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Farmers' perception and genetic erosion of tetraploid wheats landraces in Ethiopia

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Abstract

Assessing genetic erosion has been suggested as the first priority in any major effort to arrest loss of genetic diversity. In Ethiopia, although it is generally accepted that significant amount of genetic erosion has occurred and is still occurring, there is little data on its amount and extent. Thus, this study is conducted to quantify the extent of genetic erosion in Ethiopian tetraploid wheat landraces and to identify major causes of genetic erosion. To this end, a field survey of 126 farmers, randomly selected over five districts in eastern, south-eastern and central highlands of Ethiopia during 2001/2002 and 2002/2003 main cropping seasons was undertaken. Questioner was used to collect primary data from farmers who are potentially rich sources of information on genetic erosion at the variety level. Additional data were collected through key informant interviewing. Moreover, resampling was made from Tulo, Chiro and Harar Zuriya districts in eastern Ethiopia. Analysis of history profiles from primary and secondary data indicated a reduction in the use of local varieties over years. *Triticum polonicum* and *T. turgidum* are becoming very localized, and therefore, they are under greater threat of extinction. Using the calculation scheme: gene erosion = 100% − gene integrity, i.e., the still extant landraces, genetic erosion was calculated for the three different areas where resamplings were made. Genetic erosion of 100% was observed both in *T. durum* and *T. dicoccon* in Tulo district. Likewise, genetic erosion of 85.7, 100 and 77.8%, respectively, was calculated for *T. durum*, *T. turgidum* and *T. dicoccon* in Chiro district. In Harar Zuriya, a genetic erosion of 88.9% for *T. durum* and 100% both in *T. turgidum* and *T. dicoccon* was detected. Number of farmers growing landraces of tetraploid wheats drastically decreased in all surveyed areas in the past decades. Displacement of landraces by other crops was the prominent factor for ending landrace cultivation. Farmers' preference to yield potential and cash crops subsequently reduced the chance of maintaining landraces. Institutional factors like access to credit and the extension advice have influenced farmers' decision regarding cultivar choice. In all surveyed areas, the most important initial source of seed of improved wheat varieties is the seed credit from the Ministry of Agriculture which uses a 'plant now, pay later' scheme to promote the distribution of improved varieties and fertilizers. The problem of genetic erosion through inappropriate maintenance of *ex situ* collections was also recognized and discussed.

Introduction

The Ethiopian environment is dominated by heavily dissected and rugged extensive mountains and highlands, which are estimated to cover about 45% of the total area (over one million square kilometers) of the country. The major physiographic features are a massive highland complex of mountains and plateaus divided by the Great Rift Valley and surrounded by lowlands along the periphery. The diversity of the terrain is fundamental to regional variations in climate, natural vegetation, soil composition, and settlement patterns. The presence of wide altitudinal range (120 m below to 4600 m a.s.l.), substantial temperature, edaphic and rainfall differences created a wide range of agroecological conditions that provided sustainable environments for a broad range of life forms. As a result, Ethiopia is considered as one of the richest genetic resource centers in the world. For several economically important cereals such as wheat (*Triticum* spp.), barley (*Hordeum* spp.) and sorghum (*Sorghum bicolor* (L.) Moench), Ethiopia is considered as center of diversity (Vavilov 1997; Worede 1997) and also a center of origin for crops like anchote (*Coccinia abyssinica* (Lam.) Cogn.), khat (*Catha edulis* (Vahl) Forsk. ex Endl.), coffee (*Coffea arabica* L.), enset (*Ensete ventricosum* (Welw.) Cheesman), gesho (*Rhamnus prinoides* L' Hérit.), gomenzer (*Brassica carinata* A. Braun), noog (*Guizotia abyssinica* (L.f.) Cass.), Oromo potato (*Plectranthus edulis* (Vatke) Agnew) and teff (*Eragrostis teff* (Zucc.) Trotter) (Harlan 1971). For some very old crops like the primitive wheats, *Triticum dicoccon* Schrank, *Triticum polonicum* and *Triticum spelta* L., Ethiopia is one of the few refuges where they have survived. *T. aethiopicum* Jakubz., an endemic species of tetraploid wheat, also occurs in Ethiopia (Phillips 1995).

Agriculture in Ethiopia is predominantly traditional and thus mainly landraces are grown (Tessema and Bechere 1998). Harlan's (1975) classic definition of landraces describes them as 'balanced populations – variable, in equilibrium with both environment and pathogens and genetically dynamic … the result of millennia of natural and artificial selections.' Landraces are the genetic bases for further breeding works. Thousands of genetically distinct varieties of our major food crops owe their existence to years of evolution and to careful selection and improvement by our farmer ancestors. Nevertheless, processes that once took hundreds or thousands of years to develop could then be carried out within decades or even years under human influence (Hammer 2004). There has been a significant loss of genetic diversity during the last 100 years and the process of gene-erosion continues (Hammer et al. 2003). In the field of plant genetic resources for food and agriculture the irreversible loss of single genes or combinations of genes in genotypes, the so-called gene-erosion, is of major concern. Diversity is the basic factor of evolution in species. It made it possible for crops to be adapted to diverse environments and uses, and genetic diversity will allow them to respond to the challenges of the next century (Hammer et al. 1999). As a result, the loss of biodiversity belongs to one of the central problems of mankind, next to other important matters such as climate change and securing an adequate supply of drinking water. In the centers of diversity that he studied, Vavilov was able to observe and document the unbroken result of an evolutionary process that had lasted thousands of years (Hammer 2004). The threats to this diversity only became visible later, as for example, when the American plant explorers Harlan and Martini (1936) recognized the problem of genetic erosion in crops. Several approaches have then been employed to estimate the degree of genetic erosion that a particular taxon faces in a certain region over a given time. Methods usually rely on either the analysis of molecular data (Provan et al. 1999) and allozyme analysis (Akimoto et al. 1999), or comparison between the number of species/cultivars still in use by farmers at present time to those found in previous studies (Hammer et al. 1996) or using the genetic assessment model presented by Guarino (1999) or using a checklist of risk factors (Oliveira and Martins 2002). The most widely used figures in estimating genetic erosion is indirect, i.e., the diffusion of modern crop varieties released from crop breeding programs. Various authors have estimated genetic erosion in different crops using different approaches. Harlan (1950) reported a decreasing trend of landrace cultivation in Turkey. The two case studies conducted by Hammer et al. (1996) to estimate genetic erosion in landraces revealed that genetic erosion was found to be 72.4% in Albania and 72.8% in South Italy. The study of 220 landraces with 147 forms in South Korea (Ahn et al. 1996) showed a medium gene erosion of 74%. Stephen et al. (2002) also informed that farmers in the north-eastern Philippines had a marked reduction rice diversity from 1996 to 1998. Gao (2003) reported that the widespread adoption of high-yielding rice varieties has led to biological impoverty of rice germplasm, as local rice varieties are abandoned for modern varieties.

To reverse the unabated gene erosion, conservation of genetic diversity is a fundamental concern in conservation and evolutionary biology, as genetic variation is the raw material for evolutionary change within populations (Frankel and Soulé 1981). Detecting and assessing genetic erosion has been suggested as the first priority in any major effort to arrest loss of genetic diversity. Generally, nevertheless, many national programs have not regarded quantification of genetic erosion as a high priority, as apparent from the paucity of information in the State of the World Report (FAO 1997). Also in Ethiopia, while there is clear evidence for a reduction in the number of tetraploid wheat landraces grown and a decline in the area in which landraces are grown, the extent to which allelic diversity has been lost has not been documented. Hence, this study was conducted to determine the extent of genetic erosion, and to identify major causes of genetic erosion. The study also assessed the measures that are being taken to reduce the problem of genetic erosion.

Materials and methods

Selection of study sites and farmers

A stratified random sampling procedure was used to identify farmers. First, the different wheat producing districts were selected in consultation with the Institute of Biodiversity Conservation and Research (IBCR) and Ministry of Agriculture (MoA) personnel. Accordingly, two districts namely Chiro and Habro from eastern Ethiopia, two districts namely Hetosa and Tiyo from Arsi region of south-eastern Ethiopia, and two other districts known as Ginchi and Gimbichu from central highlands of Ethiopia were identified (Figure 1). Within each district, major wheat producing peasant associations (PAs) were selected. Within each PAs, a group of old and experienced farmers were selected in close contact with development agents (extension staff of MoA) and a total of 126 farmers were randomly sampled from the different groups. The household characteristics and major crops grown in surveyed districts are presented in Table 1.

Data collection and analysis

To examine the extent of genetic erosion occurred in the last decades temporal comparison was used. This was done by re-sampling and through indigenous knowledge surveys as described by Guarino (1999). Re-sampling of landraces of *T. dicoccon*, *T. turgidum* and *Triticum durum* Desf. was done in three areas namely Harar Zuriya, Tulo and Chiro districts in eastern Ethiopia in 2001/2002 and 2002/2003 main cropping seasons and compared with germplasm accessions collected by IBCR from the

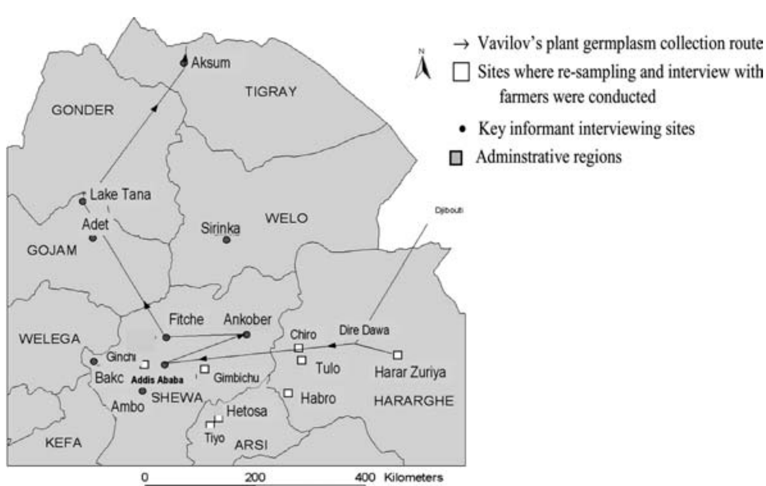

Figure 1. Map of Ethiopia showing the travelling route of Vavilov in 1927 and investigation sites in 2001/2002 and 2002/2003, respectively.

Table 1. Household characteristics of surveyed areas.

District	N	Gender		Average age of farmers	Average family size (no.)	Average farms size (ha)	Major crops grown
		Male	Female				
Chiro and Habro	32	25	7	47.3	7.9	1.72	Sorghum, maize, khat, tef, bread wheat, haricot bean
Hetosa and Tiyo	40	35	5	54.9	6.0	2.41	Wheat, barley, potato, noug, beans, peas
Ginchi	24	21	3	51.2	7.6	1.96	Wheat, tef, maize, noug, beans, peas
Gimbichu	40	32	8	49.5	6.3	2.27	Tef, wheat, lentil, chickpea

same areas at different times in the past and conserved *ex situ*. For locating the sites, where previous collections were made, to undertake re-sampling information on the passport data from earlier years of collection was used. Among others, the passport data of IBCR contains information on collection site like administrative region, district name, altitude, latitude, and longitude of collecting site including the distance from the nearby town.

Brown et al. (1997) and Synnevåg et al. (1999) provided a useful list of features or indicators that could be measured singly or in combinations on individuals and populations of a given species in a defined area as part of a systematic effort to monitor changes in genetic diversity in the species. Modified lists of such indicators were used in developing the questioner used to collect primary data on indigenous knowledge and experiences of local farmers that are potentially rich sources of information on genetic erosion at the variety level. The main topics included in the questioners were topics like change in cropping systems and reasons for change, adoption of improved varieties of wheats, assessment of the seed supply systems, change with regard to the use of landraces and reasons for change, trends in the area of cultivation of tetraploid wheats, and needs farmers perception about comparative advantages of landraces. The questionnaires were administered to sample farmers in collaboration with development agents using local languages. Additional data were collected through key informant interviewing. Key informants included MoA staff, wheat researchers, IBCR staff, developments agents, and NGOs staff. Data was also collected from secondary sources like scientific publications, reports of extension departments of MoA, IBCR, and Ethiopian agricultural research organization (EARO).

For each question, the percentage of farmers who gave similar responses was calculated for each district. For re-sampled areas, genetic erosion (GE) was calculated as GE = 100% − GI (Genetic integrity) (see Hammer et al. 1996). This approach is possible because collecting missions have been carried out in 2001/2002 and 2002/2003 covering the same areas, and following the same procedures of IBCR germplasm collection method. However, pooled accessions collected between 1963 and 1988 in Harar Zuriya, between 1979 and 1988 in Tulo district and between 1964 and 1987 in Chiro district were used as a base for calculating genetic erosion unlike Hammer et al. (1996) who used comparisons of accessions collected in 1941 and 1993 in Albania and in 1950 and 1983/1986 in South Italy. For this experiment, it was not possible to calculate the rate of genetic erosion per year because of the longer time difference in the pooled accessions.

Results

Assessment of genetic erosion: field studies

Using the calculation scheme: gene erosion = 100% − gene integrity, i.e., the still extant landraces, a genetic erosion was calculated for Harar Zuriya, Tulo and Chiro districts. Genetic erosion of 100% was observed both in *T. durum* and *T. dicoccon* in Tulo. Likewise, genetic erosion of 85.7%, 100% and 77.8%, respectively, was detected in *T. durum*, *T. turgidum* and *T. dicoccon* in Chiro. In Harar Zuriya, a genetic erosion of 88.9% in *T. durum* and 100% in *T. turgidum* and *T. dicoccon* was found (Table 2).

All the interviewed farmers in the different districts reported that they were growing tetraploid wheat landraces mainly *T. durum* and *T. dicoccon* in the past. However, the number of farmers growing landraces of tetraploid wheats drastically decreased in the past two decades in all surveyed areas (Table 3), implying reduction in the area coverage of landraces as other crops were adopted. The highest displacement of landraces was observed in Hetosa and Tiyo where 87.5% of the sampled farmers grew only improved varieties of bread wheat. Adoption of modern wheat varieties is inversely correlated with landraces diversity mainly in Ginchi, Hetosa and Tiyo, in which farmers have abandoned landraces to a greater extent (Table 3).

Assessment of genetic erosion: a review

Worede (1983) reported that the traditional tetraploid wheat varieties have been almost completely replaced by modern, uniform, and advanced cultivars in areas such as Arsi and Bale, major wheat growing areas of the country. There are reports indicating the decline of area cultivation of tetraploid wheats in the country. Hailu (1991) reported that the estimated area of durum and bread wheat to be, respectively, 85 and 15% in 1967 and 60 and 40% in 1991, whereas Aquino et al. (2000) as cited by Eshetu (2002) reported the wheat area covered by durum and bread wheat in Ethiopia to be 40 and 60%, respectively. The native Ethiopian durum wheat is suffering from serious genetic erosion and is being lost (FAO 1996). Owing to their soaring price, the acreages of tef and khat have increased at the expense of major crops such as sorghum, wheat, maize, and barley (Hailu 1991). According the report of IBCR (2002), populations of *Triticum polonicum* faced extinction problems.

The presence of modern varieties in a farming system is taken as *prime facie* evidence of genetic erosion. Mulugetta (1994) studied the economics of smallholder wheat production and technology adoption in five wheat-growing districts of Arsi region during the 1990/1991 cropping season from a sample of 426 wheat farmers and found that all the sample farmers planted improved wheat varieties. Likewise, Setotaw et al. (2001) surveyed a total of 300 farm households in five major wheat-

Table 2. Estimating genetic erosion in landraces of crops in Harar Zuriya, Tulo and Chiro districts by comparison between collecting missions at various times. GI = genetic integrity, GE = Genetic Erosion.

Crop	Harar Zuriya				Tulo district				Chiro district**			
	1963–1988*	2002	GI%	GE%	1979–1988*	2002	GI%	GE%	1964–1987*	2003	GI%	GE%
	Samples collected	Samples collected			Samples collected	Samples collected			Samples collected	Samples collected		
T. durum	18	2	9.1	88.9	15	2	13.3	76.7	14	2	14.3	85.7
T. turgidum	3	0	0	100	–	–	–	–	2	0	0	100
T. dicoccon	4	0	25	75	7	0	0	100	18	4	22.2	77.8

*accessions were collected by the Institute of Plant Genetic Resources Center, Ethiopia.
**Some parts of Habro district were also included in the analysis.

Table 3. Comparison of percentage of farmers growing tetraploid wheat landraces or improved wheat varieties in the past and at present. IV = Improved varities, FV = farmers varieties (landraces).

Name of district	N	In the past (before 10–20 years)			During 2001/2002 and 2002/2003 main cropping seasons		
		Growing FV only	Growing IV only*	Growing both	Growing FV only	Growing IV only	Growing both
Chirro and Habro	32	18.75	31.3	50	0	9.4	3.1
Hetosa and Tiyo	40	22.5	42.5	35	0	87.5	12.5
Ginchi	24	45.8	16.7	37.5	8.3	54.1	16.7
Gimbichu	30	60	10	30	40	13.3	36.7

*Improved varieties include both improved bread wheat varieties and durum wheat varieties.

growing areas of the Arsi zone to examine the rate of adoption of wheat production technology and about 95% of the sampled farmers had grown wheat during the 1998 crop season. They revealed that 91.5% of the farmers adopted improved bread wheat varieties. According the their findings, about 73% of wheat growers planted a single variety of wheat. Similar trends were also observed in other major tetraploid wheat growing areas of Ethiopia. Bekele et al. (2000) reported that the total area planted to the most important improved bread wheat varieties from 1992 to 1997 has increased dramatically in Bale province. In Yelmana Densa and Farta District of northern Ethiopia, the rate of adoption of improved wheat varieties increased from less than 1% in 1981 to 72% in 1998 (Tesfaye et al. 2001).

The heterogeneity of farming systems in centers of diversity is believed to limit the diffusion of modern varieties and maintain production spaces for indigenous varieties. Contrary to this, improved Kenyan wheat varieties were found by Dr. Hermann Kuckuck of the Federal Republic of Germany over a decade ago 'in very remote areas of Ethiopia, accessible only by mules' (Fowler and Mooney 1990). They also reported that the native wheats of the Nile Valley will soon be gone, replaced by modern varieties provided by a government program. Currently, with the aggressive extension package in action and the dynamism of the farmer to farmer seed exchange in Ethiopia, the diffusion of improved varieties is likely to be deeper than expected.

Reasons for the displacement of landraces: survey results

The main reason for the reduction or abandonment of cultivation of landraces is displacement of landraces by other crops (Table 4). In Hararghe, only 9.4% of the interviewed farmers grew landraces only and 3.1% farmers grew landraces along with improved wheat varieties (Table 3). The remaining 87.5% of the interviewed farmers abandoned landraces and shifted to cultivating khat, maize and sorghum. The major reason for the expansion of khat production is its high price. In Ginchi, Hetosa and Tiyo districts, durum and emmer wheats were replaced by bread wheat cultivation while the latter is high yielding and fetches a higher market. Low grain yield of landraces is among the important factors mentioned for the replacement of tetraploid wheat landraces by improved bread wheat varieties (Table 4). The erratic and unstable rainfall coupled with the longer growing period of landraces also forced farmers to adopt early maturing modern wheat varieties or other crops that either escape or tolerate droughts. In Habro and Chiro districts, farmers shifted from wheat to sorghum, maize, khat and tef production because these crops are less vulnerable to low moisture stress than wheat. The pro-improved varieties extension advice and credit facilities have influenced farmers' decision regarding cultivar choice (Table 4). Farmers were motivated to grow improved varieties so as to benefits from the associated credits. Decrease in soil fertility was

Table 4. Farmers' reasons given to end cultivation of landraces (% of responses)*.

Reasons	Habro and Chiro (31)**	Hetosa and Tiyo (35)	Ginchi (18)	Gimbichu (7)
Displacement by improved varieties of durum	3.22	–	5.6	14.2
Displacement by other crops	80.6	88.5	61.1	28.57
Decrease in soil fertility	35.4	25.7	33.3	–
Decreased and unstable rainfall	38.7	17.1	27.7	14.28
Low yields	61.3	82.8	61.1	57.14
Weeds, disease and insects	6.4	20	16.7	0
Lodging problems	25.8	40	33.3	14.28
Marketability	19.4	34.3	16.7	28.6
Longer growing period	22.5	25.7	22.2	–
Threshabilt problems	22.5	22.8	22.2	–
Influence of extension agents	9.6	25.7	16.7	–

*Sums over 100% are due to multiple answers.

**Figures in parentheses refers to number of farmers who ended cultivating landraces and interviewed for the identifying reasons to end cultivation of landraces.

also one of the major factor led farmers to start using inorganic fertilizers in which the landraces were unable to perform well because of lodging problems (Table 4).

Farm location and the ways in which farmers articulate with formal seed supplies is an important determinant of the impact these have on farm-level diversity (Cromwell and Almekinders 2000). Of the different surveyed areas, landrace replacement by bread wheat was found to be higher in Hetosa and Tiyo districts (Table 3), which are near to Kulumsa Agricultural Research Centre and a seed multiplication and processing firm of the Ethiopian Seed Industry Agency. After seed has been released from the formal sources, the local seeds systems like gifts for relatives or friends and exchange of seeds among farmers or bartering were found to be the main roots of improved seed dissemination. Seed aids by NGOs and relief agencies at times of famine were also one of the seed sources in Hararghe. In Gimbichu district, community seed bank is the basic source of seeds of landraces (composites) for farmers (Table 5).

Reasons for the displacement of landraces: a review

There have been several catastrophic droughts in the country that caused complete crop failures and subsequently severe genetic erosion has taken place in the landraces that have been maintained through many generations. Farmers have been forced to consume the seeds normally kept for planting. The famine of the mid-1980s seriously threatened Ethiopia's biological resources. In some cases, food grain from relief agencies became the only source of seed for planting after farmers ate their own seed, or sold as food commodity in order to survive (Worede and Mekbib 1993; Worede 1998).

The availability of improved varieties of bread wheat seeds in larger quantities as compared to durum wheats has been responsible for the displacement of durum wheat (Bechere et al. 2000). Comparisons of the yield potential of wheat varieties that have been released over years have revealed that the yield potential of bread wheat has increased by 89% at Holetta and 71% at Kulumsa during the last 38 years of wheat breeding activities. That of durum wheat has increased by 56% during the last 25 years (Amsal 1994). These changes in bread and durum wheat potential grain yields in the central highlands of Ethiopia were strongly associated with changes in harvest index with no change in biological yield, which is the characteristics of most modern wheat varieties containing dwarfing genes. This is a welcome development approach, although, paradoxically, it is a threat to genetic diversity on which future crop improvement work is based. Since the start of the high input extension package in 1994–1995, cultivar abandonment and replacement has been taking place especially in the major wheat growing areas of the central rift valley and central highland of Ethiopia by both package and non-package user farmers (Eshetu 2002). The better performance of bread wheat varieties with fertilizers has contributed to their increased adoption (Tesfaye et al. 2001). In most surveyed areas, the most important initial source of seed of improved varieties is the seed credit from the MoA which uses a 'plant now, pay later' scheme to promote the distribution and multiplication of improved varieties and fertilizers (Table 5). The two main inputs,

Table 5. Farmers response of wheat seed sources in the different survey areas (% responses)*.

Factor	Habro and Chirro	Hetosa and Tiyo	Ginchi	Gimbichu
Seed aid from NGOs and other relief institutions	34.3	0	0	0
Community Seed Bank	0	0	0	80.0
Seed credit from MoA and SG-2000	53.1	80.0	91.7	20.0
Gifts from relatives and friends	12.5	20.0	50.0	30.0
Exchange of seeds (bartering)	21.9	30	25	26.7
Manual labor for seeds	9.4	0	0	16.7
Local markets	32	24	34	16.7
Saved seeds (self supply)	21.9	52.5	58.3	60.0
Research centers	9.4	15	0	0

*Sums over 100% are due to multiple answers.

fertilizer and improved seeds, have witnessed widespread and increasing rates of adoption, since the 1995/1996 cropping season the period that the aggressive fertilizer and seed credit transfer package was taken up by the MoA in collaboration with the SG-2000 (Eshetu 2002). At present, the package program is fully operational in all regional states and ecological zones of the country. The higher price of tef in the market and its elasticity in terms of ecological distribution attributed to the displacement of durum wheat (Bechere et al. 2000; Eshetu 2002). Institutional factors, principally access to credit, extension contacts, and farmer education level, significantly influenced the adoption of bread wheat production technologies (Setotaw et al. 2001). In Ethiopia, agribusiness sectors like small-scale private farmers, state farms, and producer cooperatives who were active in major wheat growing areas of south eastern Ethiopia were in favor of monoculture cropping and therefore have also played a prominent role in the increased adoption of improved bread wheat varieties at the expense of traditional varieties of tetraploid wheats.

Loss of diversity in ex situ genebank: a review

The discovery, collection, and conservation of potentially valuable but endangered plant genetic resources for food and sustainable agriculture (as well as other plant genetic resources that have potential value for future development) are the primary obligations of all countries and institutions adhering to the FAO international undertaking on plant genetic resources (Hammer et al. 2003). Consequently, the Plant Genetic Resources Center/Ethiopia (PGRC/E), the then IBCR, was established in 1976 to collect, evaluate, document, conserve and promote the utilization of crop plant germplasm in the country. Despite the big financial problem and lack of trained personnel it had, the institute has made tremendous efforts to collect, evaluate and maintain genetic resources of Ethiopia since its establishment. The institute currently maintains about 12,000 accessions of *Triticum* species in its *ex situ* gene banks.

The problem of genetic erosion through inappropriate maintenance of *ex situ* collections is widely recognized. Genetic erosion can occur at many stages in the preparation, sub-sampling, exchange, storage and regeneration of seed (Sackville Hamilton and Chorlton 1997). They also highlighted loss of diversity through genetic shifts and convergent selection during regeneration as a potentially severe and often under-acknowledged problem. In the world collection, beyond the problem of duplication among accessions, the security of *ex situ* conservation as a whole is endangered. About half of all gene bank accessions urgently require rejuvenation, and in several countries the percentage is even higher (Hammer 2004). The germplasm passport data of IBCR mainly contains collection data like accession number, species name, and information on collection site (administrative region, altitude, latitude, and longitude), and date of collection. However, it is common to find accessions that lack one or more of the above data. It was also observed from the passport data and an interview that samples were collected with a low frequency. The stock of seeds of some accessions in the genebank has been exhausted as a result of frequent requests but not having been replenished appropriately. As a result of financial problems, lack of staff and shortage of farms, rejuvenation of seeds weren't being done as per scheduled. Tsehaye (2002) observed that the durum wheat materials from the genebank have showed poor germination potential and vigor in the field, which is an indicator of genetic erosion.

Community genebank activities

The primary solution to the genetic impoverishment of crop germplasm is genetic conservation and utilization in breeding of the vast genetic variation found in natural populations of the wild progenitors and landraces of cultivated plants (Frankel and Bennett 1970; Tanksley and McCouch 1997). The Global Plan of Action (FAO 1996) calls for strengthened on farm conservation and management to preserve genetic diversity in farmers' fields, and points to the pressing need for more research. Recognizing this, coordinated in situ conservation in Ethiopia started in 1988 when Plant Genetic Resources Center of Ethiopia in collaboration with the Unitarian Service Committee of Canada (USC/C), implemented the Seeds of Survival Program, Ethiopia (SoS/E) and conducted a farmer-based crop genetic resource conservation and utilization program. One aspect of the program seeks to restore the landraces to regions where farmers had once planted them extensively but where they had been replaced by new, exotic or improved (high input) varieties. In the region of Ada, in Central Shewa, the indigenous durum wheat has nearly disappeared because of displacement by introduced bread and durum wheat varieties (Worede 1993). To promote the conservation, enhancement and utilization of indigenous durum wheat in Ada and other areas of Central Shewa, the genebank, in close collaboration with the wheat breeding team at Debre Zeit Agricultural Research Centre and the SoS program, undertook extensive collection of landraces from which elite landrace selections were developed as composites, multiplied and distributed to farmers (Tessema 1987). Composites, which are competitive with modern varieties with respect to yield, help to raise productivity while keeping diversity alive (Tessema and Bechere 1998). Consequently, farmers in Gimbichu district re-introduced landrace cultivation.

A biodiversity conservation project of the Global Environmental Facility program of the UN was also undertaken from 1994 to 2002 (Tsehaye 2002). The program worked on institutional strengthening, community-based conservation activities, and identifying incentives for *in situ* conservation. In 2001, the Ethio-Organic Seed Action Programme (EOSA) was established to promote integrated conservation, use and management of plan genetic resources. The report of EOSA indicated that the policy environment is one challenge they have faced. It has been one where government has been more interested in increased production to cater for growing population demand at the expense of maintaining diversity. This has resulted in less support for conservation initiatives and has proved to be a challenge to program implementation. Mburu and Edilegnaw (2003) observed the presence of mistrusts between EOSA and IBCR. The latter fears that the EOSA can eventually take over the bulking activities and start using them to solicit for funds.

The value of diversity is in its use (Gao 2003). Only in use can diversity be appreciated enough to be saved and can continue to evolve, and thus retain its value (Partap 1996). Cognizant to this fact, community gene (seed) banks were established to mitigate the unabated genetic erosion of landraces of indigenous crops with a guiding principle of 'conservation through use'. Currently, there are twelve community gene (seed) banks in Ethiopia. A survey was made to beneficiaries of community seed bank association in Gimbichu district. The association was organized by IBCR. To become a member of the association, farmers have to pay a membership fee and contribute an agreed amount of seed as membership shares (one share is equal to 50 kg of seed). A farmer can have up to maximum of 10 shares. During the time of seed scarcity, farmers are given seed from the gene bank on credit basis and should pay in kind at the end of the season. In addition, these farmers are free to sell the rest of the seed to the seed bank at the local market prices. Members of the association indicated that they reintroduced landrace cultivation to benefit from the various advantages of composites (landraces) (Table 6). Landraces provided farmers reasonable yield under natural conditions, without fertilizers and pesticides. As a result, farmers were free from extension credits which farmers were often unable to pay because of low market price at times of good harvest. Moreover, they expressed that landraces are good for making different local foods such as '*genfo*' (porridge), '*nifro*' (boiled grain), 'kinche' (crushed kernels cooked with milk or water and mixed with spiced butter), and '*kolo*' (roasted grain). In other districts, the nutritional value was the most frequent reason mentioned for maintaining landraces of emmer wheat in face of competition from modern bread wheat varieties and other crops. Farmers expressed that none of the improved varieties released so far were comparable with landraces particularly to the farmer's variety that is locally named as 'Tikur sinde', which is named tikur (black) after its seed color, in making local alcoholic beverages. This local variety is also praised for its long stalk, good taste, non shattering characteristics, and its resistance to storage pests and moisture variability. Despite its black color, it has high market price. Since most of landraces are tall in height, they compete well with weeds and their straw is good for thatching roofs. As landraces are resistant to weevils, they have longer storage life. Farmers mentioned their time and labor shortage problems during harvesting when they grow improved varieties as these varieties shatter if not harvested soon after maturity. Landraces, nevertheless, do not shatter and would

Table 6. Farmers' perception of comparative advantages of landraces of durum over improved varieties of wheat in Gimbichu district.

Factor	Landrace Materials	Improved Varieties
Plant height	Taller	Shorter
Food value	Nutritious	Less nutritious
Storage period	Longer as they are resistant to storage pests (weevils)	Shorter because they are easily eaten by weevils
Shattering	Non-shattering	Shatter if not quickly harvested
Weed, disease and insect pest resistance	More tolerant	Susceptible
Tillering capacity	High	Low
Kernel weight per unit volume	Heavier	Lighter
Adaptation	Well adapted	Poorly adapted
Chemical Requirements	Do not require fertilizer and other chemical inputs	Do not perform well without chemicals
Planting Seed requirements	Less seed per unit of land	More seed per unit of land
Stability of yield	Fairly stable	Unstable

keep longer before harvest. Landraces have heavier kernels weight per unit volume than modern varieties. Worede (1998) also reported that a sack of 100 kg capacity filled with landraces weighs more (upto 30 kg in excess) than improved wheats. In addition to reintroducing landrace cultivation, which is one the best achievements of the association; it created a good link between farmers, researchers and IBCR staff, an important factor to ensure sustainable on farm conservation activities.

Discussion

In all the study areas, cultivation of landraces has been decreased. In Hararghe, a genetic erosion up to 100% was observed. Hararghe was one of the areas where tetraploid wheat landraces were growing (Bechere et al. 2000). During a germplasm collecting trip to Ethiopia, the plant explorer Vavilov (1997) has visited Harar in January 1927 and described the huge wheat variability he observed as 'the characteristic wheat, cultivated in an enormous amounts in the Harar region, no doubt belongs to a special kind, different from every thing I had seen and collected in other agricultural areas of the world. The fields display incredible mixture of varieties. It was necessary to collect hundreds of ears to obtain a representation of the botanical composition. I discovered at once endemic types with violet grains, not known anywhere else in the world.' The number of farmers growing landraces of tetraploid wheats and area of cultivation of these crops have declined. Thus, landraces of these species mainly of *T. polonicum*, *T. dicoccon* and *T. turgidum* might face a survival problem as natural selection is often incapable of action with too small population, and random genetic drift will accelerate the loss of genetic polymorphisms. For plants and some animals, area measurements of habitat patch sizes will provide a reasonable basis to estimate population size (Brown et al. 1997), an important factor determining survival of individuals. The size and number of individual populations are related to their ability to cope with both random (stochastic) fluctuations in the environment and steady (systematic) long-term change. Smaller populations are vulnerable to demographic and environmental stochasticity and the decline in fitness associated with genetic drift and inbreeding (Frankel and Soulé 1981). Hawkes (1983) reported that smaller area in traditional crops reduces diversity. The frequency distribution of the sizes of individual populations is likely to reflect the way in which genetic variation is partitioned within and among populations, with small populations being at increased risk of loss of alleles, reduced heterozygosity, increased uniformity, enhanced inbreeding or possible extinction. Van Treuren et al. (1990) reported that in some cases the loss of particular crop varieties is not complete, but instead reduces surviving members of a landrace to a few isolated populations. In such cases there is significant risk of the ultimate loss of diversity, because small populations will lead to increased inbreeding principally in cross breeders which reduces the fitness of individual plants and hence may lead to extinction. One of the factors resulting in the loss of genetic variability is reduction in population size through the decline of plant number, so called bottleneck effect (Leberg 1992). Allozyme genetic diversity, inversions and visible mutations all declined more rapidly in smaller than large populations (Montgomery et al. 2000). Most probably, this resulted in a bottleneck effect over this population and consequently genetic diversity might have diminished, as revealed in allozyme variability.

Genetic erosion in farming systems of centres of crop diversity rested on two conjectures. First, it was believed that modern varieties would diffuse throughout in these systems. Second, it was thought that the adoption of modern varieties would lead farmers to stop planting of landraces (Brush and Meng 1998). Landraces replacement particularly in Hetosa and Tiyo were in agreement with these hypotheses. Much of the evidence for genetic erosion presented in the 1970/71 FAO survey (Frankel 1973) is data on the diffusion of modern cultivars rather than on the loss of local material (Kjellqvist 1973). Adoption of high yielding improved bread wheat varieties is the cause for the displacement of tetraploid wheat landraces. Unless durum wheat production is increased either vertically or horizontally, it is likely that shortages will occur as farmers adopt the high yielding bread wheat varieties (Bechere et al. 2000). Heisey and Brennan (1991) reported that most of the studies have come to a conclusion that yield (or yield potential) is the most important criterion for the choice of a variety by a farmer. As a result of a gradual decline in the amount and distribution of rainfall farmers are forced to shift from wheat crops like tef and sorghum, which are relatively more drought tolerant. According to Erskine and Muehlbauer (1990), droughts of just a single season could result in people consuming seed stocks, while successive years of drought can prompt changes in cropping patterns and the geographic distribution of crops. These changes in cropping patterns may also include the use of alternative, more drought resistant crops in preference to the traditional landraces. The study of Stephen et al. (2002) showed a marked reduction in rice diversity in the northeastern Philippines from 1996 to 1998 as a result of drought due to the El Niño phenomenon in 1997 and flooding due to two successive typhoons in 1998. Moreover, because of decline in soil fertility the productivity of tetraploid wheat landraces became low and consequently farmers were forced to grow that varieties or crops perform well with fertilizers unlike landraces that lodge when grown with fertilizers. Indigenous crops are adapted to the conditions of less developed agriculture. As these conditions change with improved traction and fertilizer, the existing adaptation of landraces turns from asset to liability (Harlan 1975). Traditional high-yielding cultivars adapted to optimal local agronomic conditions are probably the crop plant genetic resources that are most at risk of future loss from traditional societies through habitat destruction or by replacement by introduced elite germplasm (Brush 1995). Tunstall et al. (2001) described that landraces, which are grown because of their high resistance to pests during seed storage, may become less important if improved storage systems are introduced. Pesticide introduction could therefore erode landraces and farmers' knowledge of landrace pest resistance.

Farmers are interested to reintroduce more emmer wheat cultivation if they obtain high yielding and easily threshable varieties. However, little attention was paid to fulfil farmers' request. Most of the national and regional research institutions that are researching on wheat emphasize on hexaploid wheat. Tetraploid wheat like *T. polonicum*, *T. dicoccon* and *T. turgidum* are not in wheat research priority lists of most research centres. The promotion of bread wheat over tetraploid wheats is greater. The pro-improved varieties extension advice and credit facilities have motivated farmers to grow improved varieties so as to benefits from the associated credits. Tunstall et al. (2001) pointed out that the modern world is placing a range of pressures on wild areas and on traditional agricultural communities, and external interests (often dominated by economic or political issues) strongly impinge. The major external forces advocate the introduction of high-yield varieties, accompanied by mechanization and major chemical inputs, as the means to increase total production and economic return. These forces change the nature of the decision-making process dramatically; the farmer is encouraged to grow high-yield varieties in monoculture using inputs of fertilizer and pesticides. Similarly, Louette et al. (1997) reported that the fact that farmers were given several socio-economic incentives to replace varieties that evolved within their agro-ecosystem with improved/introduced varieties in many regions of the world.

Due to its large demand by the ministry, wheat, particularly bread wheat, ranks first in the priority settings of the Ethiopian seed industry agency seed multiplication and distribution scheme. Of the various crops for which improved seed was multiplied and sold by the agency, wheat remained the first since the last three decade (Eshetu 2002). It was also found that the local seed supply systems are vital enough to enable smallholder farmers to access improved seeds once it after was distributed by research centres and seed agencies. In Mexico, Louette et al. (1997) concluded that seed flow is high enough to mean that no farmer is planting seed stock bequeathed from parents.

In the *ex situ* genebank, the problem of insufficient passport data was observed. This affects not only the utilization of accession but also results in difficulties in planning where, when and which seed stock to rejuvenate and increase. It also affects the planning of effective collecting trips. The stock of seeds of some accessions in the genebank has been exhausted as a result of frequent requests but not having been replenished appropriately. Therefore, a strong differentiation should be made between the basic collections and the active collections so as to keep enough seeds. Because of financial reasons collections were made with low frequencies. This exposes the surviving tetraploid wheat landraces, which are under greater risk of replacement by improved bread wheat varieties or other crops, to further extinction particularly in areas where modern agriculture is expanding. As a result of financial problems, lack of staff and shortage of farms, rejuvenation of seeds were not being done as per scheduled. The long-term storage strongly reduces the metabolism and therefore highly limits viability and seed vigor. Considerable evidence indicated that damage to chromosomes, some of it resulting in heritable changes, takes place as seeds loose their viability. Studies in barley and wheat showed that as storage age increases, chromosome aberrations (per cell) increase (Gunhardt et al. 1953). Changes in the properties of DNA associated with loss of viability in rye seeds, namely the loss of DNA-template activity (Holden and Williams 1984) and decreases in the molecular size of extractable DNA (Cheah and Osborne 1978), also have been observed. Therefore, priority should be placed on securing and providing financial support to strengthen the inner structure of IBCR that guarantees the necessary genebank functions such as appropriate collection, maintenance, characterization and documentation of plant genetic resources.

In this study, one of the main challenges faced while dealing with genetic erosion is lack of reliable time series data, in the different district bureaus of MoA and research centers, about the number and areas of improved varieties being disseminated and adopted, which is very useful to analyze processes that took place over time. The absence of data on effective crop population area covered by tetraploid wheats both at regional and national level in the Central Statistical Authority was also the major problem to examine the trend in area and population size of these wheats. The authority yearly reports a summed figure for all wheats grown in each administrative regions of the country. Therefore, this problem should be solved to effectively monitor the periodic changes in tetraploid wheats genetic resources.

Although all parties in Ethiopia agreed that conservation of biodiversity is important, the predominant opinion among researchers and policymakers was that widespread adoption of green revolution technologies was absolutely necessary to ensure food security. However, introducing uniform cultivars with narrow genetic base into Ethiopia's wide range of microclimates, which can differ sharply from one village to the next, makes agricultural productivity extremely vulnerable to yield-limiting factors. Therefore, national agricultural policies should pay more attention to agricultural stability. A mechanism to link the different stakeholders should be devised. National food security strategies and policies on conservation should be harmonized. Policy should direct national, research and agricultural academic institutions to give priority to collaborative research on conservation issues. Mburu and Edilegnaw (2003) noted that effective coordination among the different sectors would eliminate the difficulties faced by extension agents trying to pass mixed messages to the farmers and hence enhance their participation in conservation initiatives.

NGOs are being contributing a lot to strengthen on farm conservation of landraces and thus special attention should be paid to guarantee the continuity of these activities particularly after the NGOs left.

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