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Wheat Breeding Research and Major Achievements in Ethiopia: A Review

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Abstract

Bread wheat plays a major role among the few crop species being extensively grown as staple food sources. The historical background of wheat breeding in Ethiopia is briefly reviewed, with due emphasis on varieties released to date. Further, most of the varieties released were either from introduction and/or selection programs; however, the strengthening of the molecular marker assisted selection program is imperative in order to produce varieties which are better suited to changing climatic conditions. Most Wheat improvement is a complicated trait which is controlled by polygenes and their expressions are influenced by various environmental elements. This means that breeding for this trait is so difficult and new molecular methods such as molecular markers, quantitative trait loci (QTL) mapping strategies, and expression patterns of genes should be applied to produce improved wheat genotypes. About one hundred ten (110) improved wheat varieties with various desirable characteristics were released for the four major agro ecologies of Ethiopia. However, wheat breeding in Ethiopia still not advanced using the existing genetically diverse wheat resource. Particularly, application of Biotechnology in crop improvement is limited; hence further crop improvement using advanced breeding technology to be considered accordingly.

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Introduction

Wheat (*Triticum* spp.) is a self-pollinating annual plant, belonging to the family *Poaceae* (grasses), tribe *Triticeae*, genus *Triticum*. According to different classifications, number of species in the genus varies from five to 27 (Merezhko, 1998). The species of *Triticum* (*T.*) and their close relatives can be divided into diploid, tetraploid and hexaploid groups, with chromosome numbers of 2n = 14, 28 and 42, respectively, in which the basic chromosome number of wheat is x = 7. The wild species are diploids (2n = 2x = 14), *e.g.* with the genome designation AA (*T. monococcum*), DD (*T. tauschii*, syn. *Aegilops squarossa*), and SS (*T. speltoids*), or tetraploids (2n = 2x = 28), *e.g.* with the genomes AABB (*T. durum* or *T. turigidum*) or AAGG (*T. timopheevii*).

The two main groups of commercial wheats are the durums (*Triticum durum* L.) and bread wheats (*Triticum aestivum* L.) with 28 and 42 chromosomes respectively. *Triticum durum* originated thousands of years ago from a hybridisation between the wild diploid *T. monococcum* L. (A genome donor) and the donor of the B genome which, according to morphological, geographical and cytological evidence, has been recognised as *T. speltoides* (Tausch) Gren. or a closely related species (Colomba & Gregorini, 2011; Von Buren, 2001). The domestication of diploid and tetraploid wheat is thought to have occurred in the fertile crescent of the Middle East. Domestication of the diploid and tetraploid wheat is thought to have occurred at least nine thousand years ago with the hybridisation event producing hexaploid wheat occurring more than six thousand years ago (Simmons 1987; Feuillet *et al.*, 2007). Within tetraploid wheat, cultivated emmer (*T. dicoccum*) was the first to be domesticated. Others such as *T. durum, T. turgidum, T. aethiopicum* and *T. polonicum* might have originated from cultivated emmer through mutation(s) that reduced the toughness of the glumes to attain free-threshing (Morris & Sears, 1967).

The presence of high genetic diversity in cultivated tetraploid wheat and considered Ethiopia to be a centre of diversity and the site of origin of tetraploid wheat (Vavilov 1929; Vavilov 1951; Zohary, 1970).

Most of the studies to date on Ethiopian wheat landraces have been based on the diversity of agro-morphological characters, which are highly heritable, on isozymes and on cytological markers showed the presence of a high amount of genetic diversity in Ethiopian tetraploid wheat landraces (Teklu *et al.*, 2005; Messele, 2008; Hailu, 2011).

Wheat is the most widely grown cereal grain, occupying 17 percent of the total cultivated land in the world. Wheat is the staple food for 35 percent of the world's population, and provides more calories and protein in the world's diet than any other crop (IDRC, 2016). According to the Agricultural Sample Survey of 2014, there are 4.7 million wheat farmers in Ethiopia. Of these, more than three-quarters (78percent) live in Oromia and Amhara. SNNP accounts for 13 percent and Tigray 8 percent. Less than 1 Percent of wheat farmers live in other regions of Ethiopia.

The average wheat area per farm in Amhara, Tigray, and other regions is between 0.28 and 0.39 ha/farm (Minot *et al.*, 2015). Ethiopia produced 42,315,887.16 quintals (4.23 million tons) of wheat which is cultivated on 1,663,837.58 hectares (1.66 million ha) in 2014/15, making it the largest wheat producer in Africa south of the Sahara by a considerable margin (CSA, 2015). Ethiopia represents just 0.6 percent of the 729 million tons produced globally (FAO, 2015). This review study is initiated to assess the provide update information on wheat breeding in Ethiopia and to review history of wheat breeding, germplasm conservation status and efforts made to improve wheat genetics in Ethiopia.

History of Wheat Breeding in Ethiopia

In Ethiopia, collection and evaluation of indigenous wheat and the introduction of exotic germplasm for testing under local conditions began early in the 1930s. During this period, several wheat varieties were introduced from Europe and yielded satisfactorily until they succumbed to diseases. On the other hand, the local varieties produced consistent and reasonable yields because of their good adaptation (*Hailu*, 1991). From 1930-52, introduction, hybridization and selection began, culminating in the release of Kenya1 and Kenya5. A formal wheat improvement program started in 1949 at the Paradiso Government Station near Asmara with the testing of large numbers of indigenous and exotic varieties. As a result, some promising local variety selections, including AlO, R18, P20 and H23, and 3 bread wheat varieties of Kenyan origin, namely Kenya 1, *5* and 6, were released during the early 1950s (*Hailu*, 1991).

Wheat research continued at Paradiso, Debre Zeit, Alemaya and Kulumsa during the period 1953-66. In the north, as the Kenyan varieties increased in hectareage, they became susceptible to stem and leaf rust. Therefore, the program at Paradiso looked for other international sources of germplasm and identified and released 2 varieties of Mexican origin in 1960. At the same time, the station initiated hybridization amongst local and exotic durum wheats. The main objective of these crosses was to incorporate stem rust and leaf rust resistance in the high quality, disease susceptible introduced durum varieties. The College of Agriculture, using the Debre Zeit Experiment Station, Jima Agricultural and Technical School and the Extension Service of the Ministry of Agriculture, strengthened its wheat research activities by obtaining nursery materials from Paradiso and also external sources. The major research activities included germplasm screening, variety testing, crop management studies and seed increase. This effort resulted in the release of 6 bread wheat varieties plus the multiplication and distribution of seed of the varieties Kenya 1 and Kenya *5* in the Shewa and Arsi highlands (Tesemma and Mohammed, 1982).

The national wheat improvement program has been organized most effectively from 1967-1990. The establishment of the Institute of Agricultural Research (IAR) in 1966 was followed by the creation of several other research and development institutions, resulting in an effectively organized national wheat research program. In addition to a'chain of stations and substations under IAR and the Debre Zeit Agricultural Research Center, other important agricultural research and development organizations which came into being since 1967 have contributed directly or indirectly to wheat research in the country. Prior to 1967, no policy guidelines existed in Ethiopia regarding the release of crop varieties to farmers. The decision to release varieties depended solely on the judgement of the breeder working on the crop. Coordinated variety testing at the national level developed after the National Crop Improvement Committee was created in 1967. During these 24 years, a comprehensive program has developed and 30 improved wheat varieties have been released. Wheat research is handled nationally by a multidisciplinary team of experts from different institutions organized into two components, first dealing with bread wheat and the other with durum wheat (*Hailu,* 1991).

At present, wheat is identified as one of the priority national commodity crops by the government with research headquarters at Kulumsa for bread wheat and at Debre Zeit for durum wheat. A total 110 varieties have been released since 1990 to 2016. From this varieties 76 were bread wheat and the rest 34 were Durum wheat (MoARD, 2016).

Conservation of Wheat land races

Many landrace germplasm has been collected during the 1970-1990 era and is being conserved across the world mostly in long-term national and international genebanks (Frizon *et al.,* 2011). However, a small portion of this diversity is being conserved and used on-farm where it continues to evolve (Brush and Meng, 1998). Both of these conservation methods have its merits and limitations. On-farm conservation is the sustainable management of genetic diversity of locally developed traditional crop cultivars and landraces along with associated wild and weedy species or forms within traditional agricultural systems. This conservation strategy provides a natural laboratory for evolution to continue and helps a gradual buildup of traits imparting adaptation to specific eco-geographical regions and those matching the requirements of farmers, local communities and populations to continue. Several authorities indicated that the need for on-farm conservation of landraces is one of the most important recent questions in plant genetic resources management (Le Boulch *et al.,* 1994; Kebebew *et al.,* 2001). Research results indicated that the likelihood of wheat landraces to be conserved on the farm increases when the markets for their derived products are expanded through improved consumer access to information on recipes, nutritive and cultural values. Therefore, local knowledge of landrace diversity, when documented through interaction with farmers and linked to food traditions, local practices and social norms, is vital for on-farm conservation and would increase their competitive advantage if farmers have other alternative options. For example, socio-cultural values and culinary attributes motivated farmers in central Ethiopia to conserve a durum wheat landrace on their farms; they appreciate its peculiar organoleptic qualities and multiple uses, including 14 dishes and two drinks, despite the availability of several improved durum wheat varieties in their locality (Kebebew *et al.,* 2001). Moreover, hundreds of farmers who accessed the landrace through reintroduction program expressed their appreciation and future commitment to growing and conserving it on the farm. This example strongly indicated that farmers in a community collectively can sustain more crop and landrace diversity than individual farmers, thus meeting overall conservation needs and objectives (i.e., private and public values of a landrace). A renewed interest in and increased demand by farmers to grow this durum wheat landrace and the promotion of landrace-derived products generated income, created green jobs for local communities, and supported on-farm conservation of the landrace. Along with economic benefits, on-farm conservation and utilization of such wheat landraces is also linked to peoples' cultural, social and ritual values. However, for individual farmers, private values of a landrace are the main motivating factors for growing landraces as a source of income and a means of survival. Therefore, *ex situ* conservation in a genebank may be the only practical option to conserve landraces having low private but high public value (Le Boulch *et al.,* 1994). *Ex situ* conservation continues to represent the most significant and widespread means of conserving PGRFA. Most conserved accessions are kept in specialized facilities known as genebanks maintained by public or private institutions acting either alone or networked with other institutions. PGRFA can be conserved as seed in specially designed cold stores or, in the case of vegetatively propagated crops and crops with recalcitrant seeds, as living plants grown in the open in field genebanks. In some cases, tissue samples are stored *in vitro* or cryogenically and a few species are also maintained as pollen or embryos. Increasingly, scientists are also looking at the conservation implications of storing DNA samples or electronic DNA sequence information. About a total of 856,168 wheat accessions were globally conserved in the genebank of CIMMYT and NSGC/USA029/ (CIMMYT, 2007). However, over

12000 tetraploid wheat accessions were conserved in genebank of Ethiopia (Newbary and Ford, 2008).

Yield Improvement

Grain yield improvement is the ultimate goal for most wheat breeding programs across the world. Although grain yield is a complex trait with low heritability and highly influenced by genotype x environment interaction, high yielding commercial varieties of many crops including wheat have been developed through direct selection for grain yield even if the relationship of yield with its component traits has already been established. The major grain yield determining traits of wheat are kernel number per unit of land area, harvest index and kernel weight. Yield of wheat can be improved by increasing seed number and/or weight, the latter by increasing the amount of starch, which is the most abundant component (more than 70% of seed weight) of wheat endosperm, or by regulation of endosperm development. Starch synthesis in cereals is regulated by ADP-glucose pyrophosphorylase (AGP), that is likely involved in determination of seed sink strength (Hannah and James, 2008).

The number of tillers formed on each plant is among many factors that determine yield in wheat (and in rice), by influencing the number and size of panicles and seeds produced. MONOCULM1 (MOC1), a gene that controls tillering in rice, has been identified (Li *et al.*, 2003). Changing the architecture of the plant by the formation of more tillers and leaves which are spread out would expose a larger leaf surface for the capture of sunlight for increased photosynthesis, leading to improved productivity (Sakamoto *et al.*, 2006; Kuraparthy *et al.*, 2007). The other possible approaches for yield improvement include: changing C3 wheat into a C4 plant (which is much more efficient because of greatly reduced loss of carbon by photorespiration) or the production of wheat hybrids (heterosis or hybrid vigor has been used to obtain dramatic increases in crop yields for nearly 75 years) (Wang *et al.*, 2005).

In Ethiopia wheat cultivar improvement commenced in 1949, has concentrated on increasing grain yield potential, adaptability, lodging, disease resistance and tolerance to several environmental stress. A number of bread wheat and durum wheat cultivars with high yield potential have been recommended for production. Currently, farmers using recently released Bread wheat varieties, 'Danda'a', 'Kakaba',late 'Ga'ambo', 'Ogolcho', and 'Hidase'which is orginated from CIMMITY achieved ≥ 6 t/ha yield under well-managed conditions [31]. Recently, two CIMMYT originated Durum wheat varieties ('Hitosa' and 'Denbi') and 5197 genotypes respectively were evaluated across locations in Ethiopia during 2010-2012 were released, and these varieties gave 5-6 t/ha in a variety verification plots at Sinana and Kulumsa (Abeyo *et al.*, 2012).

Thirty-five historic durum wheat varieties released between 1966 and 2012 were evaluated at Debre Zeit and Enewari in 2012 during main cropping season and result indicated significant differences among the varieties for all the traits considered at both locations except for hectoliter weight at Debre Zeit (Bogale *et al.*, 2013). The rate of yield improvement ranged from -75.39 kg ha-1 yr-1 (-1.39% yr-1) for Enewari to 48.23 kg ha-1yr-1 (3.23% yr-1) for Debre Zeit, which suggests that the breeding effort does not have similar effect on the two locations (Bogale *et al.*, 2013).

Wheat Genetic Improvement for Biotic Stress Resistance

A large number of fungal (such as rust caused by *Puccinia* spp., smut and bunt caused by *Tilletia* and *Ustilago* spp., blotch caused by *Septoria* spp., *Fusarium* blight/scab, *Helminthosporium* leaf blight, powdery mildew caused by *Blumeria graminis*, etc.), bacterial (such as leaf streak caused by *Xanthomonas translucens*) and more than 50 viral diseases are known to cause considerable worldwide damage to wheat production (Curtis *et al.*, 2002). Losses of wheat production owing to pathogens are estimated to be 12.4%, but as high as 16.7% without crop protection (Oerke *et al.*, 1994). Only limited protection against pathogens can be achieved by chemical treatments or cultural practices (Curtis *et al.*, 2002). Resistance breeding is a continuing and difficult process as resistance in most cases appears to be under polygenic control, and even when resistant cultivars are developed, they do not provide long-term relief due to ever-evolving or mutating pathogens (Friesen *et al.*, 2006).

Leaf and stem rust are among the most important diseases in wheat. The selection of wheat genotypes with combination of non-race-specific genes defining durable resistance over years as well as race specific genes at seedling stage is a task of high importance for breeding programs. A research result indicated that a considerable level of seedling plant resistance is available from Ethiopian grown wheat varieties and lines when tested by known leaf rust and stripe rust pathotypes (Hussein and Pretorius, 2005). Currently there are 60 leaf rust resistance genes with permanent gene designations from lr1 to lr 60 (McIntosh *et al.,* 2007). These genes have been found and characterized in common hexaploid wheat, tetraploid durum wheat and many diploid wild wheat species (McIntosh *et al.,* 2007).

Recently done wheat disease surveys in Ethiopia have shown that none of the cultivated bread wheat varieties are resistant to the present stem rust complex. Sr2 stem rust resistance gene has provided durable, broad-spectrum resistance and has been used as an effective control measure against wheat stem rust in modern wheat breeding. The use of Sr2 in CIMMYT wheat improvement program resulted in the release of several popular varieties worldwide carrying this gene (Singh *et al.,* 2009).

Hence, effort to transfer valuable *Sr* genes from cultivated tetraploid wheats could be rewarding for Ethiopian wheat improvement efforts. Ethiopian cultivated tetraploid wheat accessions are still good sources of stem rust resistance. The presence of Sr28, 29, 30, 31, 32, 8b, 9a, 9b and SrTt-3 genes was postulated in those emmer and durum accessions (Betesilassie, 2005). Similarly the presence of Sr genes in Ethiopian durum wheat varieties and tetraploid wheat landraces based on linked or associated molecular markers were reported (Haile *et al.,* 2012). Several species of insects have been recorded on wheat both under field and storage conditions. Fortunately, very few of these are considered to be economically important. Under field conditions, the most important pest species are *Schizaphis graminum*, *Diuraphis noxius*, *Decticoides brevipennis* and *Locusta migratoria migratoriodes.* Some species such as *Aiolopus longicornis* and *Schizonycha* spp. are also locally important. Studies conducted on the host preferences ofthe Russian wheat aphid *(Diuraphis noxius)* at Chacha and in the laboratory at Holetta showed that barley and *Bromus pectinatus* are the most preferred hosts followed by wheat. Screening of 22 varieties of wheat for resistance to the Russian wheat aphid at the HARC in 1990 showed lower aphid counts and lower chlorosis on the lines HAR 1349, HAR 1520, HAR 424, HAR 605, and F5YR 20-6/87 (Abdulahi and Haile, 1991).

Wheat Genetic Improvement for Abiotic Stress Tolerance

Abiotic stresses (drought, salinity, flooding, excessively high or low temperatures, high levels of minerals such as salt, heavy metals, etc.) cause adverse affects on plant growth that can reduce crop productivity in wheat by more than 80% (Bray *et al.,* 2000).

Drought is one of the most important phenomena which limit crops' production and yield. Understanding plants' responses to drought at every life stage is crucial to progress in genetic engineering and breeding. Early maturity, small plant size, and reduced leaf area can be related to drought tolerance (Rizza *et al.,* 2004). Another research claimed that the length and area of flag leaf in wheat increased while the width of the flag leaf did not significantly change under drought stress (Lonbani and Arzani, 2011). Moreover, the number of leaves per plant, leaf size, and leaf longevity can be shrunk by water stress (shao *et al.,* 2008). Peduncle length and excursion were positively correlated with grain yield under water deficit condition (Bogale, *et al.,* 2011). Negative and significant relationship was found between peduncle length and drought susceptibility index suggests the peduncle length as an indirect selection criterion in wheat under drought conditions.

Leaf posture and rolling had a profound effect on grain yield and other attributes. The genetic variability found for these morphological traits among durum wheat genotypes studied also suggest opportunity for selection superior genotype in water limited environments. In vivo studies of evaluation of bread wheat suggest that the local cultivar is more tolerant to moisture stress and it could be used for breading tolerant cultivars (Tamru and Ashagre (2014). In wheat, there are several genes which are responsible for drought stress tolerance and produce different types of enzymes and proteins for instance, late embryogenesis abundant (lea) protein, responsive to abscisic acid (Rab), rubisco, helicase, proline, glutathione-S-transferase (GST), and carbohydrates during drought stress (Nezhadahmadi *et al.,* 2013). The research finding indicated that *HVA1* gene assists to increase wheat growth under drought stress (Sivamani *et al.,* 2000).

HVA1 gene produces a kind of protein which is in group 3 LEA and has 11 amino acid motifs in nine repeats. Proline is a crucial protein that has a vital function in water stress tolerance (Sivamani *et al.,* 2000). A study conducted to screen Ethiopian wheat germplasm for tolerance to acid soils showed that 8.7% of 654 accessions screened were found to be tolerant, having relative root length values greater than 0.65%. Out of the 57 tolerant lines, 56% were tetraploid while 44% were Hexaploid (Krauss and Giorgis, 1985).

Wheat Grain Quality Improvement

For most traditional uses, wheat quality derives mainly from two interrelated characteristics: grain hardness and protein content. Grain hardness is a heritable trait but it can be strongly affected by a normal weather conditions such as excessive rainfall during the harvest period. Protein content is weakly heritable and strongly dependent on environmental factors such as available soil nitrogen and moisture during the growing season (Belderok *et al.,* 2000). In addition, each end-use requires a specific 'quality' in the protein. Durum wheat cultivars have the hardest grain texture and are usually high in protein content. They are especially suited to the production of pasta because of their highly vitreous grain (high milling yield of semolina), unique combination of storage proteins for good cooking quality of pasta, and high yellow pigment content required for attractive appearance of cooked product. All three characteristics are highly heritable and can be readily improved by conventional breeding. Recent research has shown that the presence of γ-gliadin 45 is a reliable marker of good cooking quality. This marker is now used for screening early generation material in many durum wheat breeding programs (Belderok *et al.,* 2000).

Bread (also common or hexaploid) wheats cover a wide range of grain hardness and protein content. The hardest wheats of this class, generally highest in protein, are used for pan bread. Common wheats of medium hardness and lower protein content are used for other types of bread and noodles. Wheats with softest texture and lowest protein are used for cakes and cookies. In some end-uses, e.g., Chinese-type noodles, starch quality is important together with protein quality; this feature should be taken into consideration in developing a screening strategy for wheats for this application. Screening tests that reflect end-use requirements for most of the known products are available, and should be applied in testing wheats according to intended use (Bushuk, 1998). Wheat landraces represent interesting biological material because of their genetic variability. Some of them possess genes, not occurring in modern cultivars, although these genes can be valuable for improvement of their quality. Thus, screening landraces for the novel HMW-GS alleles for further utilization has become a part of some breeding programs (Gregova *et al.,* 2006). Marker-assisted selection and backcross breeding can be successfully employed in wheat breeding programs and that molecular markers can be used alone or in combination with the A-PAGE technique in each backcross generation (Yildirim, *et al.,* 2013). Quality targeted breeding through marker-assisted backcross breeding in this work was completed in about 3 years by raising 3 generations per year. With the help of marker assisted selection, breeding time was reduced and the efficiency of backcross breeding was increased, leading to the development of a durum wheat candidate with elevated protein content and gluten quality (Yildirim, *et al.,* 2013).

Most Ethiopian grown wheat intended for leavened traditional bread production also appear to have high-quality HMW-GS alleles (Tarekegne and Labuschagne, 2005). The sub unit composition in bread wheat was generally of good quality, with more than 70 % of cultivars and lines achieving the highest quality score of 9 and 10. Gluten quality, measured by SDSS, correlated significantly with the overall quality score and with scores at Glu-B1 and Glu-D1 loci. In this set of cultivars and lines, about 44 % of the total variation in the gluten quality was accounted for by the variation in the HMW-GS composition, of which 23.5 % was accounted for by the variation at Glu-D1 and 18.2 % at the Glu-B1 locus.

In durum wheat, about 25 % of the total variation in the SDSS values was accounted for by the variation at the Glu-B1 locus. The prevalence of Glu-B1b, demonstrated to have a favourable effect on bread-making quality in bread wheat, among the cultivars and lines, especially among the landraces, may reflect the past selection history exerted on landraces towards good leavened bread quality and indicate the potential use of Ethiopian landraces in the development of dual purpose (for both bread- and pasta-making quality) durum lines (Tarekegne and Labuschagne, 2005). Similarly Mohammed *et al.,* (2012) in their study depicted the presence of substantial variations among Durum wheat genotypes of Ethiopia for all quality parametres tested.

Major Achievements in Wheat Breeding in Ethiopia

Over the past four decades about 126 improved wheat varieties with various desirable characteristics were released for the different agro ecologies (MoARD, 2018). Of these 85 were bread wheat varieties and 41 are durum wheat on the current recommendation (Table 1 and 2). The Debre Zeit Agricultural Research Center and Alemaya University of Agriculture has been and still is the coordinator of the Durum Wheat Improvement Program of the Nation. One of the main objectives of the program is to develop and release good-quality, high-yielding varieties of durum wheat suitable for various parts of Ethiopia.

Table.1 List of released Bread Wheat varieties from Ethiopia since 1974 – 2018

No	Varieties	Release year	Breeder /maintainer	No	Varieties	Release year	Breeder /maintainer
1	Hadis (ETBW 6463)	2018	Alamata ARC	45	Gasay	2007	ADARC/ARARI
2	Bondena (ETBW 6188)	2018	Areka ARC	46	DIKINESH	2007	SRARC/ARARI
3	Deka (ETBW 7638)	2018	KARC (EIAR)	47	LIDORO	2007	HARC (EIAR)
4	Hibist (ETBW7690)	2018	SARC/ARARI	48	MENZE	2007	DBARC/ARARI
5	Sinja	2018	SARC (ORARI)	49	SULLA	2007	AWARC (EIAR)
6	Jaalanne (ETBW 6440)	2017	KARC (EIAR)	50	MILLINIUM	2007	KARC (EIAR)
7	Jajabo (ETBW6440)	2017	HARC (EIAR)	51	JIRU	2006	DBARC/ARARI
8	Fentale-2	2017	WARC (EIAR)	52	Warkaye	2006	SRARC/ARARI
9	Amibara-2	2017	WARC (EIAR)	53	Meraro	2005	KARC/EIAR
10	Wane (ETBW 6130)	2016	KARC (EIAR)	54	TAY	2005	ADARC/ARARI
11	Lemu (ETBW 6861)	2016	KARC (EIAR)	55	Senkegna	2005	ADARC/ARARI
12	Kingbird	2015	K ARC (EIAR)	56	Dingalu	2005	KARC/EIAR
13	Obora	2015	SARC (OARI)	57	Tossa	2004	SRAC/ARARI
14	Dambal	2015	SARC (OARI)	58	Bobicho	2002	KARC/EIAR
15	Amibera	2015	Werer ARC (EIAR)	59	Densa	2002	ADARC/ARARI
16	Fentale	2015	Werer ARC (EIAR)	60	Sirbo	2001	KARC/EIAR
17	Bulluq (ETBW 5484)	2015	Bako ARC (EIAR)	61	Doddota	2001	KARC/EIAR
18	Liben (ETBW 5653)	2015	Bako ARC (EIAR)	62	KBG-01	2001	KARC/EIAR
19	BIQA (ETBW 6095)	2014	KARC (EIAR)	63	Dure	2001	SARC/OARI
20	Mandoyu	2014	SARC (OARI)	64	Guna	2001	ADARC/ARARI
21	Sanate	2014	KARC (EIAR)	65	Sofumar	1999	SARC/OARI
22	HONQOLO	2014	K ARC (EIAR)	66	Madawalabu	1999	SARC/OARI
23	NEJMAH-14 (Lucy)	2013	WARC (EIAR)	67	Hawi	1999	KARC/EIAR
24	ADEL-6	2013	WARC (EIAR)	68	Wetera	1999	KARC/EIAR
25	Sekota-1 (ETBW4886)	2013	SDARC/ARARI	69	Simba	1999	KARC/EIAR
26	Sorra	2013	SARC/ARARI	70	Shina	1998	ADARC/ARARI
27	FRTI-1 (Mekele4)	2013	M. A. ARC /TARI	71	Katar	1998	KARC/EIAR
28	Jefferson	2012	OARI/Fedis/morrell	72	Tura	1998	KARC/EIAR
29	Hulluka (ETBW5496)	2012	KARC/EIAR	73	Tuse	1997	KARC/EIAR
30	Ogolcho (ETBW5520)	2012	KARC/EIAR	74	Abola	1997	KARC/EIAR
31	Hidase (ETBW5795)	2012	KARC/EIAR	75	Megala	1997	KARC/EIAR
32	Mekelle-03	2012	M. &A. ARC/TARI	76	Galema	1995	KARC/EIAR
33	Shorima	2011	KARC/EIAR	77	Wabe	1995	KARC/EIAR
34	Hoggana	2011	KARC/EIAR	78	Kubsa	1995	KARC/EIAR
35	Tsehay/HAR3837/	2011	DBARC/ARARI/	79	Mitike	1994	KARC/EIAR
36	Mekelle-01/HUW-468/	2011	KARC/EIAR	80	Dashen	1984	KARC/EIAR
37	Mekelle-02/HI-1418/	2011	MARC/TARI	81	Pavon	1982	KARC/EIAR
38	Gambo=Quaiu#2	2011	KARC/EIAR	82	ET-13A2	1981	KARC/EIAR
39	Danda'a	2011	KARC/EIAR	83	K 6295-4A	1980	KARC/EIAR
40	Kakaba	2010	KARC/EIAR	84	K 6290 bulk	1977	KARC/EIAR
41	Galil	2010	HazeraGenetics Ltd	85	Dereselign	1974	KARC/EIAR
42	Inseno-1	2009	AWARC/SARI				
43	Bolo	2009	DB ARC				
44	Qulqulluu (ETBW-4621)	2009	HU				

Where, ARARI= Amhara Agriculture Research Institute, EIAR= Ethiopian Institute of Agriculture Research, HARC= Holetta Agriculture Research Center, HU= haramaya University, OARI= Oromiya Agriculture Research Institute, SARI= South Agriculture Research Institute

Table.2 List of released Durum Wheat varieties from Ethiopia since 1982 – 2016

No	Varieties	Release year	Breeder /maintainer	No	Varieties	Release year	Breeder /maintainer
1	Fetan (CDSS02)	2018	DZARC/EIAR	22	Malefia	2005	SRARC/ARARI
2	Don Matteo	2018	CGS Italian	23	Oda	2004	SARC/OARI
3	Bullaallaa 9PDYT-322)	2017	SARC/ORARI	24	Ilani	2004	SARC/OARI
4	Alemtena	2017	DZARC/EIAR	25	Megenagna	2004	ADARC/ARARI
5	Tesfaye	2017	DZARC/EIAR	26	Mosobo	2004	ADARC/ARARI
6	Wehabit (Acc=8208)	2017	MU	27	Mettaya	2004	ADARC/ARARI
7	Rigeat (Acc=208304)	2017	MU	28	Selam	2004	ADARC/ARARI
8	Utuba	2015	DZARC/EIAR	29	Laste	2002	SARC/OARI
9	Mukiye	2012	DZARC/EIAR	30	Lelisso	2002	SARC/OARI
10	Mangudo	2012	SARC/OARI	31	Yerer	2002	DZARC/EIAR
11	Dire	2012	SARC/OARI	32	Ude	2002	DZARC/EIAR
12	TOLTU	2010	SARC/OARI	33	Ginchi	1999	DZARC/EIAR
13	Hitosa	2009	DZARC/EIAR	34	Robe	1998	DZARC/EIAR
14	Denbi	2009	DZARC/EIAR	35	Asasa	1997	DZARC/EIAR
15	Werer	2009	DZARC/EIAR	36	Arsi-Robe	1996	DZARC/EIAR
16	Tate	2009	SARC/OARI	37	Quami	1996	DZARC/EIAR
17	FLAKIT	2007	SRARC/ARARI	38	Bichena	1995	DZARC/EIAR
18	OBSA	2006	SARC/OARI	39	Kilinto	1994	DZARC/EIAR
19	EJERSA LABUD	2005	SARC/OARI	40	Foka	1993	DZARC/EIAR
20	Bakalcha	2005	SARC/OARI	41	Boohai	1982	DZARC/EIAR
21	Kokate	2005	AWARC/SARI				

Where, ARARI= Amhara Agriculture Research Institute, EIAR= Ethiopian Institute of Agriculture Research, HARC= Holetta Agriculture Research Center OARI= Oromiya Agriculture Research Institute, MU=mekelle university, SARI= South Agriculture Research Institute

The breeding methods followed for developing varieties are through: selection from indigenous wheat landraces, selection from introductions, hybridization, and evaluation of selected lines for commercial production.

Summary

The two main groups of commercial wheats are the durums (*Triticum durum* L.) and bread wheats (*Triticum aestivum* L.) with 28 and 42 chromosomes respectively. The domestication of diploid and tetraploid wheat is thought to have occurred in the fertile crescent of the Middle East. Wheat is the most widely grown cereal grain, occupying 17 percent of the total cultivated land in the world.

In Ethiopia, collection and evaluation of indigenous wheat and the introduction of exotic germplasm for testing under local conditions began early in the 1930s. During this period, several wheat varieties were introduced from Europe and yielded satisfactorily until they succumbed to diseases. On the other hand, the local varieties produced consistent and reasonable yields because of their good adaptation. Ethiopian wheat is rich in both interspecific and intraspecific variability and possesses specific attributes of utility in wheat breeding programs. Its wide agro-ecological amplitude can serve as a basis for selection for specific areas of adaptation. Although the landraces are apparently less desirable in terms of yield, it is evident that they possess desirable traits that can be incorporated in high yielding, improved cultivars.

Over the past four decades about 126 improved Wheat varieties with various desirable characteristics were released for different agro ecologies. However, Productivity was still low as compared to the world standard so application of biotechnology in crop improvement should be considered future breeding program.

Since Ethiopia is the center of genetic diversity for durum wheat, there is a tremendous genetic variability in the indigenous material. Unfortunately, very little effort has been made to improve or utilize the local germplasm. Therefore, in cooperation with the Plant Genetic Resources Ethiopia, the improvement of the indigenous landraces and their utilization inbreeding programs will receive greater emphasis.

The success of wheat breeding will lie in the strategies and innovations that come through the application of molecular technologies, Include farmers view in all breeding process, Enhance generation of basic knowledge on genetics and breeding of wheat, Enhance breeding for resistance to biotic and abiotic stress, Improve local landraces by introgression of defensive and quality trait and Targeted breeding for quality traits (i.e nutritional and industrial).

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Conflict of Interest

The authors have not declared any conflict of interests.

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