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# Review on Barley Breeding and its Status in Ethiopia

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**Abstract:** *In spite of the importance of barley as a food and feed crop in Ethiopia and the efforts made so far to generate improved production technologies, its productivity has remained very low (about 1.3 ton/ha) compared with the world average (2.4 ton/ha). This is primarily due to the dominant use of low yielding farmers varieties; the influence of several biotic and a biotic stresses; and the minimal promotion of improved barley production technologies. Complex physiological responses to drought, various environmental factors, and their interactions, have slowed the development of improved cultivars for drought-prone environments. To facilitate the improvement of the Ethiopian barley collections activities like characterization and purification of the mixed collections; evaluation of the landrace collections in drought-prone and ideal environments; study of the traits that have a strong correlation with high yield should be performed. Therefore, future barley research should consider both specific and wide adaptation for stress breeding. If barley research is to be more viable and to progress systematically this effort must be supplemented with the molecular marker-assisted selection with the continuous study of the quantitative trait loci (QTLs) controlling the biotic and a biotic stress resistance /tolerance traits. The process ranging from the identification of appropriate resistance donors to the development of a selectable marker requires the collaboration of barley breeders with other disciplines.*

**Keywords:** *food barley, genetic resources, breeding for quality, stress breeding.*

## 1. INTRODUCTION

Barley belong to the genous hordium in the tribe *Triticeae* of the grass family, *poaceae* or *gramineae*. The genus *Hordeum* is unusual among the *Triticeae* as it contains both annual species, such as *H.vulgare* and *H. marinum*, and perennial species, such as *H.bulbosum* (Von Bothmer 1992). Barley is one of the most important staple food crops in the world which ranks fourth next to wheat, rice and maize. It is thought to have originated in the Fertile Crescent area of the Near East from the wild progenitor *Hordeum spontaneum* and it was introduced by Europeans to the New World in the sixteenth and seventeenth centuries. Barley is a cool season, most dependable and early maturing cereal crop with relatively high yielding potential in diverse agro-ecologies including marginal areas where other cereal crops are not adapted (Martin *et al.*, 2006). Barley can be cultivated at altitudes between 1500 and 3500 m.a.s.l, but it is predominantly grown between altitudes of 2000 to 3000 m.a.s.l in Ethiopia (Berhane *et al.*, 1996).

Barley is grown in more than 100 countries globally; over 133 million ton of barley is produced annually on about 55.4 million hectares, with productivity levels at around 2.4 ton/ha. Through the last four decades Europe has led the world in barley production followed by North and Central America and Asia while Africa, South America and Oceania have not exceeded 11 million ton. The highest productivity is attained in France (6.3 ton/ha), whereas national production is greatest in Russia (Mulatu, B. and Grando, S., 2011).

Barley farming holds a unique place in Ethiopia, and various sources agree that it has been in cultivation for at least the past 5000 years in the country. The first Ethiopians to have ever cultivated barley are believed to be the A gew people, in about 3000 BC (Zemede, 1996). In Ethiopia, barley is the fifth most important cereal crop after teff, wheat, maize and sorghum and it covers 1,018,752.94 hectare of land with 1,781,652.208 ton of annual production. The crop is produced in all regions, however more than 85% of total production comes from Shewa, Gojam, Arsi, Gonder, Wollo and Bale (Adugna Abdi, 2008).

In Western countries, barley is increasing in popularity as a food grain and is used in flours for bread making or other specialties such as baby foods, health foods and thickeners. Barley grain consists of mainly carbohydrates, proteins, and lipids(Akar et al. 2012).About 415 million people have diabetes in the world and more than 14 million people in the Africa Region; by 2040 this figure will more than double. Ethiopia is one of the 32 countries of the International Diabetes Federation (IDF) African region. Over 1.33 million people have been caused by diabetes in Ethiopia (IDF, 2015). Therefore, evidence from observational studies indicates that diets rich in whole grains like barley reduce risk of obesity and other diseases related to the metabolic syndrome e.g. type 2 diabetes and cardio-vascular disease.β-glucans have been implicated in lowering plasma cholesterol, improving lipid metabolism, reducing glycaemic index and the risk of colon cancer ( Keenan et al., 2007 ). Even more Barley β-glucans are more effective in the regulation of glucose and insulin responses compared to oat β-glucans (Yokoyama et al., 1997; Hallfrisch et al., 2003).The grain is used locally for the preparation of different food stuffs such as *injera*, porridge, *kolo*, and local drinks such as *tela*, and *borde* in Ethiopia. The straw is used as animal feed especially during dry season.

In spite of the importance of barley as a food and feed crop, the efforts made so far to generate improved production technologies, its national productivity (1.3 ton/ha)has remained very low as compared with the world average (2.4 ton/ha) (FAO, 2013). This is primarily due the dominant use of low yielding farmers’ cultivar; the influence of several biotic and a biotic stresses and the minimal promotion of improved barley production technologies. The biotic stresses include low soil fertility, low soil pH, poor soil drainage, frost and drought. While the important biotic stresses include diseases, such as scald, net blotch, spot blotch and rusts, which can reduce yields by up to 67%, and insect pests such as aphids and barley shoot fly, which can cause yield losses of 79% and 56%, respectively (Chilot Yirga et al., 1998). Therefore this paper was prepared to over view barley breeding and achievements in Ethiopia.

## 2. LITERATURE REVIEW

### 2.1. Biology of the Crop

The cultivated barley is a self-pollinating diploid species (2n=2x=14) with a genome size of approximately 5.3 x 109 BP equivalent to 5.5 pg DNA of a haploid nucleus (Bennett and Smith, 1976).The inflorescence of barley is referred to as the ear, head or spike. The flowering units, the spikelets are attached directly to the central axis, or rachis, which is the extension of the stem that supports the spike. There are three spikelets at each node, called triplets, alternating on opposite sides of the spike. Each spikelet is made up of two glumes, which are empty bracts, and one floret that includes the lemma, the palea, and the enclosed reproductive components. Depending on variety, each lemma is extended as an awn, or more rarely a hood. The sterile glumes in some varieties can also be awned. Awnless varieties are also known. In hulled or husked varieties, the palea and lemma adhere to the grain. In hull-less or naked varieties, the palea and lemma are not attached and separate from the grain on threshing (Briggs, 1978). In closed-flowering types (spring barley) the anthers remain inside each floret, thus self pollination occurs. In open- flowering types (winter barley varieties), the lodicules become turgid and push the palea and lemma apart, so that the anthers may emerge (Briggs, 1978).

### 2.2. Barley Genetic Resources and Variability

Ethiopia is an important primary and secondary gene centre for many field crop species, including barley .Ethiopian barley is recognized to have typical botanical varieties with a group of inter-fertile lines distinguished by spike characters (Zemede Asfaw, 1988). Ethiopian barley collection is one of the world’s ten largest *Hordeum* collections (Konopka, 2007), which means Ethiopia accounts for 23.3% of world total (129 000) accessions (Konopka, 2007).Over the last thirty years, the barley collection has grown to about 15400 accessions, primarily landraces and preserved at IBC. At present the collection is from one species (*Hordeum vulgare* subsp. *vulgare* L.), with 10277 accessions collected from Ethiopia and 1101 donated from nine countries worldwide. However, there were 3982 accessions of unknown origin that required further investigation. Due to their wide genetic basis, landraces are gaining attention in several breeding programs, particularly in resistance to a biotic and biotic stresses with participatory research approach. More than 80% of barley produced in Ethiopia is derived from landraces (Fekadu A. and Hailu., 1987).

The baseline survey also revealed that, among the crops grown in the study areas, barley showed the highest diversity. A total of 107 major farmer cultivars were reported to be grown (32 in central Ethiopia, 13 in north Ethiopia, 47 in north west Ethiopia, 9 in north east Ethiopia and 6 in south east Ethiopia) by small scale farmers, with diverse characteristics and use (Chilot Yirga et al, 1998). Example ,Early farmers cultivars, such as 'Semereta' in Shewa; Gojam and Belga in North Gonder; and Tebele in South Gonder, Cultivars 'Aruso' in Arsi and Bale and 'Saesa' in Tigray, 'Ehilzer' and 'Tebele'two-row types are grown in the early-growing areas of Wollo. The yield of early barley varies from 0.7 to 1.5 t/ha.

Barley has a lot of varieties which can be clubbed to form different types of classification. For instance, one way of classification is to identify it by two row, four rows or six rows barley. The six row barley can produce 25-60 grains, while two-row barley produces 25-30 grains and. In wild barley, only the central spikelet is fertile, while the other two are reduced. This condition is retained in certain cultivars known as two-row barleys. Two-row barley has a lower protein content than six-row barley and thus more fermentable sugar content. High protein barley is best suited for animal feed and malting barley is usually lower protein (Akar et al. 2012). The barley can also be classified by describing its beards (awns) which cover the kernels. In the barley germplasm database awns are described along the following.


*Showing the diversity of panicles in images: On the left, two rows barley; on the right, six rows barley (photos: ICARDA)*

## 2.3. Pre Breeding Activities

the term 'pre-breeding' to describe the various activities of plant breeding research that have to precede the stages involved in cultivar development, testing and release (Biodiversity International and GIPB/FAO, 2008). Further, the Global Crop Diversity Trust defined pre-breeding as 'the art of identifying desired traits, and incorporation of these into modern breeding materials.' Pre-breeding aims to reduce genetic uniformity in crops through the use of a wider pool of genetic material to increase yield, resistance to pests and diseases, and other quality traits (http://www.croptrust.org/main/sharingknowled.php?itemid=299).

Barley accessions being regenerated from the active collections are characterized and evaluated as an important element of genebank operation and basic agro morphological assessment. Of the 15360 accessions of the genebank, there were 10869 characterized in different agro-ecologies, using 16 descriptors, which included nine quantitative and seven qualitative traits .and among them valuable traits and genotypes have been identified. Several traits, such as disease resistances to barley yellow dwarf virus, powdery mildew, leaf rust, loose smut, and barley stripe mosaic virus, and high lysine content are unique to Ethiopia (Abebe Demissie, 2006).

## 2.4. Why do Breeding in Barley

Stresses (biotic and abiotic factors) influences the strategy of breeding and selection of wide adopted cultivars or selection for specific (favorable or unfavorable) environment. The main goal of barley breeding is improvement of stress tolerance that represents a major goal for the plant breeders and for the agriculture in the future. Thus, the success of modern food barley cultivars is largely due to high yield potential, wide agro ecological adaptation and high responses to agronomic inputs (fertilizers, irrigation).

*2.4.1. Raising Yield*

Plant breeders have focused on enhancing and protecting crop yields through improvements in crop physiology, improvements to crop quality and resistance and/or tolerance to diseases, pests and weeds. Yield components to be improved in barely are spikes x number of grains/spike x weight of grain (or number of grains/unit area weight of grain in that unit). It is not possible to simultaneously select for all the yield components because of the presence of negative inter correlations among them.

*2.4.2. Lodging Resistance*

Breeders have succeeded in breeding high yielding varieties with lodging resistance (Marshall *et al.*, 2013), Resistance to lodging can help to maximize harvestable yield by reducing harvest losses (HGCA, 2005) and has been a breeding target across all crop groups studied. Resistance to lodging is a key criterion on the winter and spring barley which will be improved through management or incorporating lodging resistant gene (HGCA 2015c; HGCA 2015f).

*2.4.3. Drought Tolerance*

Drought is one of the major production constraints that reduce crop yields in water-limited areas, where many of the world's poorest farmers live (Nguyen, Babu and Blum, 1997). As the world population continues to grow and water resources for crop production decline, development of drought-tolerant cultivars and water use efficient crops is a global concern. Characterization and Evaluation of land races for their drought tolerance traits is vital for low input agriculture in food barley breeding in Ethiopia.

Investigation of drought tolerance has been focused and developed in collaboration between physiologists and breeders (Blum et al., 1994,). Study of numerous physiological and biochemical traits (water use efficiency, abscisic acid content, stomatal conductance, transpiration efficiency, senescence etc.) and developmental, morphological and ultra-structural traits leads to the concept of pyramiding physiological traits (Yeo et al., 1990) and definition of ideo types for drought conditions.

*2.4.4. Maturity*

Early maturing varieties fit the early barley production system, being ready for harvest in August–September when other crops are still green. Thus, development and promotion of such varieties has been the major target for this production system. Early maturing varieties allow food barley producers to use the land for double cropping, break the seasonal food shortages farmers face when most of crops are still too green for harvest, and escape yield losses from late commencement and early termination of rain.

*2.4.5. Resistance /Tolerance to Disease*

Resistance and tolerance to disease is a key to protecting crop yield. Diseases remain a major biotic constraint on barley production in Ethiopia. As many as 23 fungi, two bacteria, two viruses, and nine nematodes infect barley (Yitbarek Semeane *et al.*, 1996). Scald, blotches, rusts, and powdery mildew are among the most widely distributed foliar diseases in the country (Eshetu Bekele, 1985).

Various research centers have been undertaking research toward effectively managing diseases in barley. Barley breeding objectives has to be protected against yield losses and there have been successes in breeding for resistance to diseases. Breeding for disease resistance consists of two steps, first identification of donor resistance and second transferring of the corresponding genes into a breeding line through back cross method or genetic engineering.

*2.4.6. Quality*

In the present market economy, product quality has become increasingly important (such as size, color etc.), processing quality like milling techniques (blocking and pearling, grinding, roller milling, flaking, etc.). Known for its varied use, the crop also has health benefits attached to its consumption. Barley has attracted health professionals for its fiber content, particularly β-glucan, which has been shown to reduce blood cholesterol and to produce a flattened glucose response. Also Barley grain is an excellent source of soluble and insoluble dietary fiber (DF) and other bioactive constituents, such as vitamin E, B-complex vitamins, minerals and phenolic compounds. Barley contains 3-11% dietary fibers made up of pentosans, beta-glucan and cellulose. Thus, the current food barley breeding focuses on improving market quality, processing quality and nutritional quality.

### 2.5. Breeding for Barley Quality Improvement

Breeding program for developing food barley cultivars targeted to specific food markets include understanding the genetic control of specific grain components as well as their relationship with processing qualities. Grain hardness is an important criterion for starch quality and barley end use and is the major determinant of the level of starch damage during milling. Similarly grain protein content and quality are also most targeted traits in quality breeding which are highly influenced by various biochemical complexity and environmental conditions (abiotic and biotic stresses).Breeders need to develop new food barley cultivars with high protein content and high starch content, plumpy endosperm, thick cell wall, and good processing qulity like milling techniques blocking and pearling, grinding, roller milling, flaking, etc.

So far, breeders conducted phenotypic selecting for barley quality. But These procedure have had limited with polygenic traits .Thus, Breeders shoud assess the barley quality through Quantitative trait locus (QTL) methods represent a step forward in applied genetics that providing assessment of numerous genes, their location and controls of phenotypic traits. This genome location information allows for the testing of hypotheses about genes determining QTL and it provides tools for marker assisted selection (Beavis, 1998; Hayes and Jones, 2000).In general molecular marker analysis allows selection at the level of the genotype rather than the phenotype. This is useful for traits which are difficult to estimate in the field such as tolerance to various stresses (This et al., 2001).

### 2.6. Genes Controlling the Three Major Quality Traits (Amylose, Amylopectin, and Β-Glucan)

Over the last 30 years, glycemic index (GI) of food has been taken as guideline for controlling diabetes, obesity and other nutritional related diseases (Kirpitch and Maryniuk, 2011) .The GI, measures how a carbohydrate containing food raises blood glucose. A food with a high GI raises blood glucose more than a food with a medium or low GI. Due to its low GI, barley is being promoted for healthy food products. Barley is an excellent source of complex carbohydrates and β-glucans (Newton *et al.*,2011).The main carbohydrate in barley is starch ranging from 62 to 77% of the grain dry weight. Amylose and amylopectin are the two components of starch, according to amylose content, barley can be classified into normal type (25–27% amylose), waxy type (non-detectable and below 5% amylose), and high-amylose type (>35% amylose). Variations in the amylose content can affect the physicochemical and functional properties of starch which may in turn affect its utilization in various industrial applications. High-amylose barley contributes toward a low GI and also promotes bowel health (Asare et al., 2011). Hence, it is an excellent source of dietary fiber. Barley waxy type starches which are almost devoid in amylose were shown to have excellent freeze/thaw stability making them suitable in frozen foods (Bahatty and Rossangel, 1997).

β-glucan is the primary component of the cell wall in the starchy endosperm of barley accounting for around 75% of endosperm cell wall mass. β-glucan consists of D-glucose monomers linked by different β-glycosidic linkages such as 1,3/1,4 bonds and ranges from 4 to 10% of the dry weight across barley varieties (Brennan and Cleary, 2005). Although the levels of β-glucans contribute little to the total grain weight, they have great influence on the nutritional value, functionality and uses of barley. β-glucans are regarded to be the most important factor determining malting potential and brewing yield by regulating the rate of endosperm modification and the viscosity of wort during brewing (Brennan and Cleary, 2005). High β-glucan and waxy phenotypes are regarded unfavorable for brewing and feed stuff, but they are considered to be a valuable source of soluble fiber in human diets showing potential functions in reducing GI and serum cholesterol levels, flattening the postprandial blood glucose levels and insulin rises (Ahmad et al., 2012). The ability of β-glucan to lower the GI is dependent on the barley starch type (Finocchiaro *et al.,* 2012) and other grain chemicals, especially the total content of fiber (Aldughpassi et al., 2012).

The amylose and β-glucan content are primarily under genetic control but environmental factors especially during grain filling have a smaller contribution to the final grain composition (Baik and Ullrich, 2008). Amylose concentrations in barley are controlled mainly by the *amo1* and *waxy* loci mapped on chromosome 1HS (5S) and chromosome 7HS (1S), respectively; another locus *sex6* on 7H is also responsible for amylose content (Morell *et al*., 2003). The amount of β-glucan was shown to be controlled by several QTLs located on chromosome 2 and 5H (Han *et al*., 1995), 4H (Wei et al., 2009), and 7H (Li *et al*., 2008).Genome-wide association studies (GWAS) for amylose, amylopectin and β-glucan concentration in a collection of 254 European spring barley varieties allowed to identify 20, 17, and 21 single nucleotide polymorphic (SNP) markers, respectively. Among the major genes responsible for β-glucan, amylose and amylopectin content, *HvCslF6*, *amo1 and AGPL2*, *sex6*, and *waxy* were identified (Tondelli et al., 2013).Moreover, Amylose, amylopectin and β-glucan were interacted among each other through a metabolic network showing pleiotropic effects. Taken together, these results showed that cereal quality traits related each other and regulated through an interaction network, the identified major genes and genetic regions for amylose, amylopectin and β-glucan is a helpful for further research on carbohydrates in barley quality improvement program (Tondelli *et al*., 2013).

### 2.7. Breeding for Disease Resistance

With yield increasing, the genetic variability on barley fields gradually decreased because local populations and landraces were replaced by cultivars. The analysis of both pedigrees and molecular data shows that many of these cultivars share related pedigrees (Graner et al., 2000). The genetic uniformity of today barley fields makes possibility for the epidemic spread of any disease. Gene mapping is very important for the breeding program. Also identification of novel resistance genes and their isolation may lead to the development of diagnostic markers that can be used for a rapid differentiation of alleles in germplasm collections.

Considerable progress has been achieved regarding the identification of major genes conferring resistance to the leaf rust pathogen *Puccinia hordei*. Molecular mapping of the race specific genes *Rph2, Rph12* and *Rph9* as well genes *Rph7* and *rph16* make clear that there are two genes for *Puccinia hordei* patho types and that their combination in one genotypes might represent an efficient way to increase plant resistance. The similar is with resistance to stem rust caused by *Puccinia graminis*. The *rpg4* gene confers complete resistance and can be replaced or combined with the dominant *Rpg1*. Regarding to the net blotch disease, *Rpg1*gene conferring resistance to selected pathotypes of *Pyrenophora teres* has been identified (Graner *et al*., 2000). Also, gene *yd2* merely confers tolerance to barley yelow dwarf virus (BYDV) located at the proximal region of 3HL chromosome where located additional resistance genes (*Rhy)* against *Rhynchosporium secalis* and *Pyrenophora teres* (Barr, 1998).

Like that of diseases, there are insect pests which limit production potential of barley. In order to develop insect resistant cultivars, barley breeders should identify source of resistance gene from wild species. Screening of wild barley collections were identified as sources of resistance like *Hordeum marinum* and *Hordeum bulbosum* that showed antibiosis to the fly (Lhaloui, *et al.,* 2000). Using of wild barley as a source for barley breeding we need to know what patho type strategy to adopt (local, exotic, pure, mixed), whether resistance is prevalent, rare or absent, what is genetic bases of any resistance, whether wild resistance shows predictable geographic patterns, relationship between wild resistance barley cultivars, whether molecular tags available to expedite breeding etc.

### 2.8. Food Barley Breeding Achievements in Ethiopia

Barley research was started at Debre Zeit Agricultural Research Centre in the 1950s.More organized research on the crop began in 1966 with the establishment of the Holetta Agricultural Research Centre (HARC) to represent the central highlands of Ethiopia, with barley being a major focus in crop research. A more detailed research plan was set up in 1969, with the bulk of the work being conducted at Holetta, including hybridization; selection from large collections from local and foreign sources. Breeding and genetics research in the 1980s focused on developing varieties responsive to high external inputs (Mulatu and Grando, 2011). However, in the 1990s, the research direction became geared towards a participatory and multidisciplinary approach, with majore emphasis on-farm research with the full participation of farmers. In line with this, a research grant was obtained, from 1993 to 1998, from the Royal Netherlands Government to strengthen research and transfer of technology for sustained food barley production. It was a collaborative project between the then IAR and the International Center for Agricultural Research in the Dry Areas (ICARDA) (Mulatu, and Grando, 2011).

The general goal of the project was to develop and transfer new technologies to small scale farmers, to increase the productivity of barley and to ensure the sustainability of barley production in the various barley agro-ecologies. In general, the breeding programme has given more emphasis to the evaluation of landraces under low to medium inputs rather than replacing the local germplasm by exotic materials. To enrich and improve the germplasm base, exotic germplasm of both food and malt types have been introduced from ICARDA and other sources. According to MoARD crop variety registry (2013), 36 improved food barley varieties have been released so far with their unic important characters. Among the released varieties some are described beneath for their yield and other agronomic performance.

**Table1**.*Varieties under Production*

| Varieties | Year of release | Yield(kg/ha) | Adaptation area | Suitability |
|---|---|---|---|---|
| Walker | 2012 | 2500-3500 | dry land moisture stress area | resistance to barley loose smut , moderate resistance powdery mildow |
| Golden eye | 2012 | 2500-3500 | dry land moisture stress area | resistance to barley loose smut , moderate resistance powdery mildow |
| Aquila | 2012 | 2500-3500 | dry land area | moderate resistance powdery mildow |
| Cross | 2012 | 2500-5600 | high land area | resistance to scaled and leaf blotche |
| EH14939 | 2012 | 2500-6100 | high land area | resistance to scaled and leaf blotches |
| Gobe | 2012 | 42110 | low moisture stress | resistance to scaled and leaf blotches |
| Fetina | 2012 | 4500 | medium moisture | resistance to scaled and other disease |
| Hriti | 2012 | 4000 | high moisture area | resistance to scaled and other disease |
| TILLA | 2007 | 2720 | wide adaptability | moderate to major foliar diseases |
| Bentu | 2006 | 4090 | low-moisture area | resistance to scaled and leaf blotches |
| HB-1307 | 2006 | 3500-5000 | wide adaptation | resistance to leaf rust and scald |
| SHIRE | 2005 | 3600 | for specific adoption | has disease and lodging resistance |
| Yedogit | 2005 | 2650.5 | Early variety (67–70 days) | tolerance to frost that usually occurs around mid-October |
| Setegn | 2004 | 2270 | wide adaptability | moderate to major foliar diseases |
| Shedho | 2003 | 2516.2 | The early variety (67–70 days) | tolerance to frost that usually occurs around mid-October |
| Abay | 1997/98 | 2750 | wide adaptability | and moderate to major foliar diseases |

## 3. Conclusion

Barley is one of the most important staple food crops in the world which ranks fourth next to wheat, rice and maize. In spite of the importance of barley as a food and feed crop in Ethiopia and the efforts made so far to generate improved production technologies, its productivity has remained very low (about 1.3 ton/ha) compared with the world average (2.4 ton/ha). This is primarily due to the dominant use of low yielding farmers varieties; the influence of several biotic and a biotic stresses; and the minimal promotion of improved barley production technologies. Complex physiological responses to drought, various environmental factors, and their interactions, have slowed the development of improved cultivars for drought-prone environments. To facilitate improvement of the Ethiopian barley collections activities like characterization and purification of the mixed collections; evaluation of the landrace collections in drought-prone and ideal environments; study of the traits that have strong correlation with high yield should be performed. Therefore, future barley research should consider both specific and wide adaptation for stress breeding to sustainably supply desirable recombinant lines, which subsequently could be released as commercial varieties. If barley research is to be more viable and to progress systematically this effort must be supplemented with molecular marker assisted selection with the continuous study of the quantitative trait loci (QTLs) controlling the biotic and biotic stress resistance /tolerance traits. The process ranging from the identification of appropriate resistance donors to the development of a selectable marker requires collaboration of barley breeders, phytopathologists and geneticist.

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