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Review Article

Review on Genetic Erosion of Barley (*Hordeum vulgare* L.) in the Highlands of Ethiopia

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Abstract: Ethiopia is a center of origin and diversity of many cultivated crops and their wild relatives including barley. The richness and range of genetic diversity in Ethiopia, particularly of landraces, is currently subject to serious genetic erosion and irreversible losses due to the changing nature of agricultural production. In this review, the most important factor possibly leading to genetic erosion is the replacement of FV's by modern cultivars followed by weather variability. Barley, as a food and feed grain, is important to the livelihood of farmers. A number of previous studies have shown higher level of barley diversity in the highland of the country. Traditional barley variety is suffering serious genetic erosion due to displacement by introduced varieties. Knowing the causes of genetic erosion is equally important for devising conservation measures. In conclusion, the use of genetic resources will remain the best way of meeting future food needs and driving the economic and social benefits for the world's rapidly growing human population.

Keywords: Genetic Diversity, Genetic Erosion, Highland, Land race.

1. INTRODUCTION

Ethiopia is a diverse country in terms of altitude, temperature, rainfall and soil types. One can sense such diversity within a short distance in a given locality. Such diversity of environmental elements was the cause for the existence of diverse vegetation, crop species and farmers' varieties of crops that are observed in farmers' fields in most parts of the country (Vavilov, 1951). Ethiopia is the center of origin and diversity for many cultivated crops and their wild relatives. The country is located near Equator, but due to higher altitude, it experiences a temperate climate, especially at altitudes of more than 2000 meters above sea level. In addition, soil variation, ecological diversity, substantial temperature and rainfall variations, diverse social and cultural conditions are some of the possible explanations for the existence of tremendous genetic variation of crop varieties in the country. The diversity in plants is the basis for food and other human needs for millennia and it continues to do so for the development of plant characters useful to human needs.

Barley is one of the major cereals grown in the wide agro-ecology of the country with its economic and social importance. It is cultivated from 1,400 m above sea level to over 4,000 m a.s.l., and it has adapted to specific sets of agro-ecological and microclimatic regimes throughout the country (Asfaw, 2000). Landraces represent over 90% of the barley cultivated in Ethiopia. In contrast to the genetic uniformity of modern cultivars, landraces show variation both between and within populations. This within-population diversity of these barley landraces might allow them to cope with environmental stresses, which is very important for achieving yield stability (Zhu *et al*., 2000). In Tibet, Nepal, Ethiopia and the Andes, farmers cultivate barley on mountain slopes at altitudes higher than any other cereals (Matz, 1991). The diversity of barley ecologies is high, with a large number of folk varieties and traditional practices existing in Ethiopia, which enables the crop to be more adaptable in the highlands (Fekadu *et al*., 2002).

Barley cultivation and use in Ethiopia is unique in that in no other country the crop is grown in environments so diverse in terms of altitude, rainfall, soil and farming systems. The major barley growing regions are West Arsi, Arsi, South Tigray, North Gonder, North Shewa, West Shewa and Bale (CSA, 2017). This indicates wide ecological and physiological plasticity throughout the country (Asfaw, 2007). The major use of barley includes human consumption, in malting processes and feed (Harlan, 2008). Barley grain mainly consists of carbohydrates, proteins, and lipids (Horsley and Hochhalter, 2004). It is the fifth most important cereal crop after *tef*, wheat, corn, and sorghum. It is the staple food grain especially for

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Ethiopian highlanders who produce the crop with indigenous technologies (Abu, 2013). Its grain accounts for over 60% of the food of the people in the high lands, for whom barley is one of the main sources of calories.

Landraces are the major genetic resources of cultivated barley in Ethiopia (Lakew and Assefa, 2011). Landraces are still the backbone of agricultural systems in many developing countries, mainly in marginal environments and are characterized by high genetic heterogeneity, good adaptation to local environment conditions and by low productivity (Ceccarelli and Grando, 1996). It is reported that over 80% of the barley produced in Ethiopia is derived from landrace varieties (Alemayehu and Gebre, 2010). Landrace improvement has long been recommended as a strategy for crop improvement (Qualset, 2010) but modern agriculture has lagged behind in this regard (Asfaw, 2007). Barley landraces are reported to have better adaptation and useful traits like vigorous seedling establishment, high tillering capacity, quick grain filling period, high seed weight and resistance to shoot fly, aphids and frost (Berhane *et al.*, 2006). Besides this, the unique features of Ethiopian barleys have been realized since a long time and have played a prominent role in breeding programs worldwide as source of genes for resistance against diseases and viruses (Harlan, 2008).

Genetic erosion is defined as the loss of variability from crop populations in diversity centers, that is, areas of domestication and secondary diversification (Brush, 1999). Hammer *et al*. (1996) defined it broadly as the loss of particular local landraces expressed as the ratio of the number of landraces currently available to their former number. The term “genetic erosion” is sometimes used in a narrow sense, that is, the loss of genes or alleles, as well as more broadly, referring to the loss of varieties (FAO, 1998). It is a process acting both on wild and domesticated species. It is also both natural and manmade. Naturally, it occurs when there is inbreeding between members of small population that will reveal deleterious recessive alleles. It causes a population “bottleneck” by shrinking the gene pool or narrowing the genetic diversity available. This natural process could be the cause for the losses of heterozygosity that reduces the adaptive potential of every population (Caro and Laurenson, 1999). In cultivated plants, genetic erosion is the loss of variability from the population, that is, the loss of heterogeneity of alleles and genotypes with their attendant morphotypes and phenotypes. The American plant explorers are credited for first recognizing the problem of genetic erosion in crops (Harlan and Martini, 1936).

In Ethiopia, traditional barley and durum wheat varieties are suffering serious genetic erosion due to displacement by introduced varieties (Friis-Hansen, 1999).The reduction in the area under barley in the recent past could be attributed to a number of factors, including that most of the area under barley is sown to farmer cultivars. These produce poor yields and have been in the environment for centuries, and often show significant morphological diversity.

Zemede Asfaw (1996) recorded up to 12 distinct morphotypes from a single barley field. There is low productivity in farmer barley cultivars compared with bread wheat, the latter having been very recently introduced. Wheat has given significantly higher yields than local barley cultivars in the same niche, where barley has been in production for millennia. The Ethiopian Seed Enterprise (ESE) has not sufficiently emphasized the multiplication and distribution of seeds of improved barley varieties (Zewdie *et al*., 2008). Moreover, extension work on the promotion of improved barley varieties in major barley-growing areas in the country has been very poor compared with that of bread wheat and maize. Fertilizer use on barley is the lowest among all the cereals. The current study is therefore, formulated to review the extent of genetic erosion of barley and the important factors possibly leading to genetic erosion.

2.1. Barley: Origin, Taxonomy and Distribution

Barley *(Hordeum vulgare* L.) belongs to the genus *Hordeum* of the tribe Triticeae of family Poaceae (Gramineae). The genus, *Hordeum*, has 31 species distributed over wide geographical areas and diverse ecological habitats (Kling and Hayes, 2009). Barley is a diploid species with a chromosome number of 2n=14 (Kling and Hayes, 2009). Barley is recognized as one of the oldest crops, and is believed to have originated in the Fertile Crescent Region some 8,000 to 10,000 years ago (Harlan, 2008). The Fertile Crescent includes parts of Jordan, Lebanon, Palestine, Syria, Southeastern Turkey, Iraq and Western Iran. The progenitor of cultivated barley is *H. vulgare* ssp. *spontaneum* – wild barley which has no crossing barriers to the crop (Asfaw & Bothmer, 1990). According to the genepool concept of Harlan and de Wet (1971) *H. vulgare* ssp. *spontaneum* belongs to the primary barley genepool. All other *Hordeum* species, except *H. bulbosum* (secondary genepool) belong to the tertiary genepool.

Ethiopia was first considered to be a center of origin for cultivated barley (Vavilov 1926); although later it became regarded as a secondary centre of diversity because of the absence of the wild relative (Vavilov 1951). Although Ward (1962) acknowledged the secondary nature of the Ethiopian center, some authors still claim Ethiopia as a centre of origin for cultivated barley based on the existence of very high phenotypic diversity (Negassa, 1985) and flavonoid patterns (Bekele 1983). Moreover, based on archaeological and historical studies, it has been suggested that in Ethiopia barley was cultivated as early as 3,000 BC (Brandt 1984), probably after being introduced from Asia (Harlan 1969). Recently, Orabi *et al*. (2007) studied barley accessions from three continents according to nuclear, chloroplast SSR markers, and a 468-bp fragment from the non-coding region of chloroplast DNA. They observed clear separation between Eritrean/ Ethiopian barley and barley from West Asia and North Africa, as well as from Europe, concluding that the wild barley as it is found today in the Fertile Crescent might not be the progenitor of the barley cultivated in Eritrea (and Ethiopia). However, whether or not Ethiopia is a centre of origin for cultivated barley, a series of endemic varieties have indeed originated there (Asfaw 1996).

2.2 Distribution and Importance of Barley in Ethiopia

Ethiopia, with its diverse agro-ecological and climatic features, is well known for being one of the 12 Vavilovian Centers of Diversity (Harlan 1969; Vavilov 1951). The altitudinal variation which ranges from 110m below sea level in areas of Kobar Sink to 4,620 m.a.s.l. at Ras Dashen (IPGRI 1996), temperature and rainfall differences coupled with edaphic factors create a wide range of ecological conditions in the country. This complex topography and environmental heterogeneity provide sustainable environment for a wide range of life forms. As a result, Ethiopia is considered as one of the richest genetic resources centers in the world. According to (Lakew *et al*., 1996) Barley can be cultivated at altitudes between 1500 and 3500m, but is predominantly grown between altitudes of 2000m and 3000m. This wide distribution demonstrates the wide ecological amplitude throughout the country. As reported by CSA (2017) highlands of West Arsi, Arsi, South, Tigraye, North Gonder, North Shewa, West Shewa and Bale are major producers of barley where about 85% of the total production comes from. Barley is the major staple crop and is deeply rooted in the socio-cultural lifestyle of the Ethiopian communities (Eticha *et al.*, 2010).

Kemelew and Alemayehu report that among the major cereals, barley ranks fifth in area, productivity and total production in Ethiopia, as a whole it matures early and an emergency crop bridging the critical food shortage occurs in September (Kemelew & Alemayehu, 2011). Barley accounts for over 60% of the food of the people in the high lands of Ethiopia. It is used in diverse recipes that have deep roots in culture and tradition. Some recipes such as *Besso* (fine flour of well-roasted barley grain moistened with water, butter or oil), and *Chiko* (*besso* soaked with butter alone), which have long shelf life, can only be prepared from barley grain. Other recipes, such as *Genfo* (thick porridge), *Kolo* (de-hulled and roasted barley grain served as snack), and *Kinche* (thick porridge) are most popular when made from barley grain, but can be prepared from other cereals also. Barley is the preferred grain, after *tef*, for making the traditional bread called *Injera*, which can be used either solely or in combination with *tef* flour or other cereal flours. Other recipes, such as *Dabbo* (bread), *Kitta* (thin, unleavened, dry bread) and *Atmit* (soup) can be prepared with only barley or blended with other cereal flours.

Among local beverages *Tella* and *Borde* are prominent, and best made from barley grain (Grando, 2005). Its straw is a good source of feed and the stem stubbles and straw can be used for roof thatching and bedding materials (Kuma *et al*., 2011). In Ethiopia, barley-growing areas gradually diminish due to the expansion of wheat and rye cultivation in some regions. Currently the crop is pushed to marginal areas (to very high altitudes where frost prevails) and threatened by genetic erosion (IBC 2007).

2.3 Genetic Diversity of Barley in Ethiopia

Genetic diversity is one of the three pillars of biodiversity, diversity within species, between species and of ecosystems (CBD, Article 2), which was defined at the Rio de Janeiro Earth Summit as the variability among living organisms from all sources including, interalia, marine and other aquatic ecosystems and the ecological complexes of which they are part. A number of previous studies have shown higher level of barley diversity (Bekele, 1983**)**. Alemayehu & Parlevliet (1997) have shown that the variation within Ethiopian barley landraces is largely overlapping between landraces. Due to this overlap, the authors suggested that the collection and maintenance of genetic variation within a region should be carried out at the crop level rather than at the individual landrace level. Asfaw (2000) reported a higher level of barley diversity in southern Ethiopia but this was not well studied and documented. Landraces need to be evaluated, characterized and properly documented so that well-defined sets of samples with specific combinations of desirable traits can easily be retrieved and used in breeding programs.

Tesema *et al*. (2009) have evaluated 106 landrace populations in the two growing seasons (*Meher* and *Belg*; the long and short rainy seasons, respectively), and reported that the divergence was very low between seasons and geographical districts, while it was high between different classes of altitude. Adugna (2011) studied 15360 accessions of the gene bank; the observations showed that gradients in altitude and differences in agro-ecology also influenced diversity variation in barley. Shumet Tenaw and Tesema Tanto (2014) studied a total of 43 land race populations from Gamo highlands and they reported that barley land race population showed an average diversity index of 0.59, implying large population diversity for the populations and showing that barley land races from Gamo highlands were constituted by highly variable land races that had large within population diversity. According to Tesema Tanto and Abebe Demissie (nd) high variation of barley was observed in Tigray, Shewa, Arsi and Bale regions. Shewa, Arsi and Bale regions have the highest variation for barley.

2.4 Status of Genetic Erosion in Ethiopia

Ethiopia is known as a centre of genetic diversity and origin for a number of cultivated and wild plants (Vavilov, 1951; Harlan, 1969). The richness and range of genetic diversity in Ethiopia, particularly of landraces, is currently subject to serious genetic erosion and irreversible losses due to the changing nature of agricultural production. Widespread adoption of modern varieties, technological change (such as use of fertilizer and irrigation), land use change, habitat destruction, and drought, among other important factors have lowered the demand for landraces adapted to marginal growing conditions in Ethiopia (Melaku Worede and Hailu Mekbib, 1993). Harlan (1931) sounded the first alarm about the loss of crop diversity caused by modern agriculture. The loss of landraces is a big concern, and hence preservation of crop genetic diversity is essential, since they are potential sources of materials for modern plant breeding, stability in crop production, and for resistance to biotic attack. They are important in more marginal and diverse agricultural environments, and with the advent of plant variety protection (Tripp and van der Heide, 1996). The extent to which native seeds are displaced varies between regions and crops. Native barley is probably among the crops most threatened by market-oriented products in the highlands of Shewa, Arsi and Bale regions; similarly in the central highlands, including northern Shewa and Gojam. Strategies are urgently needed to address conservation of particularly the native plant genetic diversity before it is forever lost.

2.5 Genetic Erosion of barley

More than 30 years have passed since the scientific community raised the alarm about genetic erosion. Jack Harlan (1975) used this term in the early 1970s to describe a potentially disastrous narrowing of the germplasm base employed in improving food crops. A dramatic decrease in diversity in a cultivated crop could bring serious consequences, since genetically uniform cultivars grown over vast areas are susceptible to devastating epidemics (Baker *et al.*, 1997). The classic example of this is the Irish potato famine of the mid-19th century or the coffee rust epidemic in Ceylon in the 1870s. More recent examples include the southern corn leaf blight epidemic in the USA in 1970 (Browning, 1988) and the mould epidemic on tobacco in the USA and Europe in the 1960s (Marshall, 1977). The variation is essential for the future breeding material, since a decrease in genetic variability in general might result in a reduction in the plasticity of the crop to respond to any environmental changes and agricultural practices (Manifesto *et al*., 2001).

Some studies did show evidences of a decrease in genetic diversity during the process of barley domestication (Provan *et al*., 1999). The replacement of landraces by modern varieties was also an important factor contributing to genetic erosion (Hammer *et al*., 1996). There is a concern about a continuous decrease in genetic diversity due to the narrow genetic base of the European barley germplasm (Melchinger *et al*., 1994). To date, a number of studies have been performed to evaluate the changes in genetic diversity in barley due to plant breeding. However, these show different results depending on the country or region of origin of analyzed material. In some cases differences were also shown when different methods for evaluation were used. For example, Reeves *et al*. (2004) in their European barley study found just a temporal flux of genetic diversity without detecting genetic erosion, similar to the results of Koebner *et al.* (2003) studying UK barley. Matus & Hayes (2002), on the other hand, in material from Busch Agricultural Resources barley improvement programme and Russel *et al*. (2000) in European spring barley detected a lower diversity level within modern material.

2.5.1 Genetic Erosion of Barley in Ethiopia

In Ethiopia, native barley varieties are suffering serious genetic erosion (Worede *et al*. 2000). Genetic erosion of crops and their wild relatives is accelerating at a high rate because of human activities in Ethiopia (Mekonen, 1997). The recurrent drought in the past decades has eroded considerable amount of biodiversity in the country. Furthermore, less is known about the causes and the degree of genetic erosion on local varieties of crop plant species or list of varieties/species lost in various parts of the country. Knowing the causes of genetic erosion is equally important for devising conservation measures. Likewise, identifying local crop varieties and associated wild relatives that are lost or are on the verge of extinction, play crucial role in designing and implementation of conservation policies.

The following studies provide some further examples of genetic erosion in landraces in specific areas within countries. Leur and Gebre (2003) reported that the cultivated area of a number of traditional barley varieties is declining rapidly. On the other hand, plot allocation for improved barley, wheat, potato and faba bean gradually increased. Eticha *et al.* (2010) reported high on-farm loss of 71% of barley landraces in the highlands of West Shewa and climatic changes, the degradation of soil fertility, the destruction of ecosystems and habitats, and changes in the farming system induced by research and extension interventions were the major causes for the loss of genetic diversity in barley landraces. Girma (2014) assessed erosion in barley in North Shewa zone of Ethiopia recording a loss of 65% of landraces between 1994 and 2010, attributed to introduction of improved varieties and other crops, recurrent drought, changed land use pattern, and lack of policy support. In two districts in the highlands of West Shewa, of 14 barley landraces.

2.6 Consequences of Genetic Erosion

Genetic uniformity leaves a species vulnerable to new environmental and biotic challenges and causes heavy damage to the society. The Irish Potato famine was a dramatic example of the dangers of genetic uniformity. By 1970 roughly three-quarters of the corn acreage in the US was planted in “Texas T cytoplasm” corn. The Texas T cytoplasm results in individuals that are male-sterile. This makes production of hybrid corn far less labor intensive, as there is no need of detassleing. However, this maize is highly sensitive to host selective toxin (T toxin) produced by race T of *Cochliobolus heterostrophus*, the casual organism of southern corn leaf blight (Hooker *et al.*, 1970). In 1970, this blight swept through fields of “Texas T cytoplasm” corn and yield was reduced by approximately 710 billion bushels. Browning (1988) argued that the epidemic was “the greatest biomass loss of any biological catastrophe” and that it was “a man-made epidemic caused by excessive homogeneity of the USA’s tremendous maize hectares.’ The loss of a significant fraction of the Asian rice crop to grassy stunt virus also illustrates the same point. The catastrophic outbreak of coffee rust in 1970 caused great losses in Brazil with higher coffee world market prices.

In 1916, a rust fungus destroyed about 3 million bushels of wheat in the United States, roughly one-third of the crop. Other examples include the coffee rust epidemic in Ceylon in the 1870s, the tropical maize rust epidemic in Africa in the 1950s and the blue mould epidemic on tobacco in the USA and Europe in the 1960s (Marshall, 1977). The loss of one species is estimated at being worth $203 million (Farnsworth and Soejarto, 1985). These authors have calculated a total financial loss for the USA through the loss of plant species at $3,248 billion dollars up to the year 2000. Presently, 33,730 plant species are characterized as being extinct or strongly endangered (Lucas and Synge, 1996).

3. SUMMARY AND CONCLUSION

Ethiopia is a center of origin and diversity for many cultivated crops and their wild relatives. Due to altitudinal variation, it experiences a temperate climate, especially at altitudes of more than 2000 meters above sea level. In addition, soil variation, ecological diversity, substantial temperature and rainfall variations, and diverse social and cultural conditions have produced suitable environments for genetic variation of crop varieties.

Genetic erosion in cultivated crop species is a complex process. As found in this review, the most important factor possibly leading to genetic erosion is the replacement of FV’s by modern cultivars followed by weather variability. The high on-farm loss of 71% of barley landraces has been reported by different studies. Climatic changes, the degradation of soil fertility, the destruction of ecosystems and habitats, and changes in the farming system induced by research and extension interventions are the major causes for the loss of genetic diversity in barley landraces.

Barley, as a food and feed grain, is important to the livelihood of farmers. It was reported that farmers’ beliefs and social and cultural situations have strong linkages with foods and drinks made from barley. The wealth of traditional sayings, poems and songs gives a picture of the importance of local barley in society’s daily life and growers show their feelings and expressions linked with barley production. Therefore, farmers’ participation in barley improvement is very important in order to use their indigenous knowledge for the conservation of varieties and share their socio-cultural preferences. Attention should be given to on farm conservation and enhancement of farmers’ varieties. In conclusion, the use of genetic resources will remain the best way of meeting future food needs and driving the economic and social benefits for the world’s rapidly growing human population. Thus, policy makers and researchers should give attention to conservation of FVs and indigenous knowledge of farmers for better use of genetic resource.

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