be genetic, the different morphotypes seen in a field are best considered manifestations of gene differences (Figure 4.4). Farmers' knowledge of this diversity survives in the elaborate folk taxonomy and system of nomenclature as well as in the beliefs, value systems, cultural songs, and aphorisms (Asfaw 1990, 1996). The extent to which value systems and expressions of culture reflect upon farmers' knowledge of crop diversity has been documented for other important major crops of the world in their centers of domestication (Bellon 1996).

The main popular groups of barley in Ethiopia

Barley is usually grouped into morphological categories based on spike row number at the top level to form major categories. However, it is observed that farmers and communities more frequently use barley groups based on differences of caryopsis or kernel type. For routine application caryopsis type is easily understood as it is a utilitarian criterion. Whether spike row number or caryopsis type is used at the top level, other spike characters have to be used for complete identification of the barley. The top level gives only major classes of barley. Using caryopsis type, three main barley groups are easily distinguished: hulled, hull-less, and partially hulled. This system is very efficient to apply at the house level and frequently used by women in both rural and urban areas. While classifying Ethiopian barley using morphological characters, application of clustering technique (ordination) gave a distinct group of only naked types at initial classification also revealing that the character is also botanically distinct and more conclusive than row number (Asfaw 1988). Caryopsis type is one character that is used for barley classification both under the traditional and the modern systems that is easier for routine application. Formal taxonomy (see Orlov and Åberg 1941; Grillot 1959) begins with spike row number, but also uses caryopsis type as one of the essential criteria since it is a distinct character on the spike. If, however, caryopsis type is used at the top level, barley types can be easily categorized into three major groups as hulled (covered), hull-less (naked), and partially hulled types. Each of these can then be further classified using other characters given in Table 4.2. The three major groups of barley based on differences in caryopsis type are highlighted below.

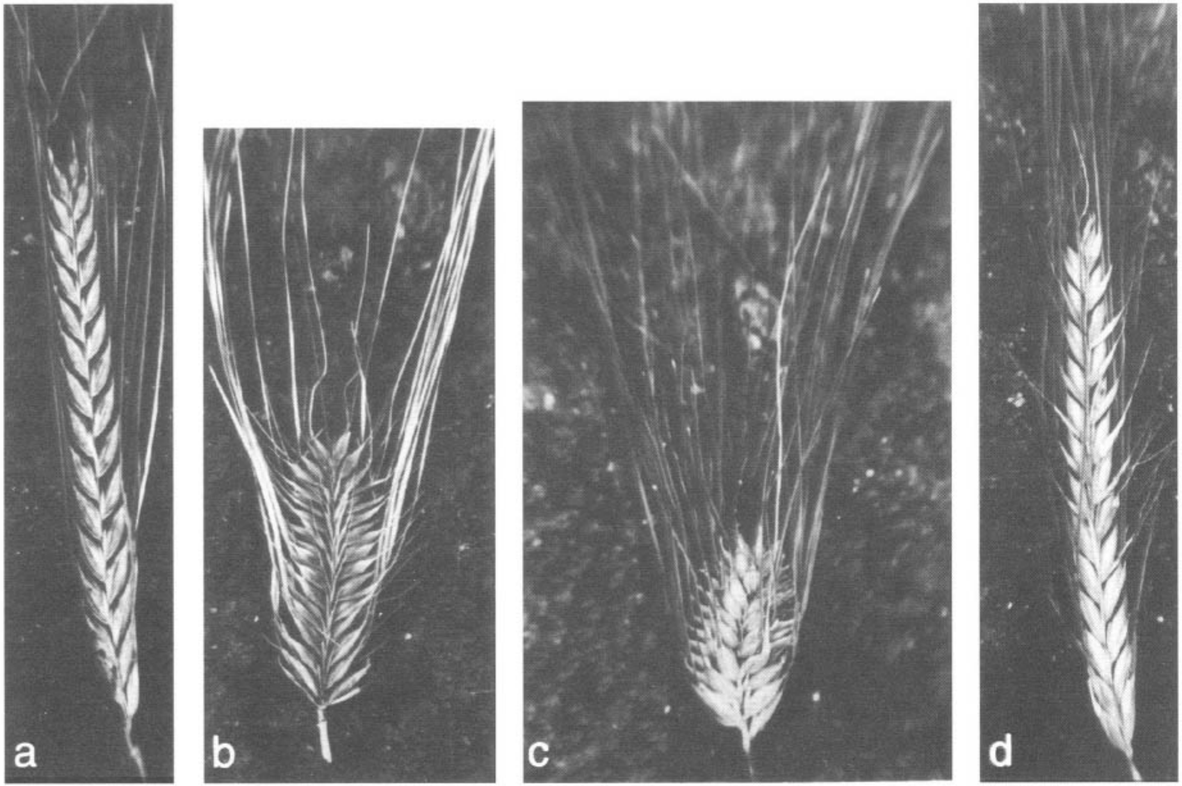

Figure 4.4 Some morphological types of hulled Ethiopian barley (a) two-row lax *Deficiens*, (b) two-row *Deficiens* with long and broad outer glumes and diverging awns; (c) six-row, dense spike; (d) two-row, lax spike, *Deficiens* type with broad outer glumes.

Table 4.2 Spike Characters Used in Folk and Modern Classification (combination not encountered) (Asfaw 1996)

		Two-Row		
Character	Six-Row	*Deficiens*	*Nutans*	Irregular
Spike	dense	dense	dense	—
	lax	lax	lax	lax
	long	long	long	long
	short	—	short	—
	stout	—	—	—
Kernel/caryopsis	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

Hulled barley. This group is known as the farmer's "true" barley. The husk adheres to the grain, requiring an arduous dehulling process to make the grain suitable for consumption. It is the largest group in terms of cultivated area, the provenance, and the number of morphological types (see Figure 4.5). All hulled barley, including partially hulled types, accounts for about 70% of the morphologically distinct barley types in Ethiopia. Hulled barley is the most diverse major category including six-rows, two-rows, irregular forms, dense, lax, hooded, long and short awned, rough and smooth awned types (Table 4.1). Traditional farmers in Ethiopia consider this group less labor-intensive in the field and of a relatively higher grain yield than other barley types. In terms of food preparation, however, hulled barley is less desirable as it is extremely time and labor intensive as reported by women.

Hull-less barley. In the hull-less (naked) barley group, the husk falls free from the grain upon threshing. The hull-less type of Ethiopian barley constitutes the genetic pool from which the lysine-high protein, hiproly

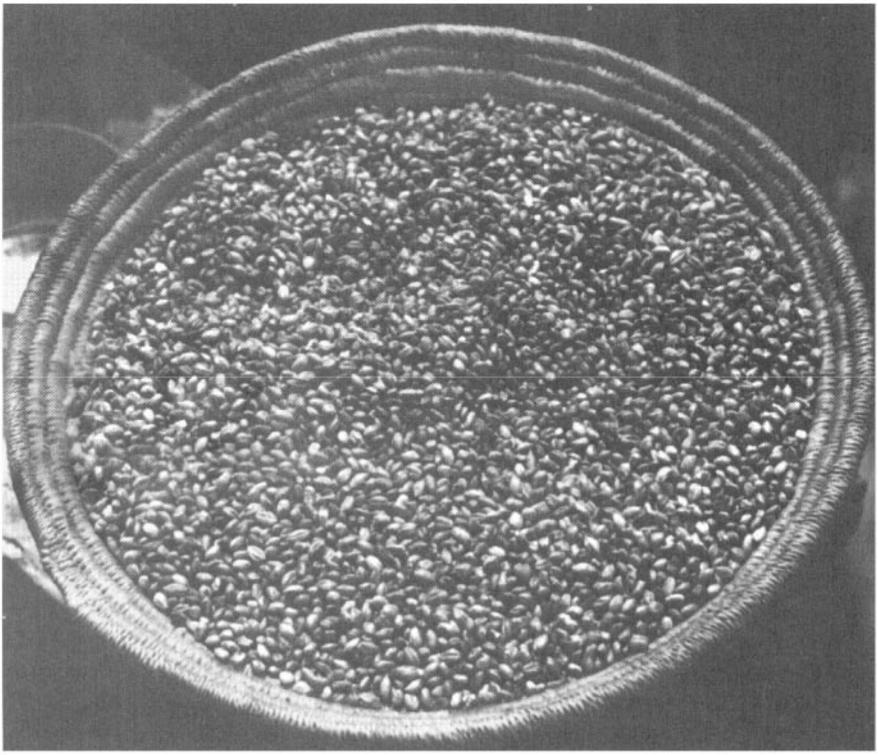

Figure 4.5 Roasted barley brought for selling at bus stop (Shena town, Shewa).

barley was recovered by screening (Munck 1992b; Jonassen and Munck 1981). Included are two-row, six-row, lax, and dense forms (see Table 4.2). Absence of the hull is a recessive character encountered in six- and two-row *Nutans* types; the character has not been encountered in *Deficiens* and *Labile* forms.

Throughout Ethiopia, the frequency of hull-less barley is low and the distribution is restricted to the highland regions of Shewa, Gonder, and Tigray. Most of the morphotypes occur as rare mixtures among fields of hulled and partially hulled types; few pure stands have been documented. In one locality in Shewa (Jib at), where the highest concentration of hull-less types was found, a total of 31 distinct barley types were identified, 4 (12%) of which were of the hull-less type (Asfaw 1990). Early surveys found that hull-less types constituted a substantial amount of the barley grown in Ethiopia, and noted a great diversity within the hull-less types (Orlov 1929; Ciferri 1944). Ciferri (1944) found that, throughout Ethiopia, hull-less types accounted for 38% of cultivated barley; Orlov (1929) recorded hull-less types as 36% of the total in the Addis Ababa region.

Farmers testify that hull-less barley has been declining in frequency, an observation that is substantiated when early records are compared with more recent ones. Some botanical types of the hull-less group identified by Orlov (1929) and Ciferri (1944) no longer occur in the areas where they were once found, demonstrating that genetic erosion has taken place. Hull-less types still occur in Shewa, Gonder, and Tigray. The farmers claimed that their frequency has diminished, and they are being replaced by covered types, which they regarded as hardier and higher yielding. Some hull-less and some partially hulled types owe their existence to women who cultivate them in small plots around living quarters with loving care. While men generally consider the hull-less types more demanding in the field, low yielding, and short lasting, women value them highly as they are less labor intensive to prepare. Recent studies on the nutritive value of hull-less barley, with respect to proteins, fats, minerals, dietary fiber, and energy content (Heen et al. 1991) support the traditional practice of cultivating this barley type for human consumption and their conservation is a critical matter in Ethiopia.

Partially hulled barley. This constitutes a diverse group of two-row barley with lax and dense forms, for which the husk is easily removed upon heating. Partially hulled types occur in many regions, but most frequently in the highlands of Shewa, Garno Gofa, Gonder, and Bale. In one locality in Shewa (Jib at), 6 (19%) of 31 distinct morphotypes featured partially hulled caryopsis (Asfaw 1990). Pure stands of hull-less barley are observed with higher frequency and wider distribution than the other main types. Partially hulled grains are consumed primarily as roasted grains, which are easy to prepare and simple to serve, requiring light roasting and pounding (dehulling). This is a characteristic reflected in its popular name, *senefgebs,* which means "the lazy person's barley" in the Amharic language. Though grains of other barley types can also be roasted, partially hulled types are of high roasting quality, attributed to the well-developed big and plump grains produced by the central florets of lax spikes.

The popularity of roasted barley among Ethiopians of all ages and the ease with which it can be served at social gatherings, as a "waiting food," and for daily and household consumption contributes to the continued cultivation of partially hulled types. It is widely sold and consumed at bus stops, in drinking houses, and at various social gatherings such as condolence sessions, religious and traditional gatherings in churches, villages, and individual residences. Monks, nuns, and hermits in monasteries and isolated churches live largely on roasted grains of barley, supplemented by wild fruits. Roasted barley is a good traveling food as it may be stored for long periods of time. Usually, roasted barley grains are served mixed with limited quantities of roasted safflower, chickpeas, peas, groundnuts, or roasted and crushed niger-seed balls, all of which improve both the taste and nutritive value. Recently, roasted barley grains have become more widely available in pastry shops and incipient export activity is already underway. Such market value will continue to favor the conservation of this group through cultivation.

The diversity of the barley cultivated in Ethiopia has been affirmed by analysis of its morphology (Asfaw 1988, and literature cited therein), biochemical composition (Bekele 1983; Asfaw 1989c; Demissie 1996), presence of disease-resistant genes (Negassa 1985; Hoyt 1988), and protein and lysine content (Jonassen and Munck 1981; Munck 1992b). The hordein polypeptide pattern is a very useful tool for assessing the range of diversity (Figure 4.6). Different morphotypes vary in their hordein pattern and, in some cases, hordein polymorphism is seen within a single morphological type. More than 40 major hordein groups have been identified, closely matching the degree of morphological variation (Asfaw 1989c).

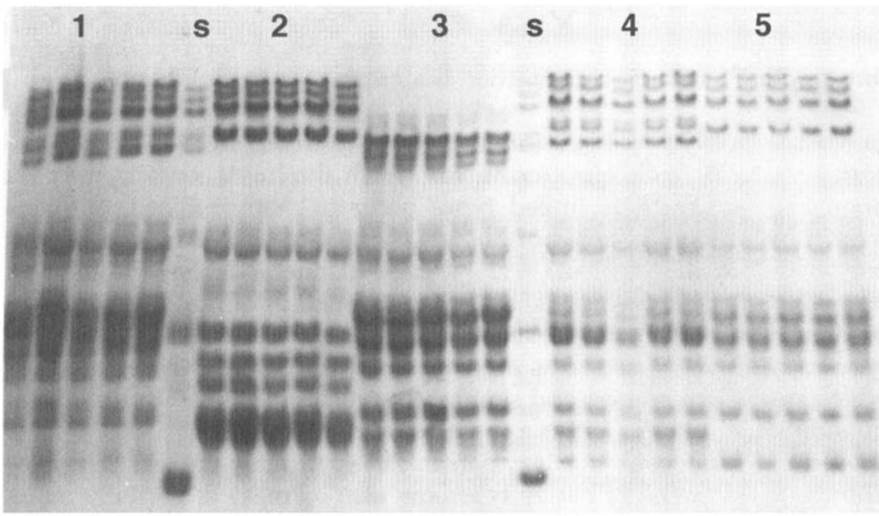

Figure 4.6 Hordein polypeptide pattern in Ethiopian barley. (Each set of 5 columns (1-5) shows patterns of grains from different morphotypes and at positions between 1 and 2 and 3 and 4 are the patterns of the standard cultivar used for comparison and calibration) (Asfaw 1989c).

Factors behind barley diversification in Ethiopia

The great variation and endemicity in barley forms has been interpreted in different ways. N. I. Vavilov initially considered Ethiopia as the center of origin for barley and later on as a secondary diversification center for the crop. The main reason for this reversal of opinion was the fact that the existence of the wild progenitor in Ethiopia has never been confirmed. In some cases, subsequent research has supported Vavilov's determination of Ethiopia as a secondary center (Takahashi 1955; Huffnagel 1961). Other studies favor of the earlier view, particularly with reference to the diversity and endemicity of forms coupled with the frequency of resistant genes for various categories of diseases. The unique endemics such as the *Deficiens* and *Labile* (irregular) types and the abundance of forms with features that are generally considered primitive in barley (discussed above) have been cited as evidence for the origin of barley in Ethiopia.

While some researchers ascribe at least some of these features to early introduction, others still consider them additional evidence for the origin of barley in Ethiopia. In his study on the biology of cereal landrace populations, Bekele (1985) discusses polymorphism and the balance of forces maintaining overall barley polymorphism in Ethiopia — mutation and selection, selection and migration, the heterogeneous environment, neutral polymorphism, frequency dependent selection, and transient polymorphism as forces. Asfaw (1989a) notes that a combination of agroclimatic and biological processes together with anthropogenic factors is behind the diversification of barley forms in the Ethiopian biophysical and sociocultural environment. The biological processes of natural selection are combined with barley's predominant selfing and limited outcrossing breeding characteristics.

The domestication process, agricultural systems, the agglomeration of different types within single fields and the deliberate selection of lines exercised by farmers have all contributed to the process of fixing characters and maintaining existence within the gene pool. While the selective pressures favor the preservation of many botanical forms, they simultaneously select against other types that consequently became less and less frequent, and even perhaps "extinct" from cultivation at present. Types reported as common in some regions and localities during the Vavilovian expedition (e.g., many naked forms including smooth-awned types) are absent or rare in those areas at the present time.

The net effect of the overall process, however, is the preservation of more types within the agricultural system. In a recent study, Feyissa (1995) supports the view that farmer selection is inversely related to genetic erosion and directly related to conservation. When farmers select, they do not select for a single character. They select for many characters, actually for combinations of characters in a given material, and these characters are directly related to adaptability, yield, nutritional values, and others of utilitarian importance. Though farmers' types often display morphological uniformity, they are not genetically uniform, in sharp contrast with breeders' types. The process helps to actually conserve those desirable characters through cultivation. This is the reason for usually finding many different types in the same field. Barley is famous for such wide phenotypic diversity, which also signifies biochemical and genetic diversity.

Conservation through cultivation is the very subtle strategy of traditional farmers yet to be understood and appreciated by the modern scientific sector. In fact, since different farmers and farming communities select for different sets of characters, the overall diversity sampled for maintenance is very high, as the number of combinations and permutations is tremendously high. Hence, selection as practiced by the traditional barley farmer in Ethiopia does not result in genetic erosion but conserves the full range of the diversity in a dynamic state. This is the ideal breeding strategy for smallholder farmers and those who use the produce largely for consumptive purposes. The nutritional balance attributed to such a genetically broad-based material is the hidden merit that farmers are beginning to realize.

Sociocultural aspects

Study of traditional sayings, lines in poems, beliefs, value systems, and whims shows the significance of barley in the life of Ethiopians to the extent that barley is locally referred to as "the king of grains." The various traditional ethos on barley are also sources of valuable indigenous knowledge because they refer to attributes such as growing habits, seed quality, food quality, brewing quality, character transmission, maturity, and yield (Asfaw 1996). Some of the vernacular names and sayings provide distinguishing attributes for particular morphotypes or landraces referring mostly to distinct botanical features. The naming system is organized under a hierarchical system that is often very descriptive (Asfaw 1990). Traditionally, at the highest level barley is grouped into three tiers: hulled, hull-less, and partially hulled. For example, a traditional classification/ nomenclatural series apparent within the partially hulled category designated as *senefgebs* recognizes one form called *senefnetchgebs-balekaport*. Three main botanical features are palpable in this name and they are in a hierarchical order: first, the barley is of the partially naked type; second, it is straw yellow; and third, it has broad outer glumes that cover the grain as an overcoat (Asfaw 1996).

Indigenous knowledge and modern science should be integrated to compile a modern database on Ethiopian barley. It is important that the indigenous knowledge on barley is collected and analyzed through ethnobotanical studies in order to enhance the conservation and use of local landraces of barley both for cultivation and breeding work. Gene banks should make ethnobotanical information part of both their routine collecting formats and their database systems. This strategy will optimize the use of the wealth found within the barley of Ethiopia.

Barley improvement in Ethiopia

Traditional breeding systems

In Ethiopia, barley is cultivated under a small-scale, mixed farming system in the traditional way, which allows for the operation of the natural breeding system. The predominance of inbreeding with some outbreeding is facilitated in the traditional barley cultivation system when different genetic types are grown as mixtures. Changes in genotypic and phenotypic characters under such a system occur gradually, allowing for retention of the wild-type character as well as some of the rare variants in the population for an extended period. The natural breeding system continues, minimally steered by traditional cultivation, seed selection, breeding, harvesting and storage methods. Farmer selection and breeding is a rather subtle process and it can be seen in farmers' maintenance of pure stands, harvesting of better sections of the field for seed, and selecting from the core section of the threshed lot wherein the best seed is found for seed.

Farmers have developed means for correcting deterioration of their barley germplasm. If they believe that the seed is no longer good, they obtain better seed material from known stocks through exchange with relatives or friends. The high quality seeds are usually brought in from the agroecological ranges where the diversity is high and the growing conditions are stable, to provide healthy and more developed grains within the range of genetic variability. Farmers know that the highlands are reservoirs of high quality barley seed as the performance of the crop is consistently better than in other regions of Ethiopia. In the highlands, environmental conditions allow for the expression of a wide array of genes and, therefore, a wide diversity of barley types. Farmers residing in lower altitudes, where growing conditions are more erratic, occasionally revitalize their barley with better quality by exchanging seeds from the highlands. The highlanders usually maintain their original seed stock unless they discover some deterioration in the germplasm in which case they seek better materials from friends or relatives in the village. Farmers who have excess seed material market their seed at the onset of the sowing season when prices are highest.

As a result of seed selection and exchange, a landrace is generally defined as a cultivated (domesticated) population that is genetically heterogeneous and has, over many generations, become adapted to the local environment and cultural conditions under which it is grown. This notation abates the active involvement of farmers in the evolution of landraces, giving the bulk of the credit to the land. The reality is that landraces are produced by farmers and farming communities through traditional breeding practices and should be called farmers' varieties to give due credit to farmers' innovative skills in selecting and cultivating special types. Farmers' varieties represent that special biodiversity found at the interface between absolute wild plant species and the fully domesticated biota under intensive human manipulation. Farmers have mixed and selected, as the case may be, to nurture the landraces that they have maintained.

Modern barley breeding in Ethiopia

Conventional barley breeding began in Ethiopia in 1955, at the College of Agriculture and Mechanical Arts, now the Agricultural University of Alemaya. The coordination of barley research was taken over by the Institute of Agricultural Research, which has implemented breeding and improvement programs at different research stations throughout the country. National barley research has focused primarily on breeding using exotic lines, such as the adaptational breeding of malting barley lines. Trials on exotic food barley lines have met with limited success. The local barley types have not received sizable attention from national research initiatives; rather, local types have been studied largely by foreigners and some staff of the Addis Ababa University. It is reported, however, that over 80% of the barley produced in Ethiopia is derived from farmers' varieties (Alemayehu and Gebre 1987). Increased dissatisfaction with exotic barley material has recently redirected the attention of national barley breeders to local material and research is now underway with the hope of developing some elite material, as with durum wheat (Bechere and Tesemma 1997). Landrace improvement has long been recommended as a strategy for crop improvement (e.g., Qualset 1981) but modern agriculture has lagged behind in this regard. The new direction taken by durum wheat improvement, the current awareness of barley breeders, and the on-farm activities taking root at the Institute of Agricultural Research signal progress in this regard.

Overall, these efforts contribute to the *in situ* conservation of barley landraces in a dynamic process where the modern and traditional systems are dovetailed. The impact will be profound as these efforts will also help to restore traditional farming systems and the associated practices such as crop rotation, intercropping, and seed exchange systems. Additionally, the barley breeding strategy will be reshaped when the participatory breeding program which includes farmers' criteria comes into full swing. The disappearance of traditional landraces has been one of the reasons for erosion of traditional knowledge on farming practices. In some parts where the partially naked barley is no longer cultivated, families are forced to prepare roasted barley food from poor quality grain through an intensive dehulling and pounding process. It is reported that younger generation farmers have no knowledge about some agricultural operations such as rotation cycles and seed rates of landraces since what they know is related to the modern package system (Bechere and Tesemma 1997). The basis for giving due consideration to indigenous barley material in future research and improvement efforts — both in formal breeding programs and in mass selections — is to develop modern cultivars and elite materials and enhance the barley gene pool in the country. The search for high yielding lines, be they landrace enhancement or developing modern cultivars, should continue in appropriate sites and localities in a holistic manner to simultaneously and effectively address conservation and food security issues.

Barley conservation in Ethiopia

Ex situ *conservation*

Ex situ conservation involves the management of living organisms outside their natural habitat. Although the typical example of *ex situ* conservation for crop varieties is that of preservation in modern gene banks, some of the practices involving seed storage and exchange by traditional societies can be interpreted as incipient forms of *ex situ* conservation. Farming communities have a network of collective and individual seed maintenance systems. *Ex situ* conservation in the modern era includes activities of gene banks, botanical gardens, field gene banks, and other systems where germplasm is regularly collected, evaluated, and maintained.

As discussed above, Ethiopian barley germplasm was first collected around the turn of the present century by foreign expeditions including those of Chiovenda and Ciferri (from Italy) (Chiovenda 1912; Ciferri 1940, 1944) and Vavilov (from Russia) (Orlov 1929; Vavilov 1951). Further collections have been made by American and British collecting missions (U.S. Operation Mission to Ethiopia 1954; Huffnagel 1961). Early collections of Ethiopian barley are still maintained in gene banks in the U.S., Germany, Russia, and Italy among others (Orlov 1929; Ciferri 1940, 1944; Negassa 1985). In 1976, the Ethiopian national gene bank was established, with barley germplasm collection and conservation as one of its top priorities. The gene bank has also incorporated among its holdings some accessions of repatriated material, through international and bilateral cooperation. The total current holdings of the gene bank include nearly 14,000 accessions of Ethiopian barley (Demissie 1996).

It has recently come to the attention of those involved with crop conservation that *ex situ* conservation must be complemented with *in situ* methods in order to conserve the genetic material with the dynamic evolutionary processes and the valuable cultural practices and knowledge systems. Furthermore, the need to collect indigenous knowledge along with germplasm of indigenous crops for better utilization and understanding is being increasingly emphasized (see Guarino 1995).

In situ *conservation*

In situ conservation is a strategy of managing living organisms in their natural state and within the natural habitat. It is a system for maintaining genetic resources with due consideration of the natural ecological and agroecological systems to ensure continuation of co-evolutionary processes. In cultivated plants, *in situ* conservation is best referred to as on-farm crop conservation. On-farm conservation involves cultivation of local crop varieties by farmers with support and monitoring from the modern formal sector. Although barley landraces continue to be conserved on-farm through traditional means, growing pressure from the modern agricultural sector, land degradation, and associated environmental problems, famine, and cultural dilution have escalated the state of genetic erosion. Consequently, farmers are forced to abandon their traditional landraces. The traditional system would need to be maintained and further developed to be rewarding for communities; for this, a modern approach is needed. The on-farm conservation scheme allows for the cultivation of the crops in heterogeneous populations, in heterogeneous agroecosystems, and with varied cultural practices. This will allow for the co-evolution of crops with diseases and pests. The value of this conservation strategy is that it carries a component of security in times of diseases or pest outbreaks, as some lines are likely to be resistant to such outbreaks.

Traditional barley conservation in Ethiopia is, in essence, an *in situ* system where the germplasm is maintained by being planted continuously from season to season in the locality of its evolution. Traditional local off-farm conservation is closely associated and strongly linked with the traditional on-farm conservation, through a farmer information network. The scheme is a collective action in which farmers and farming communities maintain the diversity of barley by planting the range of landraces in appropriate localities and micro-agrohabitats within the community so that the germplasm can be located somewhere within the bounds of that community, or sometimes in neighboring communities.

Both the agricultural and social systems contribute to the success of on-farm crop conservation efforts: the former, in terms of existing environment and cultural practices; and the latter, in reference to local seed exchange and farmer selection as well as the indigenous knowledge base in support of the process. In recent years, appreciation for the special value of on-farm crop conservation has grown considerably. In particular, the realization that evolutionary processes are arrested by *ex situ* conservation has drawn increased attention to *in situ* conservation. The signing of the Convention on Biological Diversity in 1994 and global and national policies have highlighted the importance of *in situ* conservation and pledged to support such efforts. In modem *in situ* crop genetic resources conservation the stakeholders include farmers, gene banks, researchers, and scientists. Ethiopia provides a unique set of conditions, including the accumulation of diversity, ecogeographic position, agroecologic diversity, and traditional practices of farming and crop management to make it an ideal place for modem *in situ* conservation of many crops, including barley. On-farm barley conservation provides a unique opportunity for supplementing traditional practices with a modem approach and for developing the scientific parameters of the on-farm method.

On-farm conservation and its relevance to Ethiopian barley

The history of farming is also the history of crop genetic resource management, particularly in the case of barley in Ethiopia. Genetic variations of global significance have originated at the Ethiopian local farm and rural community level, as can be illustrated with the famous examples of the barley yellow dwarf virus resistance (Hoyt 1988) and the high-lysine, high-protein barley gene (Jonassen and Munck 1981; Munck 1992b). Under natural conditions, genes exist, mutate, and increase or decrease in response to dynamic interactions with the soil, climatic factors, diseases, pests, competitors, and human selection. These dynamic interactions extend over the entire agricultural history of barley and over the whole area of its distribution. The primary conservational value of the on-farm strategy is that it fosters this dynamic process.

Crop conservation in Ethiopia has a long history and the system is on-farm conservation (e.g., Worede 1992). Farmers have been the active actors in this process. Pressure from different spheres has in recent years undermined farmers' practices so that the status of crop biodiversity is heading toward erosion and deterioration. Considering the longstanding precedence of informal crop genetic resources management, the integration of local farmers into the international conservation process through joint ventures in on-farm landrace conservation and enhancement schemes would help to enhance agrobiodiversity. This observation has been realized by the scientific sector so that farmers, scientists, and extension workers have been engaged in a program of dynamic on-farm crop genetic resources conservation since 1988 (Worede 1992).

The Ethiopian on-farm landrace conservation and enhancement program is a participatory project (cited above) involving the gene bank, breeders, scientists, and farmers that started in project sites in Shewa and Tigray and is now operating in six sites in parts of Shewa, Tigray, Kefa, Welo, and Bale. Barley is included in project sites located in Shewa, Tigray, and Bale. The project aims to support and encourage farming communities to maintain barley landraces with the associated indigenous knowledge. Farmer conservators are main targets for obtaining the traditionally cultivated landraces and their knowledge of plant characteristics. Farmers are encouraged and supported to obtain such barley landraces and conserve them as they were maintained in the past, including practices such as seed selection and exchange systems.

Indigenous knowledge held by farmers and communities is studied and documented through ethnobotanical surveys and studies. The conservation program focuses on the association of barley with other crops, interaction among crops and varieties within a crop, cultural practices, and factors that safeguard the integrity of the various interactions. Seed maintenance and exchange systems are studied and augmented by the establishment of low-cost community seed banks that operate mainly through the traditional system. Experimental plots are maintained for farmers to evaluate the germplasm for yield, diseases and pests, and other parameters. The operation of this system in Tigray described by Berg (1992) can be taken as an illustrative example. Traditionally, barley has been conserved in Ethiopia by farmers and farming communities, largely on-farm through continuous cultivation individually or within the community and in grain stores, pots, and bottle gourds.

Continuous cultivation is actually a factor in the evolution of new recombinants. Farmers generally keep some seed material for planting, by replanting it immediately or by securely storing it until the next growing season. This practice is supplemented by the community's invisible seed exchange network that ensures a given landrace is kept secure somewhere within the community. Additionally, there is also a local communication system which functions through daily conversation or social gatherings to trace and locate the whereabouts of desired types. The barley farmer may pass along information about the qualities of his barley seed and, hence, indirectly advertise it or express wishes to exchange it with high grade seed of another variety or another crop. This is similar to a farmer-based seed certification mechanism. Taken collectively, the system constitutes a traditional *in situ* conservation strategy, combined with a traditional *ex situ* strategy, which is fully supported by a local information network. Since the seed exchange system of the traditional non-formal sector usually ranges over a short distance, it can be considered part of the *in situ* system and that of the on-farm package. It follows that the best way to implement crop germplasm conservation programs today is to systematically combine *in situ* and *ex situ* conservation strategies. In gene banks, time is frozen at the time of collection and space is squeezed to the small area required to regenerate collected material, displaced from pests and diseases occurring in its natural environment. Hence, regeneration itself aggravates the level of genetic erosion. The new conservation model links farmers and farming communities with formal germplasm conservationists, such that they can learn from and assist each other. In the same manner, barley breeders will be linked with this system to complete the loop of farmer-gene bank-breeder partnership (Figure 4.7). The process will allow for reciprocal exchange of information and germplasm between the informal peasant sector and the formal sector for a mutual benefit.

Appraisal of in situ *conservation of barley*

In situ conservation cannot be viewed independently from production. Traditional Ethiopian barley farmers undertake the production and conservation of landraces simultaneously. This traditional system is of particular merit for barley because of the wide use of diversity and distribution of germplasm among farmers with individual and collective responsibilities. Seed systems of the modern era have interfered with the traditional system by unlinking the seed maintenance system from the production system. The general trend over the past few decades has promoted modern cultivars and crops other than barley, which has led to the gradual erosion of barley's genetic base. This was further aggravated by land degradation, drought, famine, and overall deterioration of environmental vigor and integrity. Consequently, *in situ* conservation of the present time cannot rely solely on the traditional system. Scientists, research institutes, and gene banks should play a supporting role to facilitate a modern *in situ* conservation strategy in the context of the existing on-farm system (Geneflow 1992). Within a framework of conservation, intervention is necessary to improve the quality of the material cultivated in terms of yield, nutritional content, disease resistance, and other attributes with attention to farmer criteria. In this way, the traditional and the modern systems support each other in embracing on-farm conservation strategies. A set of principles would include:

- Grassroots involvement to ensure preservation of the high level of diversity in Ethiopian barley;
- Promotion of small-scale farming, which is based on environmental heterogeneity and in turn favors barley diversity through new combinations of genotypes and alleles;

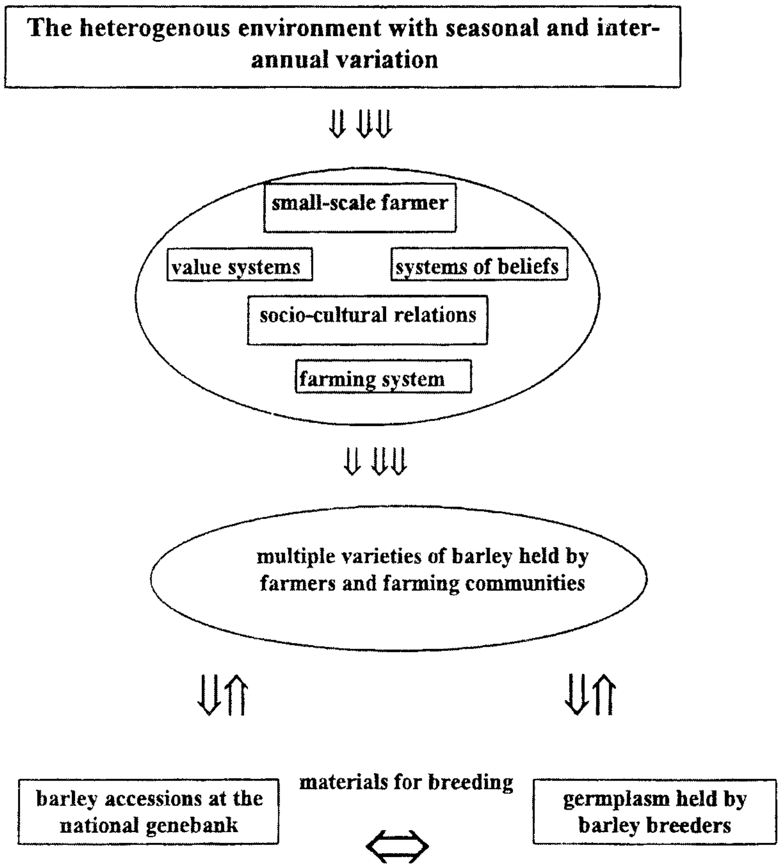

Figure 4.7 Actors and linkages in modern on-farm barley conservation in Ethiopia [Adapted for barley from the conceptual model for genetic conservation presented by van Oosterhout (1994; Figure 5)].

- An intermarriage between traditional knowledge and modern science;
- Integration of farmers' indigenous selection practices and character recognition skills with formal breeding;
- Integration of farmers' breeding strategies and selection criteria with those of the formal sector; and
- Complementary roles for *ex situ* and *in situ* strategies.

The on-farm barley conservation work in operation is a component of the *Dynamic Farmer-Based Approach to the Conservation of Ethiopia's Plant Genetic Resources Project.* Alluded to earlier, this is an innovative approach to a modern integrated *in situ* and *ex situ* conservation, based on partnership between farmers and the national gene bank with support from barley breeders and other scientists. Drawing on the principles outlined above, the project first identifies suitable areas for barley on-farm conservation based on criteria that include the extent of genetic erosion, the history of barley cultivation in the general area, and current levels of diversity.

Knowledgeable barley farmers (conservationists) are carefully identified on the basis of what landraces they have been conserving which are either lost or on the verge of disappearance from the area and their knowledge about such landraces and general crop husbandry in the area. Such farmer partners are briefed about the project and formally invited to become partners in barley conservation. Farmer partners are systematically selected to embrace and willfully encourage participation of men and women, and older and younger members of the community. Participating farmers identify potential landraces for conservation programs and offer indigenous knowledge of barley and the landraces grown in their particular locality. The project assists farmers so that they can conserve a number of barley landraces through mutual agreements and benefits, including market and non-market incentives. For example, farmers are compensated for lower gains in crop return if they happen to harvest less than what a farmer who planted modem cultivars gets. In addition, gene bank materials are made available to farmers for restoration if they wish to take them. Farmer partners are encouraged to continue cultivating landraces according to traditional farming practices, such as crop rotation, organic farming, and seed selection, storage, and exchange systems. The conservation model opts, therefore, to conserve the crop diversity with the valuable biological processes and traditional practices.

This barley conservation scheme focuses not only on the local varieties of ancestral crop populations, but also on the human knowledge and behavioral practices that have shaped this diversity for generations. In the second phase, farmers who have for one reason or another lost their traditional barley landraces, but are now interested in regaining some of them, will be incorporated into the project and assisted in conserving reintroduced landraces. Project assistance includes covering the cost of seeds that are purchased from farmers identified in the first phase and some technical advice. The project will also set up small-scale, low-cost community seed banks in each locality to be managed and used by the farmers, an activity already underway in the Tigray region and for which preparations are underway in others. In another related effort called the land race restoration effort, gene bank accessions of landraces collected in the locality some years back are now grown in project sites within small demonstration plots for farmers to see the different types that were at one time cultivated in the area. If farmers show interest in some of these activities, the seed can be multiplied and distributed accordingly.

Indigenous knowledge on these materials will also be collected as farmers often recall the types that used to grow in the area; the indigenous knowledge of the landraces survives with the people, even if the landrace itself no longer does. In association with the on-farm conservation drive, Ethiopia is pursuing what is termed the landrace enhancement scheme, which opts to improve promising landraces using farmers' selection criteria mainly through mixing morphotypes of desirable qualities. The plant structure, yield, disease resistance, and other features of barley can be targeted for improvement to develop competitive production levels. In this respect, the barley on-farm conservation effort is following the example of the durum wheat landrace enhancement scheme, under operation for many years now, where mixtures of high yielding combinations are reported to have been already released (Bechere and Tesemma 1997) to farmers in collaboration with a national nongovernmental organization — Seeds of Survival. Farmer partners are encouraged to practice the on-farm conservation strategy with creativity and intuition. Gene banks and researchers will periodically monitor the level of genetic diversity to observe changes in time and space. The International Plant Genetic Resources Institute (IPGRI) has already drafted a project proposal to study the scientific basis of on-farm landrace conservation to support the ongoing scheme.

The barley on-farm conservation program is being implemented mainly in the rugged high altitude regions, considered marginal for most other crops and unsuitable for high yielding modern barley cultivars. Thus, on-farm conservation and the continued use of landraces will not interfere with large-scale production of the crop under high input agriculture, but instead will seek to enhance agricultural systems in marginal areas. Barley landraces and high yielding cultivars can co-exist in Ethiopia's agricultural system, thereby contributing to food security from two angles: product diversification and high production. An agricultural system that conserves the indigenous landraces in some areas of the country and uses high yielding modern cultivars in other areas would help to maintain high diversity in that crop while also increasing production and productivity (see Asfaw 1989a:24). Conservation of barley on-farm can be implemented step-by-step in parts of Ethiopia where the genetic resources of the crop are still abundant. Restoration programs can also be implemented in areas where barley was at one time highly diverse, but has eroded in recent years. Although the genetic diversity of barley has been drastically reduced across such areas, the range of landraces may still occur with few farmers within the locality.

The on-farm strategy allows for a two-way flow of barley germplasm between farmers and gene banks (Geneflow 1992). Researchers and scientists associated with barley research and breeding can also be linked to this system for mutual benefits. The factors that have contributed to the diversification of barley landraces in Ethiopia range from the natural to the sociocultural; landrace conservation would require due consideration of these same factors (Asfaw 1989a). Studies of other crops confirm this observation, as with maize (Bellon 1996) and sorghum (van Oosterhout 1994). In the case of Ethiopia, numerous processes and systems have been linked and further linkages should be introduced to fully address the dynamics of barley conservation within the country (Figure 4.7).

The on-farm conservation process has the special merits of preserving the genetic diversity of the crop while it is in dynamic adaptation with the agroecosystems and in harmony with the traditional practices and knowledge. It is also open to the influx of modern scientific knowledge and breeding materials from gene banks, scientists, and researchers. The modern sector will benefit from this partnership by having access to the indigenous landraces and the knowledge base. The traditional system will be able to reap the fruits of modern science without being disadvantaged by it. Other groups including professional societies and non-governmental organizations can promote traditional landrace conservation schemes by raising and distributing seeds of those of interest for conservation. Hence, there will be an active interplay between the traditional and the modern systems. The synergistic effect obtained from the combined input of all the stakeholders and the possibility for operation of all processes will introduce into the system a unique set of advantages.

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