Farmers' Seed Management and Innovation in Varietal Selection: Implications for Barley Breeding in Tigray, Northern Ethiopia

Farmers' innovation and selection of barley varieties were studied in the Tigray Region in northern Ethiopia. Two districts each in the central and southern zones and three districts in the eastern zone of Tigray were randomly selected for this study, which sought to understand the current status of local barley varieties and to measure their relative preference by farmers. Household surveys were conducted covering 240 households to elicit farmers' views on the values, constraints, and opportunities of growing local varieties of barley. This was supported by focus-group and informal discussions with elders, key informants, and women's groups. Case studies were made of local farmers whom the community recognized as barley breeders. Twenty-four barley varieties and their major descriptors were recorded. Seed and varietal-selection criteria depended on the environmental and varietal characteristics. Investigation of intrahousehold decision making indicated that, while men tended to decide on the type of variety to grow, seed storage and processing were exclusively the responsibility of women. Farmers undertook preharvest and postharvest selection, giving emphasis mainly to earliness and spike characteristics. The distinct varietal-selection and seed-renewal procedures revealed their potential for use in further plant breeding. The case-study analysis of farmer-developed varieties provided knowledge that, if combined with scientists' knowledge, could lead to identification and development of valuable cultivars with a wide potential for use in semiarid areas of Tigray and other parts of Ethiopia.

INTRODUCTION

Ethiopia is a country renowned for the diversity of its native barley types and is recognized internationally to harbor valuable barley genetic resources. With microsatellites derived from nuclear and chloroplast DNA, a significant genetic diversity and distinctiveness of Eritrean and Ethiopian barley lines was found (1). In that study, 88% of the genetic variation was found within a field. Tigray Region in the northern highlands of Ethiopia is a major barley-producing area known for a long history of crop cultivation and diverse geographic, climatic, and sociocultural conditions. Recent collections of farmers' barley varieties in the region have shown great diversity in agromorphological traits, such as height of earliness, disease resistance, stem and/or seed color, and various quality traits (2). Studies as far back as 1929 have suggested high mutation rates on account of ultraviolet radiation at high altitudes; selection for tolerance to disease, water, and temperature stresses; and high out crossing rates, as evolutionary forces behind the observed diversity (3). Landraces differ in terms of their adaptation to soil type, time of maturity, height, nutritive value, and other properties (4). The value of local varieties as a source of genetic material for drought resistance in dry areas was shown by ICARDA breeders (5).

There are a few studies aimed at documenting and understanding farmers' seed management. Farmers' selection of ear characteristics of maize was an effective method for maintaining the variety ideotype of various maize landraces, as well as favoring more productive genotypes. It was found that some farmers in central Tigray were known locally as selectors of wheat varieties (6). Such farmers have also been regarded as providers of locally improved seeds and as potential partners in participatory plant breeding (7, 8). The importance of seed renewal and the need to distinguish it from varietal selection has been explained for barley in the northern highlands of Ethiopia (9). Farmers often noted varieties that had become "tired" and needed replacing; they gave their tired seed to farmers in cooler and more fertile areas for multiplication (10).

By using the diverse varieties or a portfolio of mixtures of varieties, farmers are able to spread the risk of crop failure, but farmers' choices and other motivations to cultivate diverse local barley varieties is less known. The culinary and varietal preferences, generally maintained by women, have a major influence on knowledge, selection, and use of agricultural biodiversity (11). Researchers are now finding that women's contribution is greater than previously perceived (12). In the literature, few studies investigate specifically the role of women in seed processing, storage, and exchange (13, 14). Other researchers have focused on specific aspects of women's work in seed management, such as selection (15–19). However, the gender dimensions in the intrahousehold decision-making process were seldom addressed in seed management research. In Tigray, for example, male members of the community commonly migrate to find work during times of food shortage, while the women who remain behind are usually involved in the management of plant varieties.

The study of local seed systems is important for development. Although a number of barley varieties from formal scientific breeding have been identified and promoted, none of them has been adopted in Tigray Region. The major reason for low or nonadoption of released varieties may be their inferior performance in farmers' fields (20). Hence, local farmers still use and indeed favor landraces because, on account of their local adaptation and buffering capacities, they often perform more predictably under a range of conditions than do modern cultivars (21). Such failure of varieties developed through the formal system has been ascribed to the facts that varietal development and testing were done in conditions not representative of those of resource-poor farmers, and that the breeding materials evaluated were only partially relevant to such conditions. In a participatory model of plant breeding, the actors in the local seed system are active partners, not passive recipients of varieties. For this reason, it is important to document and study the local seed system and farmers' role in varietal selection. In view of the great diversity already identified in local barley varieties in Tigray Region, this is an ideal site for such a study.

The major questions posed by this study are as follows.

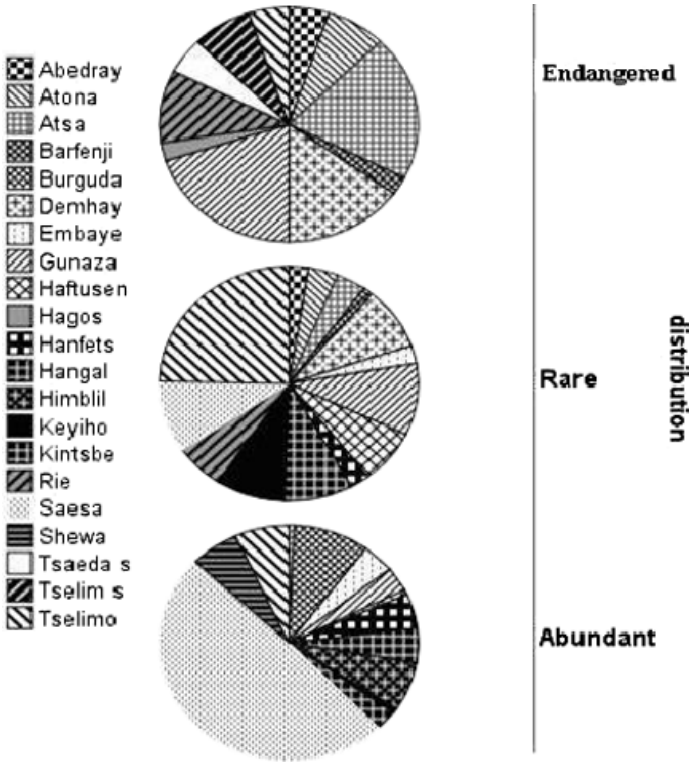

Figure 1. Area and yield of barley varieties in Tigray.

i) What are the seed management practices of farmers, and do they contribute to the genetic diversity of barley?
ii) What are the tasks, labor division, and decision-making roles in barley production and management by Tigray farmers? Are these practices influenced by gender and socioeconomic factors?
iii) Do farmers have their own selection criteria and methods to improve and maintain their varieties?
iv) How can farmer selectors be partners in formal participatory research aimed at improving livelihoods and maintaining agricultural biodiversity?

THE STUDY AREA

The Tigray Region, located in northern Ethiopia (Fig. 1), is divided into the western, northwestern, southern, eastern, central, and Mekelle City zones. These six zones are subdivided into 36 districts which, in turn, are subdivided into subdistricts and villages. Rural people constitute 85% of the people living in poverty in Tigray Region. They often live in areas with recurrent droughts, biotic stresses, and degraded soils (22). Although Tigray has experienced profound demographic, economic, and environmental problems over several decades, the farmers have still managed to retain and enhance the diversity of their varieties (23).

Three of the zones (central, southern, and eastern) were selected for the study, which was based on secondary information, semistructured interviews held with key informants (district representatives of Rural Development and Agriculture Bureau heads), and focus-group discussions. These are the major barley-growing zones in Tigray, whereas the lower lying western zone is known for sorghum and sesame production. A total of seven barley-growing districts and one village from each study district were selected for the study, with the exception of Gantafeshum District, where two villages were selected because of the greater importance of barley in terms of both coverage and cultural values in this district. Details on the study sites are given in Table 1. The sampling unit for this study was the household (HH). At the HH level, a total of 240 farmers (30 farmers from each study village) were selected and interviewed. Women household heads and elders were purposely involved to ensure good coverage of diversity in knowledge and seed management.

METHODS OF DATA COLLECTION

At the household level, information was collected on household composition, age of household head, level of literacy, variety identification criteria, seed selection procedures, farmers' reasons for their choices of varieties, areas allocated to different varieties of barley, and grain yield obtained from the different barley varieties. Questions were also posed about intrahousehold decision making related to seed management. The farmers were asked to classify and evaluate their varieties based on their uses, including those planted in the current season and those planted in the preceding years.

In addition, the farmers were asked to list all varieties they knew and the distribution of each one. Respondents classified their varieties as popular (abundant), rare, and endangered on the basis of area shared yields of varieties (Figures 1 and 2b). They defined "popular" as those varieties grown by many households over large areas. "Rare" types are those grown by few households on very small plots, and "endangered" types are grown either in mixed cultures or by only a few households in neighboring villages.

Key-informant interviews and focus-group discussions were conducted to document farmers' knowledge of the barley varieties and their preference ranking. Farmers' information

Table 1. Altitude, rainfall, temperature, and growing seasons of the study sites.

Zone	District	Village	Altitude (m asl)[1]	AEZ	TOTRF	PropRF (%)	Max. temp.	Min. temp.	Growing season
Central	Tahtay-Maichew	May-brazio	2225	*Woinadogua*	1199	61	27	12	Main wet (*meher/tsdia*) season, residual moisture for seed
Central	Dogua-Tembien	Melfa	2600	*Dogua*	662	51	22	11	Main wet season
East	Ganta-Afeshum	Buket	2500	*Dogua/ Woinadogua*	467	56	24	8	Main wet season, residual moisture for seed
		Mugulat	2675	*Dogua*	467	56	24	8	
East	Atsbi-Wemberta	Habes	2750	*Dogua*					Main wet season and residual moisture for seed and bulk production
South	Ofla	Menkere	2480	*Dogua*	836	61	22	9	Main and short wet (*belg*) season
South	Enda-mekhoni	Bolenta	3000	*Dogua*	670	54	22	10	Main and short wet season
South	Enderta	Aynalem	1980	*Woinadogua*	NA	NA	NA	NA	Main wet season

[1] Altitude based on global positioning system measurements on site; agroecological zones by local classification: *Dogua* = highland, *Woinadogua* = medium altitude. AEZ = agroecological zone. TOTRF = Total rainfall in the year, based on average of 2 y measurement. PropRF (%) = Proportion of rain that falls in July and August related to total rainfall, expressed in percentage calculated on basis of average of 2 y. Max. temp /Min. temp = average monthly maximum/minimum temperature in °C calculated on basis of average of 2 y and data from meteorology site of the district. NA = not available.

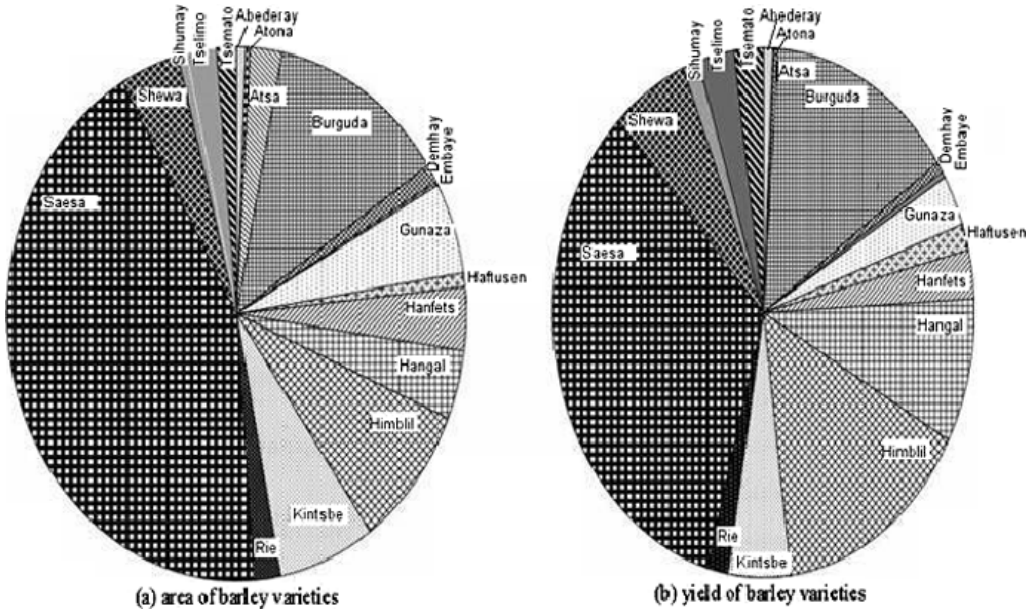

Figure 2. Farmers' perception on distribution of barley varieties.

about the origin of the different varieties, their special traits and significance, and vernacular names and their meanings were recorded. The issue of women's role in seed management was addressed not only during the household survey but also in the group discussions. The meanings of variety names were obtained from all possible sources: elders, other farmers, extension workers, and formal researchers. This was supplemented with personal observations of farmer practices.

Case studies were made of farmers who are recognized in their communities as leading barley selectors, mainly in Bolenta, Maybrazio, and Mugulat villages. The methodology of the Indigenous Soil and Water Conservation (ISWC) project (24) was adapted to identify farmers who are innovative in varietal selection (25). These methods are described in the book *Farmer Innovation in Africa* (25). Senior students from Mekelle University who were assigned for 3 months' fieldwork under a Practical Attachment Program were involved in making these case studies. They observed local differences in farmers' practices and asked local people about individuals or groups who had developed new ideas and experimented with innovations without support from formal extension services.

STATISTICAL ANALYSIS

The frequency of occurrence of each farmer variety in the seven districts was calculated and presented as cited by farmers. Simpson's index (D), an index commonly used to measure spatial diversity, was calculated for all the farmers' varieties cited (26). The index is constructed from the number of varieties occurring in a location, and data were compiled from the households across study districts.

Its formula is

$$D = \sum_{i=1}^{S} p_i^2$$

The proportion of variety i relative to the total number of varieties (p_i) was calculated and squared. The squared proportions for all the species were summed, and subtracted from 1. The derived statistics $1 - D$ expresses the abundance and represents the probability that two individuals randomly selected from a sample will belong to different genotypes. The value of this index ranges between 0 and 1, the greater the value, the greater the sample diversity.

Farmers were asked to provide information about their varieties and their preferences for each variety. The data were arranged in a two-dimensional table, and simple correspondence analysis was performed to explore the relationship of barley varieties and farmers' preference for each variety. Descriptive statistics and frequencies were calculated for intra-household decision making, farm area share of barley, and farmers' perception on barley cultivation.

RESULTS

Cultivation and Distribution of Barley Varieties

On average, barley covers 34%, 23%, and 12% of cultivated land in the eastern, southern and central zones of the Tigray Region, respectively. Higher area coverage indicates more drought-prone areas and low-input conditions. Most farmers in Tigray grow barley continuously year after year, except in a few cases where the crop is rotated with legumes (6). During the season of the survey, 24 varieties were grown. All households grew barley, but no improved variety. About 35% of the farmers were growing one variety, 44% two, 15% three, 6% four, and 1% five varieties, with a mean of 1.93. About a third of households (31%) cultivated barley on plots less than 0.13 ha in size, 56% from 0.13 to 0.25 ha, 10% from 0.26 to 0.50 ha, and only 2.6% more than 0.50 ha. Most farmers (59%) also perceived that the area sown to barley was declining, whereas 26% perceived it as increasing, and 16% saw no change. Of the farmers who noted a decline, 44% attributed it to drought and water-logging problems, 31% to lower priority given to barley by extension and research, and 25% to shortage of land. The 26% of farmers that perceived barley production as increasing associated this with its early maturity (50%), multiple uses (35%), and its low requirements for external inputs (15%).

Varietal Distribution

The distribution varied across villages, i.e., a variety rare in one village was popular in another. As a result, a given variety was registered in more than one distribution class (Fig. 1). The number of varieties specific to study sites was four each in Atsbi-Wemberta and Ganta-Afeshum districts, six in Enda-Mokeni, and two in Ofla district. In Enda-Mokeni, the six-rowed varieties of *Shewa* and *Himblil* were popular among many households and covered large areas. However, varieties such as *Atsa, Rie, Atona,* and *Sihumay* were grown on small plots or mixed stands by only a few farmers. These rare varieties are found only in the highlands of Ganta-Afeshum and Atsbi-

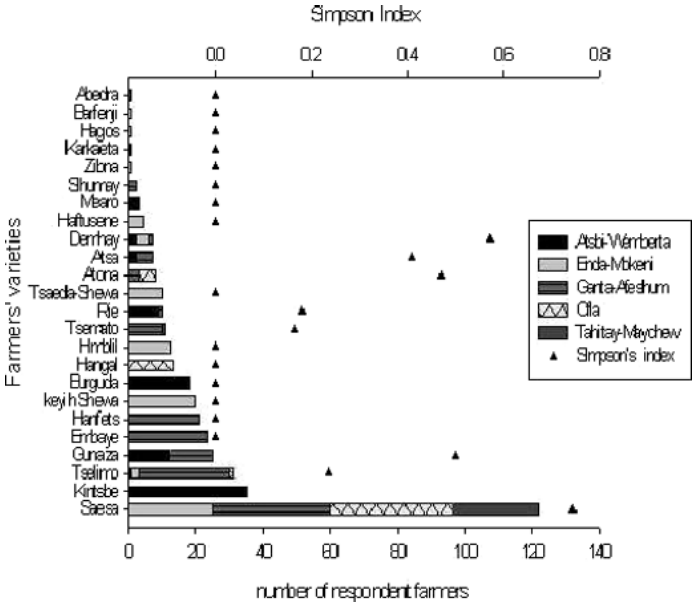

Figure 3. Frequency of farmers' varieties grown in the study area according to Simpson Index (*D*).

Wemberta districts. Although *Saesa* and *Tselimo* were found across all study sites, a higher frequency of *Tselimo* was found in Ganta-Afeshum (29 farmers) and Atsbi-Wemberta (6 farmers) districts. It was cited only once each in Ofla, Enda-Mokeni, and Tahtay Maychew districts.

The area planted and yield of barley varieties was recorded, and the average of all respondents is presented in Figure 2a,b. The largest area share is *Saesa,* followed by *Burguda* and *Himblil*. However, the yield obtained is lower for *Saesa,* than for *Burguda* and *Himblil* (Fig. 2b). The occurrence of the variety in one or more locations is presented in the bar graph in Figure 3. If a landrace is sampled in one site with higher frequency, that variety is locally common and the diversity value will be 0 or near to 0. If a variety exists in two or more sites, even if the frequency is low, the Simpson's index will be higher. The Simpson's index (*D*) also revealed the abundance of *Saesa* in the study sites (0.78) (Fig. 3). It was found to be common and widely distributed in all districts and was cited by more than 120 farmers. The high *D* value recorded for *Demhay, Atona,* and *Tselimo* was associated with citations that were fewer in number but evenly distributed across the sites. Varieties such as *Kintsebe, Embaye, Hanfets, Keyih shewa,* and *Burguda* were reported to be common but specific to only certain geographic areas (Fig. 3). The rare varieties *Rie* and *Sihumay* may have declined because of their extended vegetative growth (lateness) and *Atsa* because of its preference for highly fertile soils.

Role of Women in Barley Production

Women play a key role in barley varietal selection and management of seed. Intrahousehold decision making related to decisions on number and type of varieties to grow, seed selection, storage, and postharvest processing is presented in Table 2. In local theory, farming is perceived as men's work, but most practical decisions are made jointly by husband and wife. However, rural women in Tigray are generally less educated than are rural men and have limited freedom of movement outside the village (27). The idea that women have more environmental knowledge than men, suggested by many ecofeminists (28), is often denied by the local women themselves.

The decisions on the number of varieties to grow, plot allocation, and seed selection were mostly decided jointly (Table 2). However, the type of variety to be grown is largely decided by men (72%). On the other hand, as shown in Table 2, women are typically in charge of storage as well as postharvest processing. From the focus-group discussions, it emerged that women's practical knowledge of seed management is not static; it is influenced by locally specific social and ecological changes. The recognition and appreciation for women's role in seed management were expressed in these discussions as follows:

"If you don't have a wife, it does not pay to plough the land."

"A wife that does not keep seed is like living with no wife at all."

Vernacular Names

In the case of barley, farmers in Tigray give different names to varieties based on the characteristics they have observed in them. Most of the variety names combine group and descriptor names. For example, two-rowed varieties are known as *Netsela-sigem,* which means two rows. In Southern Tigray, most six-rowed barley varieties are known by the group name *Hangal,* which refers to the characteristic of large spikes or heads, even though the farmers know that different varieties are involved. Some of the names are associated with single descriptors. For example, the name of the variety *Himblil* was given because of its purple glumes, which make it different from others. The name given to *Gunaza* and *Tsemato* indicates their spike characteristics. Other names combine morphological descriptors with designation of the source of the seed. For example, the variety *Keyih-Shewa* is from the *Hangal* group and means six-rowed, red-seeded barley obtained from Shewa in central Ethiopia (Table 3).

Farmers' Choice of Barley Varieties

Farmers' decisions to grow local varieties, the land type and area allocated to each, and the other management practices seem to be associated with the role of each local variety in each household's consumption pattern. The characteristics of some barley varieties, as explained by farmers, are summarized in Table 4. Farmers recognize several traits associated with agromorphological and culinary purposes. Based on preference rating of 12 varieties, the simple correspondence analysis diagram in Figure 4 highlights some of the dynamics of choice. The first dimension of the simple discriminate analysis separates higher yielding, earlier maturing, and taller varieties with larger seeds from lower yielding, later maturing, and shorter varieties with small seeds. Along the second dimension, varieties are separated on the basis of their contribution for making local

Table 2. Intrahousehold decision making (%) on barley-production activities.

	No. of varieties	Type of variety to grow	Plot allocation for barley	Seed selection	Storage	Postharvest processing
Women	14	13	16	10	70	83
Men	28	72	37	32	4	4
Both	58	15	47	58	26	13

Table 3. Vernacular names and meanings for some varieties of barley.

Variety name	Group name	No. of rows	Meaning of variety name
Saesa	*Netsela-sigem*	Two	Early maturing
Tsaeda-Sigem	*Netsela-sigem*	Two	White kernel
Abederay	*Netsela-sigem*	Two	Does not do well without fertile soils
Tsemato	*Netsela-sigem*	Two	Long tie of bride bag (to indicate its long spike)
Burguda	*Netsela-sigem*	Two	Extra-white kernel
Kintsbe	*Netsela-sigem*	Two	Same as *Saesa*
Atsa(q)	*Netsela-sigem*	Two	Stiff/hairy spike
Embaye	*Netsela-sigem*	Two	Named after the farmer selector, Embaye
Mearo	*Netsela-sigem*	Two	Honey (to indicate its sweetness for malting quality)
Tselimo	*Netsela-sigem*	Two	Black seed
Hagos	*Abiyi-Ekli/Hangal*	Six	Named after the farmer selector, Hagos
Keyih-Shewa	*Abiyi-Ekli/Hangal*	Six	Red-seeded coming from Shewa
Tsaeda-Shewa	*Abiyi-Ekli/ Hangal*	Six	White-seeded coming from Shewa
Atona	*Abiyi-Ekli/ Hangal*	Six	Meaning not known
Rie	*Abiyi-Ekli/ Hangal*	Six	Visible (to indicate its large size seed)
Himblil	*Abiyi-Ekli/ Hangal*	Six	Unique/different (because of the red-rose color of its spikes/kernels during grain-filling/maturity)

beer (*tella* or *siwa,* and malt from *bukli*) and the roasted grain snack, like popcorn, known as *kolo* (Fig. 4).

Farmers describe *Demhay* as the most preferred variety for making *kolo,* because of its good popping qualities, and for making *tella* or *siwa* because of its better fermentation and flavor qualities. This is reflected in some traditional songs and sayings such as: "*Siwakhen le siwa Demhay eyu—lihameme lehiyu,*" which means: "Your local beer is made from *Demhay*—it is so good it will cure the sick." Local people sing this during festivals and marriage ceremonies to indicate the good quality of the beverage made from *Demhay*. Such songs and sayings clearly show the importance of barley in the everyday life of the people and indicate why farmers make the choices they do in sowing different varieties. *Keyiho* is likewise used for *kolo* and *siwa*. *Tihlo* (a special local food consisting of doughy balls made of barley dipped in a boiling spicy meat sauce mixed with yoghurt and eaten much like Swiss fondue) and *bukli* (malt) contributed to the opposite side of the first component and were associated with the variety *Tsemato*. *Himblil* and *Gunaza* are preferred for their drought tolerance, tall stature, early maturity, and high grain yield.

Farmers' Perceptions of Barley Varieties in Relation to Soil Fertility, Planting Time, and Drought

The decision on varietal choice is influenced by the household preferences and existing natural resources. Rainfall is the major environmental determinant for yield in dry-land farming. At the same time, growing different crops and varieties under varied field conditions helps buffer further against the variation in weather conditions. Some varieties do not grow well on heavy soils and others do not grow well on lighter sandy soils. Some varieties are better adapted to the lower part of the valley, and others to the higher slopes. In this study, we found that 34%, 43%, and 19% of the documented varieties grow in *hutsa* (sandy), *baekhel* (loam), and *walka* (clay) soil types, respectively. In addition to the extended growth period and the relatively better rainfall distribution in the highlands, the variation in soil types enhanced continued production of six-rowed barley varieties such as *Keyih-Shewa, Tsaeda-Shewa, Demhay,* and *Himblil*. Of the documented varieties, 36% of the farmers grew *Saesa* in sandy soils. In black and clay loam soils, the proportion of the variety *Keyih-Shewa* was higher than that of *Saesa*. With regard to rotation practices, 36% of the interviewed farmers rotated their barley with field peas, 43% with other varieties of barley, and 11% with Fava beans.

The farmers adjust sowing time so that crops have matured by the time the soil moisture reserves are depleted (29). Most farmers sow already in the dry season in the hopes of gaining higher crop yield by making efficient use of the early rain showers. However, some of the farmers claimed that dry-season sowing favors greater germination of weed seeds compared with sowing in the early wet season. They have their own phrase for the best time to sow barley: *mis-zehale,* meaning "after the soil has cooled." Farmers use either late- or early-maturing varieties, depending on the distribution and amount of rainfall and the soil fertility status of their plots. During the village-level Participatory Rural Appraisal (PRA) and field-observation exercises, farmers ranked a late-maturing six-rowed variety sown in July as worst, but some farmers explained the association of planting time with varietal types. One of the participants expressed his comment using the proverb: "A cheater who knows timing is far better than a farmer that does not know the seasons." This comment stimulated strong interactions among the farmers on their experiences in time of planting for barley.

According to farmers, their choice to plant a specific variety is associated with their need for rotation (47.8%) followed by multiple use (26.9%), seasonal conditions (19.7%), and availability of land (5.6%). The higher value for rotation is an indication of less fallowing, and rotation with legumes and seed exchange is practiced as a way to assure barley production in a

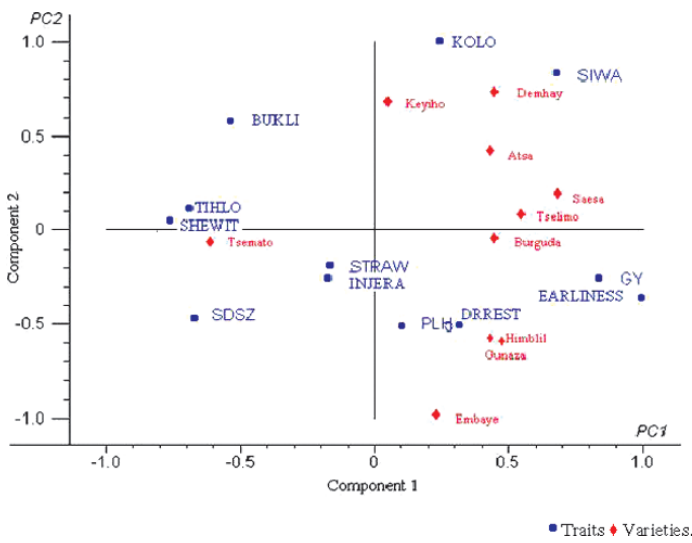

Figure 4. Simple correspondence analysis of agromorphological and use values of barley, as perceived by farmers, for straw and various foods and drink: *kolo* (crispy roasted grain snack), *bukli* (malt for local beer), *tihlo* (special dish, like Swiss fondue), and *injera* (pancake).

Table 4. Characteristics of major barley varieties in relation to preferred and nonpreferred traits.

Variety	RNO	Status	Preferred traits	Nonpreferred traits
Himblil	Six/mixed	Popular/specific	Long spike length; compact/resistant to diseases; water logging; high grain yield; medium maturity; high straw yield	More awns and lower yield; hard for hand threshing if cloudy weather; stiff straw
Saesa	Two/white	Popular	Early maturing; drought escaper; soft straw; better during drought; malt, *tihlo* and *kolo* (local foods and beverages)	Weak straw and lodging problem; sensitive to water logging; susceptible to disease and insects; high seed rate
Demhay (naked)	Six/yellow, black	Rare	Easy food processing; good for *kolo* because of popping quality and for *tihlo* (local food); lower seed rate; better for fertile soil	Not tolerant to drought; susceptible to disease; short spike length; threshing problems in cloudy weather; short and stiff straw; long maturing
Sihumay	Six/white	Rare/specific	High grain yield; good for food processing; long spike; good straw yield	Not tolerant to drought; long maturing; some pest infestation; prefers fertile soil; sensitive for terminal drought
Atsa	Two/white	Endangered	Long spike; good eating quality; tolerates temporary water logging; medium maturity	Threshing problem because of stiff stem and chaffy spikes
Atona	Irregular/white	Endangered	High–medium grain yield; high tilling capacity; high straw palatability	Hairy spikes prolong processing; stiff straw; late maturing
Tselimo	Two/black	Popular/specific	Black seed; good for local beer; early–medium maturity; high grain yield; palatable straw quality	Endangered because of late maturity; susceptible to disease
Rie	Six/white	Popular/specific	High grain yield; preferred for food; disease resistance; high tilling capacity; shed awns at harvest	Difficult to dehusk; not good for food/snacks; low yielding in poor soil and terminal drought
Burguda	Two/white	Popular/specific	Medium grain yield; early–medium maturity; required for food; medium tilling and yielding capacity	Not grown over large area because of its long maturity
Shewa	Six/red/white	Popular/specific	Late maturing; high grain yield; high tilling capacity	

season. Exchange could be with other varieties or the same varieties of different seed lots.

Farmers' Seed Renewal and Selection

Seed Selection. Most surveyed farmers (92%) conserved their barley seeds and practiced mass selection to renew and improve existing varieties. According to our informal discussions, seed selection is based on observations throughout the season, ranging from choosing the right field to condition of standing crops to grain-quality characteristics at harvesting (Table 5).

Most gave attention to spike length (89%) and earliness (87%) as reflecting the adaptation to local stresses. Grain color was used as a marker for culinary purposes. After threshing, selection was made among varieties primarily for straw quality (65%), followed by quality for *injera* (30) (34%), and beverages (33%). According to farmers, selection for disease and pest tolerance (including storability) was done both in the field and during storage. Farmers also selected their seed when multiplying new seed or when recovering seed from drought seasons Farmers also inspected each plant after harvest. The spikes that were underweight or small-sized were removed from the threshing floor. After threshing, seed for next season was separated by size (large, healthy seeds) at the threshing ground and stored separately in a marked sack or another container.

Seed Renewal. Farmers in Tigray replaced their seed when its quality was shriveled, diseased, or reduced in size. Barley seed may be saved for 6 y, but the turnover of seed is very high. The variety to be planted as a seed source is allocated to relatively fertile soil and grown in off-season residual moisture. Despite its low yield, this cropping time is recognized as weed free and produces a bigger grain size compared with main-season production. In this system, *Saesa* is frequently replaced, and the first seed reproduced in this system is called *Saesa* to indicate its earliness and the next three generations are called *Wulad* (progeny), *Salisen* (third progeny), and *Aregit* (old), respectively. These progenies are produced in the main season and are part of the bulk production. After the *Aregit* generation of seed, the farmers have to seek exchange or purchase of seed from other sources of *Saesa* or select in that specific season (using the residual moisture). The price or exchange value for the seed varies depends on the source. These observations agree with earlier findings (31, 32). In Tahtay Maychew district, some farmers have "off-farm" (outside their homestead farm) plots or a group of plots for selection of barley.

Table 5. Farmers practice of barley-seed selection (%) by cropping stage and traits in Tigray.

Traits	Preharvest	Postharvest	During threshing	After threshing	Storage
Tilling capacity	96	2	1	1	0
Plant height	95	1.25	1.25	1.25	1
Number of seed/spike	95	1	3	1	0
Spike length	92	1	1	6	0
Straw	24	1	1	74	
Earliness	97	1	1	1	0
Pest resistance	82	1	1	1	15
Drought tolerance	93	1	2	4	
High yield	50	2	33	14	1
Beverage quality	23	0	1	42	34
Food (injera) quality	14	0	1	41	43
lodging tolerance	97	1	2	0	0
Seed quality	57	1	4	34	4

Figure 5. Late- and medium-maturing types of barley: *Tsemato* (late) and *Gunaza* (medium). (a) *Tsemato*, two row long and thin spike. (b) *Crunaza*, six row short and big spike.

Why Choose to Grow *Saesa*?

Why was *Saesa* preferred by so many households? It is because of its relatively better and stable yield in seasons with both moderate and poor rainfall of the midaltitude areas. Farmers particularly favor its earliness, because there is a high risk of dryness at the end of the growing season (terminal drought). In the highlands, where rainfall is higher and the growth period in the main season is longer than in the lowlands, *Saesa* may be exposed to excessive lodging and water-logging problems. Also, its yield is low compared with that of six-row (late-maturing) varieties. In a Tigrigna proverb, the low yield potential of *Saesa* is expressed as follows: "Harvesting *Saesa* is just like trying to keep warm with small branches." However, in the highlands, it is preferred for the short wet season (*belg*) or for growing on residual moisture.

This indicates the farmers' knowledge about the different drought-resistance mechanisms of their crops. When asked to rate their varieties in terms of drought occurrence, they favor six-rowed varieties for intermittent or midseason drought. For terminal drought, farmers gave a higher rating for early-maturing two-rowed barley varieties such as *Saesa*. On the other hand, they also realized that not all two-rowed varieties are early-maturing and that not all six-rowed varieties are late maturing. For example, the variety called *Tsemato* has two rows but matures later than the six-rowed *Gunaza,* a medium-maturity type. The name *Gunaza* was given to indicate its big spike size, while *Tsemato* refers to the long tie of a bride's cosmetic bag and indicates the long spike of this variety (Fig. 5).

Saesa is also preferred for multiple household uses. The quality of its straw for use as feed is rated as high compared that of to other varieties. However, it is less preferred for making local beer. *Himblil* is still grown only in the Southern Zone of Tigray. Its area coverage is increasing there because of its high yield and better performance in water-logged soils and its high quality for making *injera*. The farmers' preferences thus depend on multiple criteria and the relative weighting of these criteria by the farm household members when deciding what to sow. As a result; there will be variation between households and villages in terms of the relative area allocated to a given variety.

Farmers' Varietal Selection: The Cases of Himblil and Demhay

Varietal Selection. Few farmers practice pure-line or mass selection for the purpose of variety renewal. Four farmer-

Figure 6. Farmer-developed varieties: *Demhay* and *Himblil.* (a) Kahsay's first variety: Demhay. (b) Comparing Kahsay's Demhay with others. (c) Kahsay's second variety: Himblil. (d) Kahsay and his variety: Himblil.

developed varieties (FDVs) were recorded from Bolenta, Menkere, and Mugulat villages in southern and eastern Tigray. *Embaye* is a variety named after the selector and now popular in Mugulat and Buket villages. *Hagos,* also named after the selector in Menkere, is not so widely popular. The cases of these varieties could not be traced, since both selectors are dead. However, *Himblil* and *Demhay* were developed by a farmer, Kahsay, aged 87, in Bolenta village (Fig. 6). He used mass and single-plant selection to develop his *Demhay* (naked) and *Himblil* (hulled) varieties, respectively. Awareness of newly selected varieties became gradually more widespread in the community after Kahsay was recognized by the community and the researchers as a breeder of barley. Out of 50 respondents from his village, more than 45% expressed a greater interest in his variety *Himblil* than in the original variety from which it was selected. Kahsay promoted his innovations among other farmers in his village. In the year 2000, he provided seed to more than 40 fellow villagers during a critical time when they had suffered a complete loss of seed because of problems with rodents. Since then and through his annual exchange of barley seed, as is customary in the area, he is considered as a local seed bank of the village.

Naked Barley. In Ethiopia, cultivation of naked (hull-less) barley is as old as that of hulled barley. It is one of the few countries in which naked barley is used as human food. Farmwomen interviewed found naked barley to be more suitable than hulled barley for food preparation because it can be used directly. However, its cultivation is decreasing because its yield is relatively low and it requires better soils and more water than do other varieties. Formal agricultural research has given little attention to naked barley, even though it is richer in proteins (33) and in lysine (34) than is hulled barley. The seed selector Kahsay has long been working on naked barley, and selected single plants from the local six-rowed barley variety called *Demhay*. This variety has not been so widely adopted by other farmers as has *Himblil,* possibly on account of its need for better soils and a long maturing period. Because scientific information on drought resistance in naked barley germplasm is scarce, it is more difficult to obtain cultivars that yield well under drought-prone conditions. It is therefore important that programs in Ethiopia seek local knowledge and practices of managing the diversity of naked barley in order to be able to conserve it and to breed more drought-resistant cultivars.

DISCUSSION

The study revealed that smallholder farmers in Tigray maintain and select between and within barley varieties. The descriptors of barley varieties identified by the farmers can be a valuable tool for measuring the diversity in population and understanding the behavioral pattern of a landrace (35, 36). The association of vernacular names with a group name was also explained for rice in Laos (37) and the specific descriptors or use value of varieties are in agreement with earlier studies of barley in Ethiopia (38). The identified characters can be utilized in barley improvement, since the initial stages of breeding for most crops have been based on locally adapted varieties. For instance, some of the Ethiopian improved barley varieties, such as *Dimtu* and *Misrach,* are pure-line selections made within local varieties. The farmers' observations and justifications for planting time match with the agronomic principles for germination of crops. Our finding on the farmers' tendency to grow later maturing varieties high on mountain slopes and earlier maturing varieties in the flat plain indicates their conscious management of their resources. It has been shown that, in Mexico, farmers select preferred maize types from their agromorphological characters (39).

This study has revealed the importance of farmer-developed varieties. The expansion and preference by farmers for informal seed exchange confirms the importance of this practice in favoring broad adaptation (40). The superior performance of *Himblil* and its adaptation to different stresses was recently observed (Fekadu pers. comm.). The superior knowledge and partnership skills of the seed selector are consistent with earlier findings, in which farmer-breeders were recognized as custodians of germplasm *in situ* (41) and as sources of germplasm for collection for *ex situ* conservation (42, 43). They are also regarded as providers of locally improved seeds and potential partners in participatory plant breeding (9, 10).

The intrahousehold decision making on barley production indicates the important role of women in barley-seed management. While men have greater authority in determining the type of variety to grow, most storage and processing is exclusively the domain of women. The number of varieties to be grown, seed selection, and plot allocation for barley are decided jointly. In addition to the well-known regular burden of household tasks, the major share made by women for seed storage and processing may indicate the substantial time they need to produce clean seed and various products made of barley, their preference for naked over hulled barley is associated with its lower time requirement for processing. It is at this point of recognizing farmers' own innovation and experimentation that led to farmer-developed varieties that formal researchers, extension agents, and farmers can design joint experimentation in order to address challenges of genetic variation and improvement.

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