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Phenotypic diversity in Ethiopian durum wheat (*Triticum turgidum* var. *durum*) landraces

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ABSTRACT

The phenotypic diversity of 274 Ethiopian durum wheat accessions was analyzed, taking their geographic origins into account. The aim was to assess the extent and patterns of agronomically important phenotypic variation across districts of origin and altitude classes for major qualitative traits using diversity index and multivariate methods. Eight qualitative and three quantitative traits were scored for 2740 plants and analyzed for diversity. The Shannon–Weaver diversity (H') index was used to estimate phenotypic diversity. The estimated H' ranged from monomorphic for glume hairiness to highly polymorphic for other traits. The highest (0.86) H' was obtained for seed degree of shriveling, possibly indicating the differential responses of the genotypes to water deficit during later growth stages. With respect to district of origin, the highest (0.72) and lowest (0.44) H' values were obtained for the Bale and SNNP districts, respectively. With respect to altitude, the highest (0.76) and lowest (0.62) H' values were recorded for altitudes 1600–2000 and >3000 m above sea levels, respectively. Principal components analysis explained substantial variation contributed by district of origin and altitude range. Genotypes were clustered into three groups by districts of origin and altitude class, with relatively strong bootstrap values of 57 and 62 for the former and latter, respectively. It could be concluded 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 of yield and for resistance to biotic and abiotic stresses, particularly terminal drought.

1. Introduction

Ethiopian durum [*Triticum turgidum* var. *durum*, $2n = 4x = 28$] wheat is conspicuously diverse unexploited landraces. They harbor high variation, which is important for durum improvement of various traits [1–5]. Ethiopian durum wheat landraces are unique sources of useful traits [7,8], although collections have not been used to their full potential in breeding programs. The natural and artificial forces operating on the crop, including high ecological variation [3], isolation, differences in agricultural practices, and natural cross-fertilization [4] may explain this great diversity, which is molecularly largely uncharacterized.

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Use of crop diversity is one of several approaches to improving agricultural productivity and is a key to achieving global food security [9]. Knowledge of existing genetic diversity and its distribution in crop species is useful for germplasm conservation and selection of parents with diverse genetic background, thereby rendering crop improvement more efficient [10]. Crop landraces are described as geographically or ecologically distinct populations that show conspicuous diversity in their genetic composition both among populations (landraces) and within them [11] and display genetic variation for useful quantitative and qualitative characters [12]. These advantages pooled in landraces are not exploited by durum wheat improvement programs of Ethiopia, despite the country's large genetic diversity of durum wheat. These genetic resources, however, have contributed to world wheat improvement. For instance, Klindworth et al. [13] found that the Ethiopian durum wheat landrace *ST464* is one of the major sources of *Sr13*, the only known gene for resistance to *Ug99* or race *TTKS*, a new stem rust race currently threatening wheat production worldwide. The identification of Sr13 in Ethiopian durum wheat landraces and the fact that Ethiopia is one of the hot spots of *Ug99*, since it appeared in the country in 2003, make the country a center for stem rust screening and the primary durum wheat phenotyping site for the Durable Rust Resistance in Wheat Project that started in 2005.

Ethiopian farmers have been growing durum wheat for centuries, and as a result durum wheat covered 60–70% of the arable land under wheat cultivation in Ethiopia until the 1980s, with bread wheat (*Triticum aestivum*) covering only the remaining 30–40% [14]. However, the introduction of improved bread wheat from international breeding programs into Ethiopia and their wide adaptation with satisfactory yield potential has shifted the predominance to bread wheat and left durum wheat landraces almost an orphan crop. Now, approximately 80% of the wheat area in Ethiopia is planted to bread wheat [14], implying that 20% of the wheat area is planted to durum wheat. Tessema and Bechere [2] reported that improved durum varieties are grown on less than 20% of durum wheat cultivation area, because of a lack of a modern seed market and farmers' low purchasing power. The majority of durum wheat grown in Ethiopia is thus landraces consisting of large numbers of different genetic lines [15]. Information about the national annual production and productivity of durum wheat has not been separately documented in annual Ethiopian statistical abstracts published by the Ethiopian central statistical agency [35]. Data on the national annual average yields of durum wheat is still scanty. Yield reported by research institutions for improved durum wheat varieties in the central highland plateau of Ethiopia under researcher-managed conditions was encouraging, although it must not be considered to be the national average yield.

Consumer demand for wheat far exceeds domestic production, and wheat imports cost the country millions of dollars in foreign exchange [14,16]. Future gains in yield potential and quality standard of the produce are desirable and require exploitation of the largely untapped genetic diversity of durum wheat landraces housed in the national gene bank [17]. The geographic pattern of diversity of Ethiopian durum wheat has been documented [1,3,4,6,18–21]. However, these studies were limited to landraces collected from fairly restricted areas, mainly the central highlands of Ethiopia, and cannot give an overall picture of diversity across the country. The results from such studies are not dependable and are often misleading [6], as the contribution from geographical region of origin to total observed variability among the landraces is unknown. The aim of this study was to extend the assessment of the extent and patterns of phenotypic variation in Ethiopian durum wheat, sampled from major wheat growing regions of the country, to agro-morphological traits. Specifically, it aimed to determine the amount, extent and distribution of genetic variation in durum wheat landraces by district of origin and altitude class for selection of landraces to produce pre-breeding lines.

2. Materials and methods

2.1. Plant materials and data collection

A total of 274 durum wheat genotypes, 271 landraces and 3 improved varieties, representing the major wheat-growing areas of Ethiopia were studied (Table S1). The districts of collection of the landraces are shown as points in Fig. 1. Landraces from individual districts were considered independent populations except those collected from various districts of Southern Nations Nationalities and People (SNNP), which were pooled into a single population because their number was only eight (Table S1). The landraces were also classified based on the altitude of collection. They were collected from five altitude classes (Table S1). This altitude classification was also used by Hailu et al. [22]. Under rainfed conditions, wheat is grown mainly at altitudes ranging from 1800 to 3000 m.a.s.l. Consequently, a small number of landraces were sampled from the last altitude class. Two field experiments were conducted during the 2011/2012 main cropping seasons at Hagreselam Tigray (13°39′ N and 39°07′ E, 2590 m.a.s.l.) and Debre Zeit Agricultural Research Centre Station (8°46′ N and 39°00′ E, 1870 m.a.s.l.). At each site, an experiment was laid out in a partial lattice design with plots 2.5 m long and 1.2 m wide containing six rows with 20 cm inter-row spacing in two replications. Seed rate was adjusted to the recommended rate for each site (100 kg ha^{-1} for Hagreselam and 150 kg ha^{-1} for Debre Zeit). Fertilizer application was performed on the basis of 100 kg ha^{-1} DAP and 50 kg ha^{-1} UREA for the Tigray site (Hagreselam) and 100 kg ha^{-1} DAP and 100 kg ha^{-1} UREA for Debre Zeit. At each site, nitrogen fertilizer was applied in two splits: two thirds at planting and one third at knee stage. All agronomic practices were applied equally to experimental plots.

At each site, 10 representative spikes (five in each replication) were randomly sampled from each landrace, listed in Table S1, during harvesting and taken to a laboratory at Mekelle University for phenotyping for qualitative traits including spike density (SD), awn length (AL), kernel color (KC), kernel size (KS), glume color (GC), glume hairiness (GH), seed nature/texture or vitreousness (VT), beak awn (BA), and degree of seed shriveling (DSH). Scoring was performed for all 10 spikes based on the International Plant Genetic Resource Institute's (IPGRI) wheat descriptor list [32]. The numbers of phenotypic classes used for the Shannon–Weaver diversity index, which differed for each trait, are listed in Table 1. Data for days to 50% booting (DB) and days to maturity (DM) were recorded on a plot basis.