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Ancient and novel Ethiopian durum wheat cultivars: What is the future for their cultivation?

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Durum wheat ancient cultivars have been grown in Ethiopia for centuries. Until the 1960s, durum wheat covered all wheat areas in the country; nearly all surfaces were represented by landraces. Now, the area dedicated to durum wheat has declined to approximately 15% of the wheat surface. Still, Ethiopia remains an immense genetic diversity resource for durum wheat. In 2019-21, a group of researchers conducted a field survey, assessment, and collection of durum wheat landraces in seven zones and 18 districts of different geographical growing areas at various altitudes in the country. The aim was to record their distribution, diversity, benefits, and define their probable future. Based on morphological differences and other characteristics, landraces received different local names, with a total of 26 names identified. Farmers mentioned that the medicinal value, taste, odor of its food, late planting time in the growing season of the crop, and its use for the preparation of local brewery had a high contribution to the existence of landraces and their diversity. However, according to the assessment result, genetic erosion is accelerating due to the scarcity of land caused by population growth, the substitution of landraces by improved durum wheat and bread wheat varieties, and less market availability for landraces. The adoption of more in situ conservation practices is essential to maintain the full diversity. Ethiopian durum wheat, which has immense diversity, could be a new source of resistant genes for national and international wheat improvement programs, exploiting valuable traits for many biotic and abiotic productions limiting factors, and utilizing unique and good agronomic traits.

Key words: Durum wheat landraces, field survey assessment, genetic erosion, in situ site establishment.

INTRODUCTION

Durum wheat landrace (*Triticum turgidum var durum*) is one of the ancient crops in Ethiopia whose diversity is still immense. The durum wheat landrace is predominantly grown in the Oromia, Amhara, and Tigray regions. It is a tetraploid wheat traditionally grown predominantly on heavy black clay soils (Vertisols) of the Ethiopian highlands between 1800-2700 masl, mainly produced by small-scale farmers.

In the 1960s and before that, Ethiopian wheat surfaces were dedicated to durum wheat landraces. The total area under wheat production in 1983 was reported to be 625,590 ha, of which 60-70% was estimated to be used

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for the production of durum wheat (Tesema, 1991). These days, the amount produced and the area under durum wheat production are not precisely known and are usually lumped together with bread wheat in reporting. However, approximately the durum wheat growing areas have declined to 15-20% from a total of 1.7 million ha of wheat-growing lands (Mengistu et al., 2016a), most of which are cultivated with Utuba and Mangudo, popular improved durum wheat varieties, and bread wheat. Currently, wheat is the third-largest crop in terms of area after Tef and Maize (CSA, 2017). In general, wheat (both bread and durum) is produced by around 4.62 million households with an estimated land area of 1.7 million ha and a mean national yield of 2.7 t/ha (CSA, 2018).

Durum wheat landraces are well-adapted to the environment, evolved through natural and artificial selections, and from crosses with related relatives. They have stable yields and are resistant to biotic and abiotic production-limiting factors. They perform well under low-input production as compared to improved varieties.

Even though modern cultivars are input-demanding, have a narrow genetic base, and are vulnerable to many biotic and abiotic factors with low adaptation, smallholder farmers prefer to grow these varieties due to land limitations. The expansion of high-yielding improved bread and durum wheat varieties gradually replaced local durum wheat varieties (landraces), resulting in the abandonment of broad genetic base farmers' varieties. This has led to an alarming rate of genetic erosion. Alemayehu et al. (2021) reported that, on average, 75.8% genetic erosion was observed in tetraploid wheat after 25 years based on direct farm assessments and survey studies in Lume, Adaa, and Chefe, respectively. The lowest genetic erosion was observed at Chefedonsa, which is found in the highlands of Shoa.

Still, the genetic diversity resource of Ethiopia for durum wheat is immense. Their contribution to the durum wheat improvement program on rust diseases like Sr13 for UG99 (Klindworth et al., 2007) and on other production constraints like drought and others was significant.

Ethiopia is one of the major centers of diversity for many plant species (Vavilov, 1951). Based on genetic diversity analysis, Mengistu et al. (2016b) reported high genetic variability in Ethiopian durum wheat landraces. Kabbaj et al. (2017) demonstrated that Ethiopian durum wheat landraces cluster separately from durum wheat of the International Centre for Agricultural Research in the Dry Areas (ICARDA), Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), and durum wheat derived from other countries.

Mengistu et al. (2016b), based on their study, suggested that Ethiopian durum wheat landraces are very diverse both within and among districts of origin and altitude classes. This wealth of genetic diversity should be exploited for wheat improvement in yield and for resistance to biotic and abiotic stresses, particularly terminal drought.

So far, 7,000 accessions have been collected in the Ethiopian Biodiversity Institute (IBC, 2013). A small part of the huge collection of durum wheat landraces hosted at EBI was characterized (Asmamaw et al., 2019; Mengistu et al., 2016a; Alemu, 2020). High genetic diversity within Ethiopian durum wheat landraces has been observed during surveys and collections, making them a target for national and international wheat improvement programs to exploit valuable traits for biotic and abiotic stresses. The objective of this study is to record their distribution, diversity, benefits, and define their probable future.

MATERIALS AND METHODS

In 2019-21, a group of researchers conducted a field survey, assessment, and collection of durum wheat landraces in 7 zones of 18 districts with different geographical and altitude ranges across the country. These genotypes will be planted at Chefedonsa (80 N 580 E, 2450 m.a.s.l research substation) and Debrezeit Agricultural Research Center (8°46′ N and 39°00′ E, 1870 m.a.s.l.) for characterization purposes.

All the necessary data important for the characterization of each genotype will be exhaustively collected. The data at Debrezeit will not be taken for all traits except for rust disease score, as Debrezeit is not the right place to grow and evaluate durum wheat landrace performances. However, since Debrezeit is a hotspot area for the evaluation of stem rust, it is suitable for disease evaluation purposes. For this reason, conducting one replica of the Chefedonsa trial at Debrezeit is essential to gather disease data from each line.

Chefedonsa is a location where durum wheat landraces are predominantly grown, and it has mid to high land agro-ecologies. Rust disease data is not frequently observed in the trial field at Chefedonsa. However, all the other necessary data, including days to heading, days to maturity, plant height, spike length, number of spikes per plant, number of spikelets per spike, spike density, thousand kernel weight, grain yield, glume color, glume hairiness, awn presence, seed color, test weight, and protein content, will be collected..

Survey study

The survey and collection of landraces have been conducted in the same areas, covering 4 regions, 7 zones, and 18 districts of durum wheat growing regions. The study regions include Oromia, Amhara, Tigray, and the Southern Nations, Nationalities, and Peoples' Region. Ethiopian landraces are found in a wide range of adaptation environments, with most of them located in mid to highland areas. Some places have become recently accessible, while others remain inaccessible for the collection of landraces as well as for interviewing farmers. Based on their morphological differences and other characteristics, landraces have been given different local names. A total of 81 smallholder farmers were interviewed in representative areas of durum wheat landrace growing regions.

RESULTS AND DISCUSSION

The dominant durum wheat-growing areas are Oromia and Amhara. Durum wheat landraces have different

Table 1. Durum wheat landrace growing areas and their name in the respective districts.

No.	Region	Zone	District	Local name
			Wechale	Qemede Guracha
		North Shoa	Debrelibanos	Shemete
			Worejarso	Qemedi Adi, Kemedi Guracha
1.	Oromia	Western shoa	Ambo	Brale
		Eastern shoa	Chefedonsa	Qurqurie
				Geja
				Gebre
				Bukere
		North shoa	Lemi	Gojam Gura (Yegojam Tikur Sndie), Shimte (white)
			Sela dngay	Amgne
			Mida woremo	Gojame sndie
		South wolo	Jama	Dmeto
			Legambo	Kurisht
			Akesta	Kurisht
			Borena	Kurisht
			Woreelu	Jiru
2.	Amhara	North Wolo	Meket	Geregera
				Gulo
		Eastern Gojam	Merto lemariam	Shimte (White and brown)
			Shebel Berenta	Abun egir
			Enemay and Djen	Wasma
			Quyi	Zenbolel
		North Gonder	Dabat and Wogera	Denkeze, Yigzaw sndie, Duragna, Anbete
3.	Tigray	South Tigray	Hagereselam	Melfa
				Wehabit
				Regiat

names in various districts of the regions. A total of 26 names have been identified in Oromia, Amhara, and Tigray regions. The names have been given based on their function, originality, growing environment, spike color, seed color, height, and growing areas' names.

Common names of durum wheat landraces in many parts of the country are: Yemesno sendie, Yedro sndie, Habesha sndie, Enat sndie, Aja, Macaroni sendie, Pasta sndie, Yeqnche sendie, Kuticha sendie, Yebetechirstian sendie. Some names in specific areas include: Brale, Qurqurie, Geja, Bukre, Gebre, Kemede Guracha, Gojam Gura (Yegojam Tikur Sndie), Shimte (white and brown), Gojam sndie, Dmeto, Qurisht (white and brown), Amgne, Abun egir, Zenbolel, Wasma (black and white), Mokele (brown spike), Bulga sndie, Kemede Adi, Laste, Denqeze, Yigzaw sndie, Duragna (Landrace mixed with Barley), Anbete Melfa, Wehabit, and Regiat (Table 1).

Most farmers say that durum wheat landraces are adapted to the environment and are reliable for giving a reasonable yield even in harsh seasons. This adaptability is due to their tolerance to biotic and abiotic stresses, having been exposed to different environments for many centuries. That is why most farmers in many areas do not want to lose their durum wheat landrace seeds.

Previous research reports and farmers' discussions in this survey study indicate that the loss of diversity in landraces has increased faster than expected in different areas of the country. This is because of the decline in

area coverage and the number of farmers cultivating durum wheat landraces. According to farmers' responses during their interviews, the root causes of this genetic erosion of durum wheat landraces are:

1. Lack of land availability due to population growth.
2. The substitution of improved durum wheat and bread wheat varieties due to their yield advantage.
3. The challenge of market availability for durum wheat landraces.

Farmers' response why they still keep durum wheat landraces with all the challenges

Even if farmers face serious market problems for durum wheat landraces and land shortages, many farmers still prefer the best landrace varieties over commercial varieties. Below are their responses during interviews explaining why they choose to grow them:

1. Durum wheat landraces are well-adapted to the environment, and they are resistant to many biotic and abiotic stresses.
2. They do not have significant desiccation problems in the field.
3. They yield reasonably well during harsh times.
4. Most of their seeds are compact and highly dense, producing more flour.
5. The taste and odor of their bread are unique compared to commercial varieties.
6. They can be grown under low-input conditions.
7. They have many medicinal, religious, and cultural values (maintenance, Holy Communion, soup, etc.).
8. The straw is soft and more palatable than the straw of commercial varieties.
9. They can be grown with residual moisture.
10. They are not labor-intensive compared to other crops during peak labor-demanding times, as durum wheat landraces are mostly planted late in the season.
11. They are resistant to seed abortion during sowing in waterlogging conditions.
12. They are good for malting to make local brewery.
13. They offer a choice of different seed colors (white, umber, yellow, light brown, purple).
14. Consuming durum wheat landrace food leaves individuals without a sense of hunger for a longer time.

Farmers also mentioned that, due to differences in morphology, durum wheat landraces provide various benefits. Their medicinal value, taste and odor of their food, late planting time in the growing season, and traditional use for preparing local brewery contribute significantly to the diversity of Ethiopian durum wheat landraces. This diversity is further influenced by differences in topography, altitude classes, and farming systems. Ethiopian durum wheat landraces are unique sources of useful traits with great diversity. Targeted collections have not been fully utilized in breeding programs. Natural and artificial forces in the selection of the crop, including high ecological variation and natural cross-fertilization, may explain this uncharacterized diversity, both morphologically and molecularly.

Why Ethiopian durum wheat landraces are unique and divers

Some of the reasons Ethiopian durum wheat landraces are unique and diverse are: Ethiopia has diversified agroecologies; Ethiopian farmers have the habit of growing composite genotypes of landraces called duragna for their local drinks, which in turn enhances natural cross-fertilization; a wide range of traditional use values of durum wheat landraces by smallholder farmers; and the habit of exchanging seeds among smallholder farmers.

The extent of durum wheat genetic deterioration and the necessity of establishing *in situ* conservation in Ethiopia

Before 2007, the genetic erosion of durum wheat landraces was low, and its area coverage was high. The accessibility of roads to many of the lowest administrative unit durum wheat landrace-growing areas of the country was also very limited. Currently, from the farmers' interview point of view, the previous production area coverage and the number of farmers growing durum wheat landraces are declining. The reduction in the number of landrace-growing farmers and area coverage confirms the danger and extent of genetic erosion on tetraploid wheat (Brown and Hodgkin, 2015).

The efforts of establishing ex-situ conservation have preserved part of the diversity, but it is still not enough, and it does not address all types of agroecologies. The ex-situ conserved materials would also have low possibilities for interaction with the environment and wild relatives to have more diversity. For the existence of all possible genetic diversity of the landraces, ex-situ conservation must be complemented with in-situ conservation.

Currently, only two in-situ sites were found during the survey to complement ex-situ conservation, which could not represent the durum wheat landrace-growing district differences and the whole altitude ranges. Hence, the adoption of more in-situ conservation practices is essential to maintain the full diversity. Landraces are genetically dynamic and are in equilibrium with biotic and abiotic stresses in the environments where they evolved (Mohammadi et al., 2015). Awareness generation via the joint work of national and international concerned organizations would be very valuable to keep this

important genetic resource. Ethiopian durum wheat, which has immense diversity, could be the new sources of resistant genes for national and international wheat improvement programs to exploit valuable traits for many biotic and abiotic production-limiting factors, and for the utilization of unique and good agronomic traits. The current gene source of modern varieties is mostly from CIMMYT and ICARDA international research organizations (Sall et al., 2019).

In conclusion, conservation at the on-farm level (in-situ) allows for continuing farmer selection, interaction with the environment, and gene exchange with wild species so that the evolution of landraces may continue. Under this system, many cultivated crop species have coexisted with local environmental factors, and the flow of genes among genotypes has taken place with minimum interference. The development of new variations and increasing the diversity within the crop genotypes has been aided. In the existing Ethiopian farming system, there is a possibility to establish in-situ conservation in all durum wheat landrace-growing areas. Ex-situ conservation needs to be complemented in a way that will maximize the retention and continued evolution of the adaptive qualities of landraces, which will avoid the loss of variation that occurs in sampling and maintenance.

Recommendations for Ethiopian durum wheat landraces to be recovered and conserved

1. Durum wheat landraces should be collected in places that were previously inaccessible, with a focus on identifying eroded areas.
2. Mapping and conducting baseline surveys of durum wheat landraces, along with recording farmers' indigenous knowledge.
3. Establishing sustainable representative in-situ gene banks in each durum wheat-growing kebele (the smallest administrative unit) with the awareness of targeted groups.
4. Ethiopian durum wheat landraces, having contributed in the past to the improvement of global breeding programs, require collaborative efforts between national and international organizations to preserve this world genetic resource wealth.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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