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Original Research

On-Farm Diversity and Genetic Erosion of Tetraploid Wheat Landraces in Ambo and Dandi Districts, West Shewa, Ethiopia

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Abstract

The aim of the study was to document wheat landraces that were and still grown in Ambo and Dandi districts, West Shewa, Ethiopia; and to investigate the extent of genetic loss and its causes. Survey was carried out in three Peasant Associations of Ambo District and four Peasant Associations of Dandi District from 2007 to 2008. Three to five farmers' group per Peasant Association containing 5 to 12 individual farmers per group were used for group discussions from September to December, 2007; and a survey in 90 households was conducted using semi-structured questionnaire prepared by researcher from August to October 2008. In total 20 diverse tetraploid wheat landraces were identified in the study areas. However, presently 4 to 5 landraces are cultivated. Genetic erosion was 75% and 62% in Ambo and Dandi district, respectively. The landraces differ concerning morphology, adaptation and end-uses. Some landraces exhibit broad adaptation that enables them to be cultivated in a wider area over different districts. Specific adaptation to various soil conditions, e.g. water logging and poor soil fertility, and short rainy season play key roles for the predominant cultivation of specific landraces over others in sensitive environments. Preferences for end-use products and market prices also display major impacts on the continuous cultivation of tetraploid wheat. The causes for the loss of landraces varieties were expansion of improved bread wheat varieties, low soil fertility and poor yield of the landraces, and shorter rainy season. Among the available varieties, *kamadi-Dima*, is predominantly grown in both districts, due to its higher price in the market for its brewing quality. Diverse farmers' indigenous knowledge supported continued cultivation and conservation of landrace varieties.

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INTRODUCTION

Ethiopian wheat includes tetraploid and hexaploid species. Tetraploid wheats are indigenous, whereas hexaploid wheats are probably a recent introduction (Bechere *et al.*, 2000). The central Ethiopian highlands are the major durum producing region. The crop is traditionally grown by farmers on heavy black soils (udalfs) under rain fed conditions at altitudes of 1800–3000 m.a.s.l. and sometimes even above 3000 m (Perrino and Porceddu, 1990; Tesemma and Belay, 1991). Most tetraploid wheat varieties in Ethiopia are landraces which are often species mixtures (Eticha *et al.*, 2006).

Ethiopian farmers traditionally grow several varietal mixtures in the same field that might have advantage to add variety to their diet and reduce the risk of pests and diseases or unusual environmental conditions (Bekele, 1984). Jain (2000) also stated that the folk often continue to grow traditional even less productive cultivars and wild relatives, and, therefore, preserve cultivars and genetic diversity.

In Ethiopia, cereals such as wheat and barley farmers cut the upper part of the

culms and bundle it. The importance of this practice could be twofold: it may result in smaller amounts of weed seeds in the harvested seed and consequently in food and sowing seeds, and more importantly this helps to familiarize a farmer (or household) with the characteristics of the cultivars (Zeven, 2002). Farmers have built up knowledge of agriculture in general and of their crops and the methods of their cultivation and storage in particular and transferred this knowledge to next generations over millennia although they probably were often not well aware and did not write about their unique knowledge. However, old knowledge is lost because farmers adopt and adapt modern technologies (Zeven, 2000). Even today, it is evident that Ethiopian farmers are practicing traditional farming and their indigenous knowledge will continue and be passed to the coming generations unless some radical interventions are introduced. Ritualistic, symbolic and religious associations with bio-resources are more deep-rooted in cultures, than the material uses of genetic resources (Jain, 2000). The exploitation or protection of bio-resources, which is selective, influences the distribution, abundance and consequent availability, which in turn compels modification or substitution in plant or animal-man relationship. Thus, the analysis of the risk of loss of landraces, which represent wild populations, serves as the starting point for considering how the human factor may exercise its influence, and for the assertion that the human factor cannot be ignored (Tunstal *et al.*, 2001).

Knowledge about the level and extent of diversity in crops such as wheat conserved on-farm is of great value for sustainable maintenance and utilization of genetic material

(Kebebew *et al.*, 2001; Teklu and Hammer, 2006; Tsegaye and Berg, 2007a,b). Studies on the assessment of loss of landraces and exploring the reasons of genetic erosion are done in the centres of diversity such as Ethiopia. The objectives of the study were: (1) to document wheat landraces that once were or still are grown in Ambo and Dandi districts of West Shewa, Ethiopia; and (2) to investigate the extent of genetic loss and its causes.

MATERIALS AND METHODS

Study Area

The study was carried out in Ambo and Dandi districts, West Shewa, Ethiopia (Figure 1). Three Peasant Associations (PAs) including Awaro, Gosu-Kora, and Ya'i-Chabo and two Peasant Associations including Warka-Warabo and Boda-Bosoka in Ambo and Dandi district respectively were used for the study from September to December 2007. From August to October 2008, similar study was carried out in four PAs namely Awaro and Gosu-Kora in Ambo District and Awash-Bole and Haro-Dule in Dandi District.

The study areas are characterized by plain to gentle or sharp slopes. Some places are rugged, with high soil erosion problems, e.g. Ya'i-Chabo and Boda-Bosoka. Heavy black soils dominate in Awaro and Warka-Warabo, whereas clay sandy soils are dominant in Ya'i-Chabo. The two soil types differ especially in water holding capacity. Interestingly the adaptation of crops to these soil types also differs. Tef and wheat are widely adapted cereals to both soil types while barley is more adapted to sandy clay loam areas such as Ya'i-Chabo.

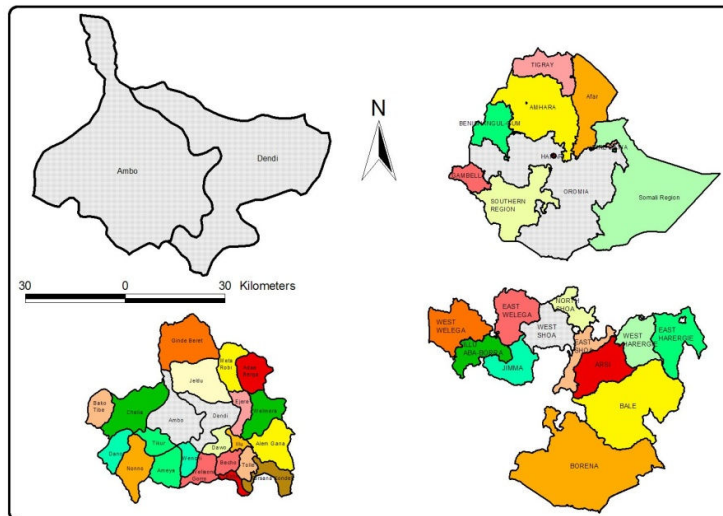


Figure 1: Map of Ethiopia (above right), Oromia (below right), West Shewa (below left), Ambo and Dandi districts (above left).

Methods of Data Collection

Group discussion

Exploration of on-farm diversity of wheat landraces was carried out for the first time from September to December 2007. A questionnaire concerning production and conservation practices by the farmers was prepared. Three to five farmer groups per PA containing 5 to 12 individual farmers per group were formed. Development agents from the districts' agricultural offices assisted in organizing the farmers in groups. Selection of farmers was not exclusively random in order to include different age groups and gender. Discussions were made among different groups of farmers following the questionnaire. Equal opportunities were given to both gender groups during group discussion. After thorough discussion, consolidated ideas were noted.

Household Survey

Based on the information from 2007, a total of 90 households study in four PAs was carried out from August to September 2008. Each household was interviewed following the questionnaire prepared by the researcher. Development agents from the Agricultural Development Office assisted and organized the farmers for interview in both districts. Purposive selection of farmers was done by using age as the simple index to identify farmers with more experience. Households with different age groups and wealthy classes were included. Farmers compared the situation of wheat landraces cultivated 20 to 30 years ago with present situations. In most cases the age of the interviewed farmers' was more than 35 years.

Statistical Analysis

Descriptive statistics was used to describe the data of both study years. The data is more of qualitative than quantitative and mainly ideas from the group discussions were used to explain the problems. The present status of on-farm genetic diversity (or genetic erosion) of wheat landraces was assessed using the formula of Hammer *et al.* (1996) and it is given as:

$$GE = 100\% - GI$$

where *GE* is genetic erosion and *GI* is genetic integrity which is given as:

$$GI = \frac{N_2}{N_1} \times 100\%$$

where N_1 is the number of landrace varieties collected in previous times and N_2 is the number of presently collected landrace varieties. According to the same authors the number of years between N_1 and N_2 is usually 3 to 5 decades. In the present study, the number of all listed varieties once grown by the farmers is considered as N_1 (20 to 30 years ago) and the number of presently available landrace varieties represents N_2 .

RESULTS

On-Farm Status of Wheat Landraces

A list of wheat landraces reported by the farmers is presented in Table 1. In total 20 landraces were listed by the farmers across the two districts. Sixteen and 13 landraces were listed from Ambo and Dandi, respectively, and some are common to both districts. Farmers of the study sites described the landraces based on morphological traits (e.g. maturity time, plant height, seed colour, glumes colour, awn length and colour, etc.), adaptation to biotic and abiotic stresses and end-uses. For instance, varieties such as *Kamadi-Dima*, *Biraye*, *Badag/Shalu*, and *Lucha* have purple coloured seeds. *Badag/Shalu* is a mixture of two varieties which are identified by the shape and size of ears. *Badag* has long and squared spikes whereas *Shalu* has short spikes. Wheat landraces also exhibit different seed size and shape. *Kamadi-Dima*, *Biraye*, *Badag/Shalu*, *Gofari* have large and elongated seeds, whereas *Hayibo* and *Magal-Sala* have large and semi-elongated seeds. Varieties such as *Barsadadi*, *Kaffelli*, and *Lucha* have small to intermediate and semi-elongated seeds. Farmers' varieties can also be grouped into different classes based on end uses, e.g. those mainly used for the preparation of different foods and snacks, and those used for the production of beverages.

Wheat landraces differ also in their reaction to diseases such as smut (*Ustilago* spp.) and rust (*Puccinia* spp.). *Hayibo* and *Lucha* are susceptible to rust, whereas *Magal-Sala* is susceptible to rust and smut, and *Badag/Shalu* is susceptible only to smut. Farmers expressed the problems in *Afan Oromo* (Oromo language) as "*Sanyiin kun dhukkuba waagii ykn awaroo qabdi*" which means that the respective variety has the problem of rust/smut disease. *Hayibo* and *Magal-Sala* are also susceptible to pre-harvest sprouting.

Table 1: Wheat landraces of Ambo and Dandi districts, West Shewa, Ethiopia.

<i>Wheat landraces</i>		
Ambo	Dandi	Common to Ambo and Dandi
Asnaka	Hayibo	Kamadi-Dima
Biranu	Magal-Sala	Biraye
Bataja / Butuji	Gofari	Badag / Shalu
Galane	Lucha	Kenya
Boroka		Kaffelli
Fitale (Dalati)		Barsadadi
Bushe		Goli-Hinga'u
		Bonde
		Boyido

Farmers reported further that it is easier to remove hulls from *Kaffelli* than *Barsadadi*, indicating that both are only partially free threshing. Moreover, the landraces differ in their nutrient demand. For instance, *Gofari* is usually grown on fertile soil while *Biraye* and *Badag/Shalu* are grown on less fertile soils. *Biraye*, however, is susceptible to water logging. *Kamadi-Dima* and *Lucha* are grown on all ranges of soil types. *Kaffelli*, *Barsadadi* and *Hayibo* are grown only on well-drained soils. *Bataja/Butuji* can be grown on fertile heavy black soils (udalfts) since it is resistant to water logging. *Galane* can be grown on all types of soil, however, it gives higher yield on fertile soils. Additionally, it is resistant to water logging. *Boroka* is less competent than others when a field is infested with weeds. Moreover, it is susceptible to diseases and can easily be broken when touched by animals due to a very soft stem.

Local Names of Landrace Varieties

Local or vernacular names of wheat landraces have their own meanings (Table 2). For instance, *Biranu* is named after its bright seed colour. *Butuji/Bataja* is named after its short and strong stem, usually resistant to lodging. *Hayibo* means 'cheese' that refers to bread and other food products made from the white flour with good taste. Likewise, *Magal-Sala* means purple awns but white seeds. *Galane* is named after its tall plant height. The vernacular names are important within farming communities to distinguish a variety from the other. Vernacular names are simple and easily understood by farmers. They are also important to maintain the identity of a variety.

Table 2: Examples of vernacular names of landraces and their meaning.

Local/ Vernacular name	Meaning
Kamadi-Dima	'Red/Purple wheat'; the name refers to the seed colour
Biraye	refers to the extreme earliness; it is adapted to well drained soils
Kenya	Most probably this variety is named after its original seed source.
Kaffelli	The word Kaffelli is strange in West Shewa communities. It is assumed that this variety was originally introduced from Italy
Hayibo	'Cheese'; refers to the end use quality
Magal-Sala	'Purple/black awned wheat'
Gofari	'Long awns'
Boyido	'Short awns'
Lucha	'Long awns'
Asnaka	'Better than others'
Biranu	'Bright/beautiful seed colour'
Galane	Refers to its tall plant height
Boroka	'Soft stem'
Goli-hinga'u	'No space to accommodate'; refers to high grain yield
Bataja/Butuji	Refers to the short and strong stem, and resistance to lodging
Fitale (Dalati)	'White and attractive seed colour'

Genetic Erosion

According to Brush (1999) genetic erosion may be defined as the global process under which landraces, previously adapted through thousands of years to different natural and man-made conditions are displaced by modern, mostly uniform and high-yielding varieties. In the present study, most tetraploid wheat landrace were replaced by improved wheat varieties. Genetic erosion was estimated for both districts systematically by exploring wheat landraces cultivated 20 to 30 years ago compared with the present situation. Genetic erosion was estimated for Ambo and Dandi districts as 75.0% and 61.5%, respectively (Table 3 and Figure 2). From 20 wheat landraces reported for both districts not more than four to five landraces are grown at present time. *Kamadi-Dima*, *Biraye* and *Bonde*

are still grown in both districts, while *Gofari* and *Kenya* are only grown in Dandi. The continuous cultivation of some landraces might be due to their unique end-use quality and wide adaptation to changing environments that is not obtained from other landraces or improved varieties. For instance, *Kamadi-Dima* is exclusively used for beverage and malt preparation (Figure 3). Some are adapted to low soil moisture because of their early maturity (e.g. *Biraye*) and are usually grown at the end of the rainy season on residual moisture. Other landraces with wide adaptation are more resistant/tolerant to pathogens and

pests. Due to its end-use quality *Kamadi-Dima* is also more expensive at the market and, therefore, worth to be cultivated by the highland farmers. The old tetraploid landraces were replaced by improved bread wheat varieties at a faster rate in both districts. Genetic erosion is not only a threat to crop species but also to the socio-cultural settings connected with the cultivation of this crop. Often both culture and beliefs support the conservation of the landraces, but once the landraces are lost the socio-cultural and religious values related to the cultivation of crops are no more existing either.

Table 3: Genetic erosion of tetraploid wheat landraces in Ambo and Dandi Districts.

Number of cultivated landrace varieties	District	
	Ambo	Dandi
Number of landraces recalled by the farmers grown before 2 to 3 decades	16	13
Number of landraces grown during 2007 and 2008	4	5
Genetic integrity (%)	25.0	38.5
Genetic erosion (%)	75.0	61.5

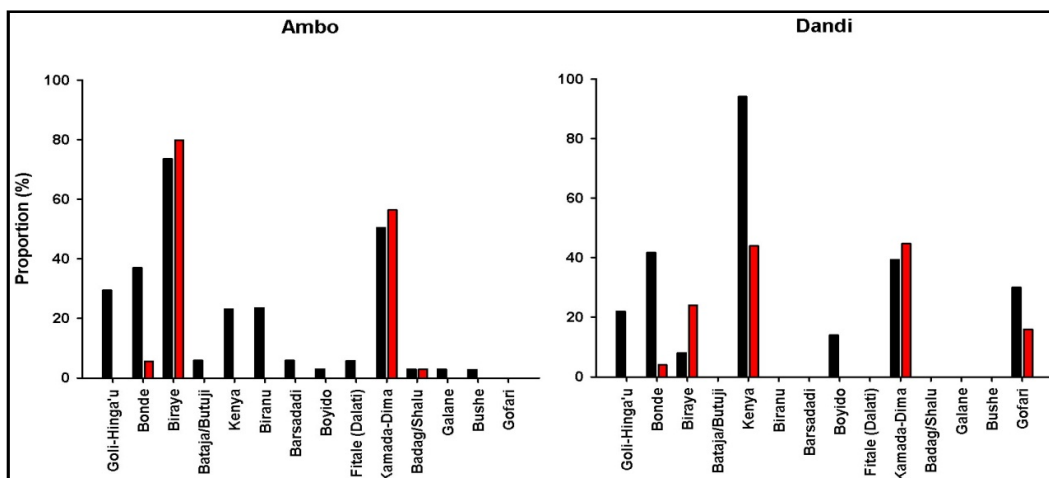


Figure 2: Proportion of households growing tetraploid wheat landraces before 2 to 3 decades (black bars) and in 2007 and 2008 (red bars) in Ambo and Dandi districts, West Shewa.

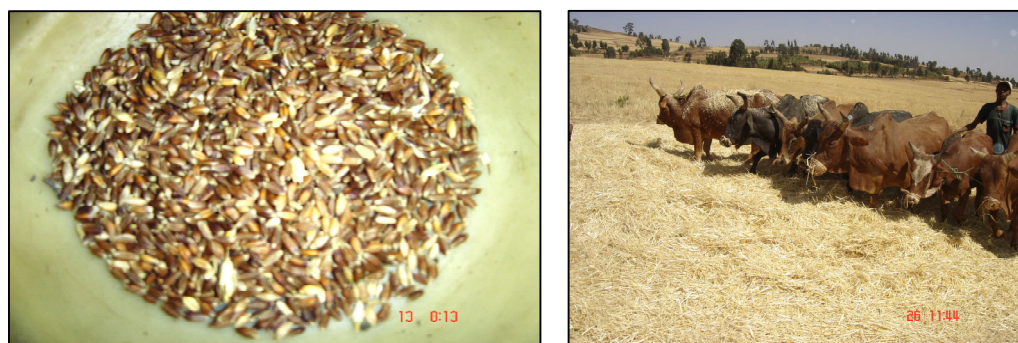


Figure 3: The popular purple seeded landrace variety '*Kamadi Dima*' and traditional wheat threshing using oxen in West Shewa.

Causes for the Losses of Landraces

Some causes of genetic erosion were identified (Figure 4, Tables 4 and 5). These included: (1) low yields of landraces and replacement by high yielding improved varieties; (2) climate change; rainy seasons are becoming shorter while old landraces are late maturing

types; (3) poor soil fertility and land degradation contributed to the abandonment of some landraces which demanded fertile soils (this was clearly seen in Ya'i-Chabo PA); (4) market price and demand (e.g. *Kamadi-Dima* has good demand and high prices in the market).

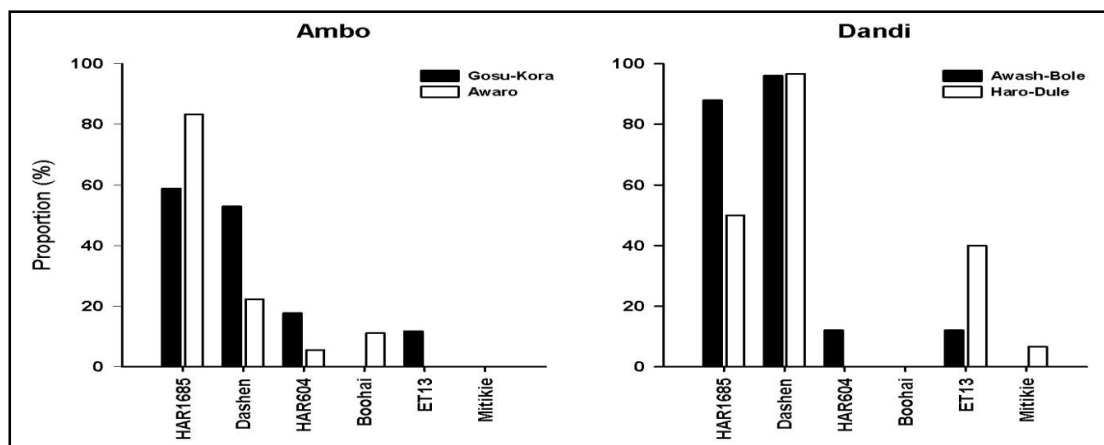


Figure 4: Proportion of households growing improved wheat varieties in Pas of Ambo and Dandi during 2007 and 2008. HAR1685, Dashen, HAR604, ET13 and Mitike are bread wheat varieties while Boohai is a durum wheat.

Table 4: Proportion of farmers citing different causes for changes in cropping system in Gosu-Kora and Awaro (Ambo).

Cause	Gosu-Kora (n=17)	Awaro (n=18)	Average
Market price and demand	65	78	71.5
Low productivity	94	72	83
Water logging conditions	0	17	8.5
Response to input	0	11	5.5
Food quality	35	17	26
Ease of processing	0	6	3
Maturity time	71	6	38.5
Availability of improved varieties	6	0	3
Climate change	18	83	50.5

Note: The percentage can add up to more than 100 since there are multiple answers per individual.

Table 5: Proportion of households citing different causes for loss of landraces in Awash-Bole and Haro-Dule (Dandi).

Cause	Awash-Bole (n=25)	Haro-Dule (n=30)	Average
Low productivity	92	100	96.0
Soil fertility / land degradation	64	93	78.5
Climate change	56	57	56.5
Lack of inputs	32	20	26.0

Note: The percentage can add up to more than 100 since there are multiple answers per individual

DISCUSSION

In the present study, wheat landraces recorded from different study sites in Ambo and Dandi districts indicated that once there were rich diversities. In total 20 landraces which were cultivated within the last 20 to 30 years were reported for the two districts. Tsegaye and Berg (2007a) identified 26 different landraces from two districts, i.e. Akaki and Lume, of East Shewa. The authors indicated that in Lume an on-farm conservation program was established with the aim of re-introducing landraces which became extinct in recent time. In the present study farmers used morphological traits, disease resistances, adaptation to different soil types and end-use quality to differentiate landraces. Seed colour is such an important morphological trait for differentiation. Purple grain colour was originally only found in cultivated tetraploid wheat landraces of Ethiopia (Zeven, 1991). Belay *et al.* (1995) reported purple grains in all Ethiopian tetraploid wheats with the exception of *T. dicoccum*. Less frequent this trait appears in *T. polonicum*, whereas it is frequent in *T. carthlicum* and *T. durum*. In the present study, the farmers reported that two landraces, i.e. *Barsadadi* and *Kaffelli*, are hulled and/or partially free-threshing. This gives indication that there might be some gene introgression from *T. dicoccum*. According to Feldman (1976) *T. dicoccum* was the first tetraploid wheat introduced to Ethiopia. Today, it is not widely cultivated except in some marginal areas (D'Andrea and Haile, 2002).

The landraces exhibited different nutrient demands. Some are adapted to less fertile and poorly drained soils, whereas others need fertile and well drained soils. Moreover, the landraces exhibited differential responses to diseases and pests (e.g. susceptible to resistant types). In wheat breeding history Ethiopian tetraploid wheat landraces were often used as sources of earliness, disease and pest resistance, nutritional quality, resistance to drought and other stresses, adaptation to low soil fertility and other characteristics useful in low-input agriculture (Worede, 1997).

Some of the landraces are common to both districts. Ambo and Dandi are neighbouring districts. People living there share common socio-cultural settings and believes. For example *Kamadi-Dima* is grown in both districts because of its unique end-use, i.e. preparation of malt and beverages. Therefore, this landrace reaches high prices at the market. Transfer of landraces from one place to another is done by (1) gifts among relatives, (2) purchase from market, (3) by

migration of people in search for fertile land, free land or other social aspects. In Ethiopia it is common to find households moving from one place to another in search for fertile farming land, relatives etc. Landraces are often more stable and adapted to wider areas compared to improved varieties. Tesemma *et al.* (1993) stated that Ethiopian wheat landraces are usually mixtures of different agro-types having wider gene pools within one population that can buffer the change of climatic and edaphic factors. Eticha *et al.* (2006) also reported mixtures of five tetraploid wheat landraces and hexaploid wheat in varying proportions in one population of germplams collected from Bale and Welo regions. The species mixtures/agro-types might have an advantage for the farmers when grown in the same field: to add variety to the diet and, on the other hand, to carry diverse genes for disease and pest resistances and adaptability to changing climatic factors (Bekele, 1984).

In the present study, most of the tetraploid wheat landraces were either totally abandoned, or marginalized within the last decades. The most serious cause of genetic erosion is the wide adoption of improved common wheat varieties by the farmers, although there are also other factors like expansion of other crops like tef, low productivity of landraces, climate change, long maturity time of landraces, diseases, and reduced land size, etc. Already Baur (1914) warned about genetic erosion but it was ignored for about 2 decades until the American 'plant explorers' Harlan and Martini (1936) were credited with first recognizing the problem (Hammer & Laghetti, 2005). Worede (1997) reported the seriousness of genetic erosion of wheat landraces and barley in Ethiopia that might be caused by different factors such as drought, famine, expansion of other crops and improved seeds (improved hexaploid wheat) etc. Similar losses of tetraploid wheat landraces as in the present study were recorded by other researchers (Tsegaye, 1997; Teklu and Hammer 2006; Tsegaye and Berg 2007a) in different parts of Ethiopia, indicating that this species are in danger. Genetic erosion within and between crop species is a worldwide problem and it is mainly related to modern agriculture, whereby uniform and high yielding varieties are grown on large scale and replaced the landraces. In addition, climate change and drought, fire, war, etc. are some other causes of genetic erosion. Shewayrga *et al.* (2008) reported genetic erosion in sorghum for north-eastern Ethiopia caused by declining soil fertility, frequent drought and unreliable rainfall, and increased pest infestations. The authors reported that landraces

that are less preferred in terms of agronomic value and end-use, introductions have become increasingly important while late maturing types were found to be vulnerable to genetic erosion. Mekbib (2008a) reported genetic erosion in sorghum for eastern Ethiopia caused by reduced benefits from the varieties, drought, khat expansion, reduced land size and introduction of other food crops. In the present investigation drought, fire, and war are not factors for genetic erosion. Reduced soil fertility, reduced land size and expansion of improved common wheat varieties are the major causes. However, other researchers (Teklu and Hammer, 2006; Tsegaye and Berg, 2007a) reported drought as one factor of genetic erosion in tetraploid wheat landraces especially in eastern part of Ethiopia.

Several scientific papers reviewing or investigating genetic erosion in crop species in different countries are available. Oliveira and Martins (2002) estimated genetic erosion of ipecac (*Psychotria ipecacuanha*), a medicinal plant in Brazil. Hammer *et al.* (1996) studied genetic erosion in cereals, vegetables, pulses and other crops in Albania and South Italy. In developing countries like Ethiopia the situation is worse since the *ex-situ* collections are not exhaustive. Moreover, some of the accessions conserved *ex-situ* lack sufficient data (Teklu and Hammer, 2006). Moreover, there are indications in the Ethiopian Gene Bank that some durum wheat landraces have lost vigour when planted in the field; and seeds for some accessions in *ex-situ* were exhausted because of requests by different institutions for research and breeding (Teklu and Hammer, 2006). Fast and huge conservation measures are necessary to protect the landraces before they are lost forever. Hammer and Laghetti (2005) calculated a genetic erosion rate for cereal, pulses and vegetables in Italy. It was high (13.2%) in early times, from 1920 to 1950, and it was low (4%) in late times, from 1950 to 1980. After the 1950s, people became aware of losses of agro-biodiversity and they tried to protect the landraces. In the late 1920s N.I. Vavilov explored Ethiopia and he was amazed by the high genetic diversity in wheat landraces particularly in durum wheat and barley. This is an indication how loss of agro-biodiversity is going fast unless strong attention is given to protect these landraces from vanishing forever.

CONCLUSIONS

Dandi and Ambo districts are among the major tetraploid wheat cultivation zones of western Ethiopia. Generally, the farmers in both districts recalled 20 wheat landraces. However, presently

4 to 5 landraces are cultivated. Therefore, genetic erosion in tetraploid wheat reached greater than 60%. This calls for due attention of every stakeholder in order to stop biodiversity degradation. The loss of landraces was accounted to different causes. These included the expansion of improved bread wheat varieties, low soil fertility and poor yield of the landraces, and short rainy season period since most landraces are long maturing types. Among the available varieties, *kamadi-Dima*, is predominantly grown in both districts due to its high brewing quality and higher price in the market.

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