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RESEARCH

Wheat Landraces Currently Grown in Turkey: Distribution, Diversity, and Use

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ABSTRACT

From 2009 to 2014 a nationwide effort was made to document, collect, conserve, and characterize wheat landraces grown by Turkish farmers. Spike samples were collected from more than 1600 farmers from 59 provinces, planted as single-spike progenies, and classified into species, subspecies, and botanical varieties (or morphotypes). Altogether, 95 morphotypes were identified representing three species and six subspecies: einkorn wheat (*Triticum monococcum* L.), emmer wheat [*T. turgidum* subsp. *dicoccon* (Schrank) Thell.], cone wheat (*T. turgidum* subsp. *turgidum*), durum wheat [*T. turgidum* subsp. *durum* (Desf.) Husn.], bread wheat (*T. aestivum* L. subsp. *aestivum*), and club wheat [*T. aestivum* subsp. *compactum* (Host) Mackey]. Compared with a nationwide survey in 1920, these findings represent a loss of 50 to 70% of the diversity found in 1920, though in four provinces, little if any loss occurred. Based on the Shannon diversity index (*H′*) and number of morphotypes, the highest diversity for bread wheat was observed in Manisa, Konya, Iğdır, Diyarbakır, and Tokat provinces and for durum wheat in Adana, Diyarbakır, and Hatay provinces. Socioeconomic data indicated that landrace farmers are found mostly in remote mountainous subsistence communities with very little grain trade, small areas planted to wheat, and relatively simple production technologies. The key reasons famers continue to grow landraces are their grain qualities and adaptation to abiotic stresses. In situ conservation should be targeted at provinces with the highest morphotype diversity, with the rarest landraces, and with the highest share of farmers growing landraces.

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Abbreviations: FAO, United Nations Food and Agricultural Organization; *H′*, Shannon diversity index; IWWIP, International Winter Wheat Improvement Program.

Wheat is an important crop in Turkey with the planted area of >7 million ha and annual production exceeding 20 Tg (http://faostat.fao.org/). Annual consumption of bread and other wheat products in Turkey exceeds 200 kg per capita and is one of the highest in the world. The presumed center of wheat origin and diversity is situated in the Fertile Crescent (Feldman, 2001), which includes part of present-day Turkey. Thus, the diversity of wheat and its wild relatives in Turkey has a global role in providing important genetic resources for wheat improvement. A comprehensive review of the history, characteristics, and use of wheat landraces in Turkey has been recently published by Karagöz (2014). There have been several major collection expeditions for wheat landraces beginning shortly after establishment of the Turkish Republic in 1923 with an expedition by the Russian Vavilov Institute following a route of some 12,000 km in Anatolia in 1925 and 1926, which documented agricultural practices and crops and collected >5700 crop samples including 291 of wheat (Zhukovsky, 1927). The Russian expedition was assisted by

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Turkish scientist Mirza Gökgöl who conducted a nationwide inventory of wheat crop in the early 1930s. Upon his request, seed samples with short descriptions (landrace name, species, planting season, irrigated or rainfed, elevation, and share of wheat area occupied) were sent to him from all administrative provinces and districts of Turkey. Overall, 2120 samples were collected. They were all grown at the Istanbul Yesilkoy Experimental Station (present-day Istanbul Ataturk Airport) and classified according to botanical traits. His findings were summarized in two volumes titled *Turkish Wheat* (Gökgöl, 1935, 1939). These books are an invaluable source of information on the status of wheat production prior to industrialized agriculture and provide baseline data for wheat landraces coverage prior to introduction of modern cultivars.

Since the 1930s, major collections were made in 1948 by Harlan (1950), who collected 2121 landraces from 63 provinces, and in 1984 by three international teams across provinces where wheat landraces were threatened. Several regional and local collections and studies of wheat landraces were done recently (Damania et al., 1996; Karagöz, 1996; Qualset et al., 1997; Tan, 2002; Karagöz and Zencirci, 2005; Akçura & Topal, 2006; Giuliani et al., 2009). There are more than 22,000 Turkish wheat landraces in ex situ collections worldwide (https://www.genesys-pgr.org). Peak collection years were in 1948 (1917 accessions, Harlan collection), 1970 to 1972 (1485 accessions); 1979 (1846 accessions), and 1984 (2515 accessions). In general, the past diversity of wheat landraces is well represented in ex situ collections including the Turkey Gene Bank in Menemen (İzmir). Socioeconomic aspects of wheat landraces in several provinces of Turkey were studied by Brush and Meng (1998) and the results served as the basis of an extended discussion on Anatolian wheat landraces by Brush (2004). However, no systematic countrywide study of existing landraces has been done since M. Gökgöl's work in the 1930s. The concept of national inventories of the landraces gained high popularity in Europe and was supported by EU-wide projects (Negri et al., 2012). These inventories not only targeted identification of what is grown where, but also suggested different options for in situ conservation and use of landraces. However, in the case of wheat there are very few landraces remaining in farmers' fields in Europe. In North America, there is a community of amateur wheat landrace advocates, and seeds can be obtained from several providers (http://www.ancientcerealgrains.org; http://www.growseed.org). Wheat landraces are still grown in Asia, on a relatively substantial scale in northwestern Iran (Koocheki et al., 2008) and Afghanistan (Buerkert et al., 2006), but no recent inventories have been conducted. In 2012 to 2014, surveys and collections supported and guided by FAO and CIMMYT identified, collected, and characterized wheat landraces in Uzbekistan (Baboev et al., 2015) and Tajikistan (Husenov et al., 2015). The fact that very few farming communities in few countries still maintain wheat landraces provides an important justification for their inventory, collection, and conservation.

The International Winter Wheat Improvement Program (IWWIP; www.iwwip.org), based in Turkey, develops germplasm for central and western Asia. The IWWIP is a cooperative program between the Ministry of Food, Agriculture, and Livestock of Turkey, CIMMYT, and ICARDA, and has operated since 1986. Its breeding activities are implemented through a multilocational network in Turkey in close cooperation with the key wheat breeding programs in the region. The main emphasis of IWWIP breeding is broad adaptation, disease resistance, and grain quality. Annually, IWWIP germplasm is sent to cooperators throughout the central and western Asia region and globally for evaluation and selection. More than 65 cultivars originating from IWWIP germplasm have been released in the central and western Asia region. The IWWIP initially turned its attention to wheat landraces as a source of drought tolerance to enhance adaptation for moisture-limiting environments and started testing them in yield trials. Their superior performance under drought suggested expansion of this work and, thus, IWWIP examined options for collecting seeds of landraces from farmers' fields. After this work started, it was realized that the scale of wheat landrace cultivation in the country far exceeded expectations, IWWIP opted to implement a countrywide inventory.

After collections have been made, it is important to describe the diversity they represent. There is a methodology for describing wheat genetic resources using morphological and agronomic traits (International Board for Plant Genetic Resources, 1985). Genomic technologies for diversity analysis have gained popularity for wheat and were recently reviewed by Khan et al. (2014). For example, Alsaleh et al. (2016) recently completed a detailed study of a collection of Kunduru durum wheat landrace accessions from Turkey and showed how genomic information can be used to understand landrace diversity. In the present study, we used the taxonomic and botanical description approach that was used by previous collectors: Zhukovsky and Gökgöl in the 1920s and 1930s. This approach is based on assignment of each sample to a species and a botanical variety (or morphotype as referred in this paper) based on the following highly heritable traits: presence or absence of awns and their color; color and pubescence of glumes, spike density, and grain color (Zuev et al., 2013). This system was initially developed by Körnike in the 1880s and then expanded and applied to Russian wheats in the 1900s by Flaksberger, later expanded by Vavilov in the 1920s and 1930s, while describing his worldwide collections, and eventually summarized by Dorofeev in the 1970s (Zuev et al., 2013). Though it never gained wide-scale popularity, it is routinely used at

Vavilov Research Institute of Plant Industry (Russia) and by gene banks in Germany, Poland, and Czech Republic. Carvalho et al. (2009) successfully used combination of genomic approaches and botanical variety description to characterize old Portuguese bread wheat cultivars. Morphotype approach was also recently used for description of durum wheat diversity (Carmona et al., 2010).

The Turkish national wheat landrace survey was conducted from 2009 to 2014 by IWWIP, the Turkish Ministry of Agriculture, and the United Nations Food and Agricultural Organization (FAO) with the aim of documenting the presence of landraces across the country and collecting them for characterization, conservation, and use. A comprehensive description of this work was provided by Kan et al. (2015) and an analysis of the socioeconomic aspects by Kan et al. (2016).

MATERIALS AND METHODS

Landrace collection was accompanied by a socioeconomic survey of the farmers growing the landraces. The methodology of collections and survey was developed at a workshop in early 2009 and was largely based on a strategy adopted by Brush and Qualset in Turkey in the early 1990s (Brush, 2004). The details of the methodology have been described by Kan et al. (2015). Considering the large territory of Turkey and a wheat production area exceeding 7 million ha, the development of the collection plan represented a significant challenge. The identification of areas of landrace cultivation was based on the knowledge and experience accumulated at the agricultural research institutes of the Ministry of Food, Agriculture and Livestock. There are 12 institutes involved in wheat breeding and research with regional mandates covering the whole country. They identified collection and survey areas in their respective regions. The collection and survey teams usually included a breeder, an agronomist, and a socioeconomist. The teams communicated with provincial agricultural authorities to identify the districts within the provinces where the landraces were likely to be grown. The teams further communicated with district administrations to identify the areas and villages likely to maintain landraces. This chain of communication was very effective and demonstrated that the areas of the landrace cultivation are commonly known by the agricultural administration at the district level. The teams visited the sites for preliminary appraisals to develop the final collection plan.

The collections and surveys were made in June to August, depending on the region and crop development, to observe landrace fields near or at maturity and to collect spike samples. The team's objective at the village level was to collect representative samples of the diversity of wheat landraces found there. Spike collections in the fields were made randomly following diagonal directions at regular intervals. The objective was to collect at least 100 spikes from each field visited. The sample of spikes was tagged by the geocoordinates of each field, the farmer's name, and the local name for the landrace. Each sample of spikes is considered to represent a random population from the field where it was collected. Seed bulks were also collected from a farmer's storage when available. Precise geocoordinates were recorded for ~80% of the collection sites. In the remainder of cases, the coordinates were recorded for the village nearest the field site where collections were made. The socioeconomic survey instrument used during face-to-face interviews with the farmers included 30 points focusing on the following topics: (i) farmer family information, (ii) wheat production details, (iii) marketing, and (iv) farmers perception of their landraces. About 80% of the collections were accompanied by completed surveys. For the remaining 20%, basic data about the farmer, including name, family, and total area in which wheat was grown, were recorded. The collections and surveys began in 2009 in three provinces (Erzurum, Karaman, and Konya) and continued progressively until 2014 as the wide-scale cultivation of landraces in Turkey was revealed. In total, 1630 fields were visited, and collections of spikes were made from 1448 of them. Seed bulks were collected from 162 farm stores. The collections were made in 59 out of the 81 provinces of Turkey, demonstrating a wide-scale cultivation of wheat landraces.

Table 1. Names and characteristics of the main morphotypes of *Triticum aestivum* ssp. *aestivum* and *T. turgidum* ssp. *durum*.

Morphotype designation by species†		Status of morphotype traits			
T. aestivum ssp. *aestivum*	*T. turgidum* ssp. *durum*	Presence of awns	Glume pubescence	Glume color	Grain color
albidum	*candicans*	No	No	White	White
lutescens	*schechurdinii*	No	No	White	Red
alborubrum	*subastrale*	No	No	Red	White
milturum	*stebutii*	No	No	Red	Red
leucospermum	*muticovalenciae*	No	Yes	White	White
velutinum	*muticinazillennse*	No	Yes	White	Red
delfi	*muticitalicum*	No	Yes	Red	White
pyrotrix		No	Yes	Red	Red
greacum	*leucurum*	Yes	No	White	White
erythrospermum	*affine*	Yes	No	White	Red
erythroleucon	*hordeiforme*	Yes	No	Red	White
ferrugineum	*murciense*	Yes	No	Red	Red
meridionale	*valenciae*	Yes	Yes	White	White
hostianum	*durum*	Yes	Yes	White	Red
turcicum	*italicum*	Yes	Yes	Red	White
barbarossa	*aegyptiacum*	Yes	Yes	Red	Red

† Additional traits can be used in morphotype characterization: *compactoides* will be added to the morphotype designation for a semidense spike; plants of *T. aestivum* with dense spikes will be classified as subspecies *T. aestivum* ssp. *compactum* with a different suite of morphotype designations depending on the four traits; spikes with black awns will be additionally distinguished by the prefix *pseudo-* added to the morphotype designation.

The samples were sent to Bahri Dağdaş International Agricultural Research Institute in Konya for analyses of the landrace morphotype composition. The samples were classified to wheat species following van Slageren (1994) (http://www.k-state.edu./wgrc/Taxonomy/comptri.html) and to morphotype following classifications used by Dorofeev et al. (1979) and recently updated for bread wheat by Zuev et al. (2013). The morphotype description is based on qualitative morphologic spike and grain traits with their combination defining specific groups (Table 1). Zhukovsky (1927), while analyzing collections from Turkey, identified a group of bread wheats that were intermediate between bread wheat and club wheat. It was classified as a different type called *grex compactoidum*. Gökgöl (1939)

Fig. 1. Main regions of wheat landrace cultivation in Turkey based on surveys and collections in 2009 to 2014. 1, southern coastal; 2, Aegean; 3, western Black Sea; 4, central Black Sea; 5, central Anatolia; 6, northeastern Anatolia; 7, southeastern Anatolia; 8, central–eastern Anatolia; 9, eastern Mediterranean. ▲ = approximate collection sites.

also identified these forms as a separate group. This study followed this classification as well. The number of spikes of each species and morphotype was counted and recorded. Approximately 70% of the landraces were mixtures of different species or morphotypes. A spike sample was assigned to wheat species and morphotype based on the major morphotype component representing 65% or more of the overall composition. Some collections were discarded if they were modern cultivars or were repetitions from the same landrace and the same farmer. In total, 1372 samples were available for field evaluations including 1034 samples accompanied by socioeconomic data. After description and classification, the spikes were planted as head rows in the fall of the collection year in Konya, Eskişehir, or Erzurum (totaling >20,000 head rows). During the season, all head rows were again classified by morphotypes to confirm or correct initial classification. Field selection of the best head rows took place while maintaining diversity. Selected head rows were bulked, and their progenies were tested in yield trials for two consecutive years. Agronomic data have been collected through replicated trials on >1000 landrace selections but not presented here. Shannon diversity index was calculated for each province and region separately for bread and durum wheat as described by Jain et al. (1975) based on the frequency of different morphotypes for each geographic area. Genetic erosion of wheat landrace diversity from the 1920s was evaluated by comparing the number of landraces, number of morphotypes, their frequency as reported by Gökgöl (1939), and as observed in the present study. The seeds of collected landraces and passport data have been deposited at the Turkish National Gene Bank in Ankara.

RESULTS AND DISCUSSION

Wheat Landrace Cultivation Regions in Turkey

Definition of the main areas of wheat landrace cultivation was based on similarity with respect to local landrace names, species, subspecies, and morphotype diversity. The physical landscape, natural borders, mountains, and valleys were also taken into account. The names of the farmers' wheats revealed that very similar landraces from the same village or district might have different names or landraces belonging to different species would have the same name. The detailed distribution of landraces at the province and district level is presented by Kan et al. (2015). The following nine major landrace cultivation regions are identified in Fig. 1, showing approximate collection sites, and in Table 2 where limited descriptive information is given:

1. Southern coastal region includes the Taurus mountains in Mersin, Konya, Karaman, and Antalya provinces, the Bey Mountains of Muğla, Burdur, and Isparta provinces, and mountains surrounding the Menderes River through the provinces of Denizli, Aydın, and İzmir. Almost 60% of all the landraces in this region are durum wheat with morphotype *hordeiforme* being the most common. Bread wheat, including the *grex compactoidum* type, accounts for 33.7%.
2. Aegean region includes the western transitional zone between the central Anatolia Plateau and the Aegean and Marmara Seas. The overall landscape is mountainous with average elevation below 1000 m asl. The frequency of durum wheat landraces was 13.5%. Bread wheat landraces were grown in every province with a high diversity of names and morphotypes.
3. Western Black Sea region strictly follows the Köroğlu mountain range. Durum and bread wheat landraces on average are almost equally represented. Einkorn wheat was found in four provinces: Bolu (landraces Yazlık Iza and Kislik Iza); Karabük

Table 2. Geographic regions of wheat landraces cultivation and proportion of main landraces and morphotypes by wheat species.

			Triticum turgidum ssp. *durum*†		*T. aestivum* ssp. *aestivum*†		Others‡	
Region	Province	No.	%	Main landrace (%) (*morphotype*)	%	Main landrace (%) (*morphotype*)	%	Species or subspecies (landrace)
1. Southern coastal	Adana, Antalya, Burdur, Denizli, Isparta, İzmir, Karaman, Konya, Mersin, Muğla	193	59.6	Sarı B. (35.2) (*hordeiforme*); Koca B. (31.4) (*hordeiforme*, *leucurum*)	26.4	Göderedi (27.8) (*greacum*, *erythrospermum*); Koca B. (26.4) (*erythroleucon*, *greacum*)	14.0	TAAC (Sarı B.); TAC
2. Aegean	Afyon, Balikesir, Bursa, Çanakkale, Kütahya, Manisa, Uşak	96	13.5	Ak B. (46.1) (*leucurum*); Sarı B. (23.0) (*leucurum*)	42.7	Ak B. (26.8) (greacum, *erythrospermum*); Köse B. (14.1) (*albirubrum*)	43.8	TAAC (Çalıbasan); TM
3. Western Black Sea	Bartın, Bilecik, Bolu, Düzce, Eskişehir, Karabük, Kastamonu, Sinop	115	35.6	Sarı Kelle (46.3) (*murciense*, *hordeiforme*); Sofu B. (19.5) (*murciense*)	38.3	Sarı B. (15.5) (*ferrugineum*, *erythrospermum*); Kırmızı Pazarcık (13.3) (*erythrospermum*, *ferrugineum*)	26.1	TM (Yazlık, Kislik Iza); TTD (Gernik)
4. Central Black Sea	Amasya, Kırıkkale, Ordu, Samsun, Tokat, Yozgat	130	57.6	Üveyik B. (22.7) (*hordeiforme*); Sofu B. (*leucurum*)	26.9	Çam B. (41.5) (*ferrugineum*, *erythrospermum*); Ak Dimenit (9.7) (greacum, *erythrospermum*)	15.5	TTD (Siyez, Mahsul B.); TM (Mahsul B.)
5. Central Anatolia	Adana, Aksaray, Kayseri, Kırşehir, Nevşehir, Niğde, Sivas	96	9.4	Şahman (80.9) (*hordeiforme*)	87.5	Kamçı (34.1) (*albirubrum*); Zerun (30.9) (*delfii*)	3.1	
6. Northeastern Anatolia	Ağrı, Artvin, Bayburt, Bitlis, Erzurum, Giresun, Gümüşhane, Iğdır, Kars, Van	228	1.7	–	84.2	Kırik (23.1 (*albirubrum*, *delfii*); Karakılçık (7.7) (*pseudo-meridionale*); Topbaş–(6.7) (*delfii*, *erytroleucum*)	14.1	TAAC; TAC (Topbaş)
7. Southeastern Anatolia	Batman, Diyarbakır, Mardin, Şanlıurfa, Siirt, Şırnak	144	61.1	Kırmızı B. (19.3) (*murciense*); Sorgül (17.2) (*murciense*, *hordeiforme*); Karakılçık– (12.4) (*reichenbachii, valenciae*)	26.3	Kırmızı B. (18.4) (*ferrugineum*); Sergun (18.4) (*erythrospermum*)	12.6	TAAC (Bağacak); TTC
8. Central–eastern Anatolia	Adıyaman, Bingöl, Elazığ, Kahramanmaraş, Malatya	166	31.9	Siverek (26.4) (*hordeiforme*); Ohlemaz (15.1) (*africanum*)	52.4	Aşurelik B. (19.5) (*erythroleucon*); Çirpuz (18.4) (*erytroleucum*); Ağ Buğdayı (14.1) (*erythroleucon*)	13.8	TAAC (Kırmızı B., Ak B.); TTT
9. Eastern Mediterranean	Adana, Gaziantep, Hatay, Kilis, Osmaniye	114	68.4	Karakılçık (24.3) (*reichenbachii, leucomelan*); Alibayır (9.0) (*africanum*); Havrani (9.0) (*leucurum*)	22.8	Kelbuğday (36.0) (*albidum*, *lutescens*); Bozbuğday (15.0) (*erythrospermum*, *greacum)*	7.8	TAAC; TAC (Amik B.)

† B., Buğday (wheat).

‡ TAC, *T. aestivum* ssp. *compactum*; TAAC, *T. aestivum* ssp. *aestivum* grex *compactoidum*; TM, *T. monococcum*; TTD, *T. turgidum* ssp. *dicoccon*; TTT, *T. turgidum* ssp. *turgidum*.

(Kaplıca Buğdayı); Kastamonu (Siyez, Gernik), and Sinop (Catal Siyez, Gernik).

4. Central Black Sea region represents the northern transitional zone with high rainfall and is dominated by durum wheat, especially in the Amasya, Kırıkkale, and Samsun provinces. Hulled einkorn wheat (landrace Mahsul Buğday) and emmer wheat (Siyez) were collected in Samsun province.
5. Central Anatolia region has scattered, relatively high mountains and also includes the Cappadocia region famous for its landscape. The landraces of bread wheat were predominant (87.5%) with a great diversity of morphotypes: *albirubrum, albidum, erythroleucum,* and *delfii*.
6. Northeastern Anatolia region is almost entirely composed of high mountains including the Pontic, Mescit, Aras, and Ala ranges. There are almost no durum wheat landraces here. Wheat production is challenging because of severe cold in winter and short, hot summers. Bread wheat landraces Kırik, Karakılçık, and Topbaş are cultivated on relatively large scales as a result of their specific adaptation and excellent grain quality.
7. Southeastern Anatolia region follows the southeastern Taurus Mountains and the valley of the Tigris River. Frequency of durum wheat exceeds 60%, with a high diversity of morphotypes dominated by

murciense. Bread wheat landraces are mainly *ferrugineum* and *erythrospermum* morphotypes.

8. Central–eastern Anatolia region extends from Adıyaman to Bingöl provinces along the Euphrates River. Though it is close and similar to the previous region, the composition of the landraces is quite different. Bread wheat landraces collectively exceed 60% of all landraces collected. The landraces are also relatively uniform with the dominant *erythroleucum* morphotype. Durum wheat landraces are present in Adıyaman and Malatya provinces.
9. Eastern Mediterranean region includes the hills and mountains along the border with Syria. The share of durum wheat landraces is the highest among all regions (68.4%) with the great diversity of landraces and morphotypes. There is no dominating morphotype for durum wheat. Bread wheat landraces, although not numerous, were also represented by club wheat and grown in all provinces.

In general, wheat landraces were found in all the ecological regions of Turkey except the European Thrace region, where highly industrialized crop production is practiced. In Regions 1, 4, 7, and 9, durum wheat landraces dominate; in Regions 2, 5, 6, and 8, bread wheat landraces are more frequent; and in Region 3, they are about equal (Table 2). A limited number of landraces were not assigned to bread or durum wheat as they were complete mixture of two species with almost equal representation. It is difficult to estimate the area of landrace plantings in Turkey. Their widespread presence and great diversity does not translate into coverage of large areas. Karagöz (2014) estimated that wheat and barley landraces are grown on an area exceeding 0.55 million ha. The current study agrees with this estimate. The other important question is how many landraces are cultivated in Turkey. This is again difficult to estimate without using modern genomic tools. Even in the same province or region, phenotypically similar landraces have different names. The third important question concerns the extent that the current collection included all the wheat landraces in Turkey or whether some additional surveys are needed. By no means did this study visit all areas growing wheat landraces in Turkey. However, we believe that the majority of landraces have been collected.

Diversity of Wheat Landraces Among Provinces and Regions

From the conservation perspective, it is important to identify the areas with the highest genetic diversity and the areas with the greatest danger of losing rare genetic diversity (Negri et al., 2012). There is a diversity of landraces at a regional or provincial level. Assuming that morphotypes of different wheat species represent units of diversity, then a higher number of botanical varieties translates into higher diversity. The Shannon diversity index was calculated for data from the 30 provinces where the number of collections exceeded 15 as well as overall for each of the nine regions (Table 3). For durum wheat, the highest diversity of morphotypes and Shannon index were in the southeastern Anatolia and eastern Mediterranean regions with Diyarbakır (Shannon index $H' = 1.88$) and Adana ($H' = 2.15$) provinces having the most diverse durum wheat landraces. For bread wheat, the highest diversity was found for Manisa province (Aegean region) accounting for 38 morphotypes with the highest Shannon index among all provinces (2.65) and with the highest diversity within individual landraces: 5.5 components per landrace. The province of Manisa is followed by Konya ($H' = 2.21$), Iğdır (2.20), Diyarbakır (2.17), Tokat (2.17), Adıyaman (2.07), and Bitlis and Adana (both 2.06). Considering the variation of all wheat species and subspecies the highest diversity was in the Aegean region (four species; $H' = 3.01$) followed by the eastern Mediterranean (two species; $H' = 2.84$) and northeastern Anatolia (two species; $H' = 2.75$) regions. Though the Shannon index for the western Black Sea and central Black Sea regions is not high (2.08 and 2.27, respectively), they host very rare emmer wheat and einkorn wheat landraces.

The diversity of the landraces in the provinces may derive from numerous diverse collections with very high intralandrace homogeneity. Alternatively, the diversity may come from highly mixed landraces and populations. Each situation requires a different strategy for collecting and in situ conservation. The former would be treated as fixed cultivars of a self-pollinated crop, while the maintenance of the second group requires attention to the balance of different components. Some landrace cultivars, like the durum wheat Kunduru, originated as selections from landrace populations and have been grown subsequently in relative uniformity (Alsaleh et al., 2016). The structure of wheat landrace diversity is different depending on the region and province. In Manisa province, a center of bread wheat landrace diversity, only one collection out of 56 was homogeneous and the others represented mixtures or populations (Table 3). In provinces such as Samsun, Kahramanmaraş, and Malatya, the share of homogeneous landraces exceeded 60%, demonstrating that they had been maintained for a long time in relative purity, much like modern cultivars. Inter- and intralandrace heterogeneity is important for agronomic performance and the overall wheat genetic diversity and its drivers need to be understood. A preliminary Kompetitive allele-specific polymerase chain reaction–single nucleotide polymorphism based genetic diversity study of >2100 bread wheat lines selected from the landraces has been completed (Morgounov et al., 2015). The results of the genomic analysis will be coupled with the morphotype

Table 3. Genetic diversity of wheat landraces in provinces and regions as estimated by the number of landraces, number of morphotypes (NoM), Shannon diversity index (H'), percentage of uniform landraces (% ULR), and the number of morphotypes per landrace (M/LR).

Region	Province	No. of landraces in province	No. of species	*Triticum turgidum* ssp. *durum*		*T. aestivum* ssp. *aestivum*		All species			
				NoM	H'	NoM	H'	NoM	H'	% ULR	M/LR
1. Southern coastal	Antalya	30	2	6	0.87	13	0.87	19	1.56	3.3	4.4
	Karaman	42	2	3	0.48	13	1.66	16	1.86	30.9	2.5
	Konya	59	2	4	0.29	17	2.21	21	1.97	25.4	3.1
	Mersin	25	2	4	0.67	7	1.58	11	1.41	28.0	2.3
	Region	183	3	9	0.71	25	2.17	35	2.02	31.1	2.8
2. Aegean	Manisa	56	3	7	0.58	38	2.65	47	2.75	1.8	5.5
	Region	97	4	8	0.86	46	2.83	57	3.01	15.5	4.6
3. Western Black Sea	Bilecik	20	2	3	0.47	8	1.51	11	1.08	5.0	3.1
	Bolu	21	3	4	0.81	9	1.80	14	1.37	10.0	3.2
	Sinop	23	3	3	0.40	5	0.52	9	1.43	26.1	2.4
	Region	115	4	4	0.73	19	1.55	26	2.08	13.9	2.9
4. Central Black Sea	Samsun	30	4	3	0.29	8	1.74	14	0.83	70.0	1.6
	Tokat	56	2	3	0.75	30	2.17	33	2.27	19.6	3.1
	Yozgat	16	2	4	0.92	9	1.27	13	1.73	25.0	3.2
	Region	130	4	5	0.97	33	2.17	41	2.27	32.3	2.8
5. Central Anatolia	Aksaray	32	2	2	0.42	16	1.76	18	1.99	6.2	3.5
	Niğde	25	2	2	0.69	12	0.95	14	1.07	4.0	3.4
	Sivas	19	1	0	–	7	0.48	7	0.48	10.5	2.3
	Region	108	2	4	0.46	20	1.67	24	1.93	13.9	2.8
6. Northeastern Anatolia	Ağrı	56	2	1	–	19	1.77	20	1.78	1.9	3.2
	Bitlis	19	2	0	–	17	2.06	17	2.06	5.5	3.1
	Erzurum	47	1	0	–	16	1.57	16	1.57	21.3	2.5
	Giresun	30	2	3	1.01	13	1.65	16	1.87	16.7	3.0
	Gümüşhane	19	1	0	–	12	1.86	12	1.86	47.3	2.1
	Iğdır	33	2	2	0.06	22	2.20	24	2.29	36.4	2.2
	Region	176	2	5	1.24	39	2.67	43	2.75	29.0	2.7
7. Southeastern Anatolia	Diyarbakır	59	2	11	1.88	20	2.17	31	2.69	33.9	2.2
	Mardin	39	2	3	0.44	5	0.78	7	1.15	38.5	2.0
	Siirt	25	2	3	0.90	8	1.46	11	1.90	28.0	3.2
	Region	144	2	11	1.71	22	1.95	33	2.48	31.2	2.4
8. Central–eastern Anatolia	Adıyaman	27	2	9	1.24	16	2.07	28	2.35	22.2	2.9
	Elazığ	16	2	1	–	10	0.64	12	1.08	68.7	2.2
	K. maraş	25	2	1	–	10	1.55	11	1.70	62.5	2.0
	Malatya	95	2	5	1.13	18	0.94	25	1.70	60.0	1.9
	Region	165	2	9	1.20	32	1.35	46	2.00	49.1	2.1
9. Eastern Mediterranean	Adana	28	2	11	2.15	16	2.06	27	2.77	25.0	3.1
	Gaziantep	15	2	4	1.12	7	1.25	11	1.48	53.3	2.0
	Hatay	45	2	10	1.71	16	1.41	26	2.25	35.3	2.4
	Region	114	2	14	2.21	27	2.32	41	2.84	35.9	2.4
Overall		1229	4	14	1.69	64	2.68	89	3.06	29.5	2.9

classification and agronomic data to delineate individual landraces and establish a core set of germplasm for further detailed study.

Erosion of Wheat Landraces Diversity in 2010s versus 1920s

Gökgöl (1935, 1939) provided detailed botanical description of the landraces following Vavilov's approach. The Gökgöl data were transferred into spreadsheets and served as a baseline for evaluation of the changes in landraces diversity collected in this study. One of the challenges in making such a comparison was the change in the administrative division of provinces and districts as well as their renaming, which took place in the last 80 to 90 yr. While the Gökgöl books listed 60 provinces, present-day Turkey is divided into 81 provinces. The Gökgöl surveys identified the actual area cultivated with different landraces, while the current study used the frequency of the landraces collected with the assumption that it could be appropriately translated into an area estimate.

Table 4. Wheat landrace diversity for selected provinces in Turkey found in the 1920s compared with the current results (2000s).

Region	Province (districts)†	Period	No. of landraces	Percentage of landraces belonging to different species‡				No. of morphotypes	
				TAA	TAC	TTD	Others	Total	Per landrace
Southern coastal	Adana (Feke, Kozan, Saimbeyli)	1920s	8	12.8	7.4	50.4	29.4 (TTT)	31	3.9
		2000s	10	47.4	3.1	45.1	0	35	2.7
	Konya (Bozkır, Hadim)	1920s	6	2.8	48.8	48.4	0	20	3.3
		2000s	8	35.5	5.7	57.9	0	22	2.7
Aegean	Manisa (Akhisar, Kula)	1920s	9	5.9	24.4	69.7	0	47	5.2
		2000s	10	78.8	0.4	17.0	3.8 (TTT)	41	4.1
Western Black Sea	Bolu (Mudurnu)	1920s	5	71.1	10.0	18.7	0	16	3.3
		2000s	4	11.5	0	29.1	54.4 (TM)	4	1.0
Central Black Sea	Samsun (Ladik, Vezirköprü)	1920s	11	22.0	2.2	75.8	0	29	2.6
		2000s	4	1.5	0	81.3	17.2 (TTD,TM)	16	4.0
	Tokat (Merkez)	1920s	5	33.5	10.6	55.9	0	22	4.4
		2000s	9	39.0	0.1	58.3	0	26	2.9
	Yozgat (Merkez, Akdağmadeni)	1920s	2	2.8	19.5	77.7	0	17	1.5
		2000s	5	40.5	0.5	57.4	0	13	2.6
Northeastern Anatolia	Ağrı (Diyadin, Eleşkirt)	1920s	9	97.4	0.4	0.1	2.12 (TTC)	38	4.2
		2000s	4	100.0	0	0	0	7	1.7
	Erzurum (Oltu, Pasinler)	1920s	16	84.4	1.8	10.7	2.3 (TTC)	68	4.2
		2000s	6	75.3	23.0	0	0	13	2.2
	Giresun (Şebinkarahisar)	1920s	5	23.1	43.2	33.6	0	26	5.2
		2000s	9	83.6	0	9.4	0	13	1.4
	Gümüşhane (Kelkit, Torul)	1920s	10	41.1	28.0	31.9	0	33	3.3
		2000s	5	100.0	0	0	0	12	2.4
Southeastern Anatolia	Diyarbakır (Lice, Çermik, Ergani)	1920s	12	64.8	0.1	35.8	0	27	2.2
		2000s	10	33.8	3.2	59.9	0	12	1.2
	Mardin (Midiyat, Savur)	1920s	5	10.3	21.7	67.9	0	23	4.6
		2000s	3	28.4	0	71.5	0	4	1.3
	Siirt (Eruh, Merkez)	1920s	5	51.8	7.8	39.5	0	34	6.8
		2000s	7	42.0	0.2	57.8	0	21	3.0
Central–eastern Anatolia	Elazığ (Baskil, Merkez, Palu)	1920s	13	55.8	5.7	27.7	5.2 (TTT)	32	2.5
		2000s	3	87.1	1.1	0	11.2 (TTT)	7	2.3
	Kahramanmaraş (Elbistan)	1920s	5	42.9	0.9	38.5	17.6 (TTT)	22	4.4
		2000s	2	24.5	0	72.6	0	2	1.0
	Malatya (6 districts)	1920s	20	56.0	9.7	23.9	0	46	2.3
		2000s	10	69.6	0.6	29.3	0.1 (TTT)	22	2.2
Overall		*1920s*	*146*	*39.9*	*14.2*	*41.5*	*3.3*	*213*	*3.7*
		2000s	109	52.9	2.2	38.0	5.1	63	2.3

† Merkez designates the central district of each province.

‡ TAA, *T. aestivum* ssp. *aestivum*; TAC, *T. aestivum* ssp. *compactum*; TTC, *T. turgidum* ssp. *carthlicum*; TTD, *T. turgidum* ssp. *dicoccon*; TTT, *T. turgidum* ssp. *turgidum*; TM, *T. monococcum.*

For a combination of 17 provinces and districts, the coverage of Gökgöl's surveys was matched by the current study (Table 4). The first observation was that the names of the landraces changed over time almost entirely. Gökgöl mentioned generic names of 93 landraces, while the current collection from the same provinces and districts mentioned 81 names. However, only 18 names were preserved. In the 1920s the most common name was Kislik (winter wheat) at 15.6%, followed by Karakılçık (blackawn wheat) and Yazlık (spring wheat) at 8.0% each. Currently the most common name is Ak Buğday (white wheat) at 9.8% followed by Sarı Buğday (yellow wheat) at 7.9%, Kırik (cracked) at 6.7%, and Kırmızı Buğday (red wheat) at 4.1%. As agronomy evolved, climate changed, and adaptive requirements for wheat production changed, the landraces evolved and acquired new names reflecting their properties, use, or origin. The second observation was that in the past, up to 40% of wheat was planted in the spring, and currently, >95% of the landraces are planted in the fall.

In the 1920s, throughout the provinces and districts listed in Table 4, bread wheat and durum wheat occupied almost equal acreage: 39.9 and 41.5%, respectively, with an additional 14.2% of area devoted to club wheat. Currently, bread wheat landraces dominate planted

areas (52.9%), durum wheat landraces have been slightly reduced (38.0%), and club wheat landraces almost entirely disappeared (2.2%). This tendency of higher frequency of bread wheat at the expense of club and durum wheat is more pronounced in Adana, Konya, Manisa, Yozgat, Giresun, Gümüşhane, and Elazığ provinces. The frequency of durum wheat landraces increased in areas traditionally growing this crop: Diyarbakır, Mardin, and Siirt. The changes in environments, agronomy, and farmers' preferences resulted in substantial changes affecting not only the proportion of different species but their composition as well. The predominant morphotypes had changed in 30% of the districts for bread wheat landraces and in 50% of the districts for durum wheat landraces.

The loss of genetic diversity can be estimated by the frequency of rare species. Cone wheat disappeared in Adana and Kahramanmaraş but was observed in Manisa province after not being registered there before. Einkorn wheat was not observed in Bolu and Samsun provinces in the past, but several fields of it were identified by this study. The reduction in the number of morphotypes per province varied from 90% in Kahramanmaraş to an actual increase in Konya province. Erzurum had the highest number of morphotypes in the past (68) compared with the 13 identified now. Manisa province lost very little—only six morphotypes. Adana, Konya, and Tokat provinces seemed to gain some diversity. The landraces grown now are more homogeneous (on average 2.3 morphotypes per landrace) than the observations of the 1920s (3.7). The total number of morphotypes listed by Gökgöl for the provinces and districts in Table 4 was 213 vs. 63 identified in the present study, a loss of 70%. However, the description of the morphotypes by Gökgöl went into minor details such as the length of awns (using the prefix *sub-* for morphotypes with shorter awns), the color of the glume (using prefixes: *griceo-*, *negro-*, *triste-*, *rubro-* for different colors), and the state of the culm (using prefix *pleno-* for solid culm). This detailed description by Gökgöl identified 62 minor morphotypes with frequencies below 0.2%. In the present study, such a detailed degree of description was not attempted because of limitations in capacity and time. However, even if we remove 62 minor morphotypes from the estimate of Gökgöl, there has still been a 59% loss of distinct morphotypes. If we compare all collections of the 1920s with those of the present time without a focus on the common comparison areas of Table 4, from all the eight species or subspecies, 388 morphotypes were identified then compared with 95 now, a 75.5% reduction.

The Drivers of Wheat Landrace Diversity

The first and foremost question is why Turkish farmers still cultivate wheat landraces. Socioeconomic data collected during the survey and summarized by regions for durum and bread wheat growers is presented in Supplemental Table S1 and for selected provinces in Table 5. The landrace farmers are found mostly in remote mountainous subsistence communities with market distance exceeding 15 to 20 km and having very little grain trade (<3.4% for bread wheat and <6.4% for durum wheat). Cultivated wheat area per farm varied from <1 ha in the southern coastal region to a maximum of 4 to 5 ha in the central Black Sea region, which is lower than regional averages. The share of farmers never changing seed exceeds 43% for bread wheat landraces and 31% for durum wheat landraces. Hand planting or use of primitive spreaders is practiced, on average, by 74% of farmers and hand harvesting by almost 40%. A substantial share of farmers apply seed chemical treatment to prevent seed-transmitted diseases. The average age of farmers exceeds 53 yr and 90% of them either lack formal education or graduated only from primary school. On average, there are >5.3 people per household growing landraces vs. the national average for rural areas of 4.9. Depending on the region, up to 80% of the farmers have tried modern cultivars and most of them kept growing them along with landraces. The proportion of area growing wheat landraces to total wheat area in farmers' fields varied from 45 to 55% in the central Black Sea region and up to 98% in the southern coastal region.

Farmers have access to modern cultivars but still keep their landraces. The main reason for maintaining landraces is satisfaction with the landraces' performance. While, on average, only 25 and 30% (bread wheat and durum wheat growers, respectively) of the farmers rated yield of the landraces as good; 83% of the respondents for bread wheat and 93% for durum wheat were happy with the grain quality and its suitability for homemade products (Fig. 2). The other highest ranked traits for bread wheat and durum wheat, respectively, were straw yield (74 and 80%) and straw quality (70 and 76%), cold tolerance (78 and 82%), and drought tolerance (71 and 84%). For most of these traits, durum wheat landraces were rated slightly higher than bread wheat landraces. It appears that excellent adaptation of landraces to cold and drought coupled with highly suitable grain quality were the key factors considered by farmers when they decide to keep the landraces. The second, less obvious, but also important, factor is tradition and inclination of the farming communities to follow the practices of the older generation and peers.

Very substantial differences between provinces in the diversity of wheat landraces (Table 3, 5) may be explained by diversity in the wheat production environments, changeable weather and climate, different farmers' practices (including use of machinery and the end use of grain and straw), initial wheat diversity at the time when industrial agriculture started, rate of spontaneous hybridization, and possibly other factors. Characteristics of the farmers in the provinces with the high (Manisa, Tokat, Diyarbakır, and Adana) and relatively low (Samsun, Mardin, and Siirt)

Table 5. Socioeconomic and technical characterization of farmers growing wheat landraces in selected provinces of Turkey.

	Region						
	Aegean	Central Black Sea		Southeastern Anatolia			Eastern Mediterranean
	Selected province						
Parameter	Manisa	Samsun	Tokat	Diyarbakır	Mardin	Siirt	Adana
No. of farmers surveyed	48	21	53	57	30	25	28
No. of wheat species	3	4	2	2	2	2	2
No. of morphotypes	47	14	33	31	7	11	27
Shannon diversity index (*H′*)	2.75	0.83	2.27	2.69	1.15	1.90	2.77
No. of morphotypes per landrace population	5.5	1.7	3.2	2.1	1.9	2.7	3.1
Elevation above sea level (m)	667	735	1074	831	968	826	1062
Farmer age, years	53.5	51.4	55.2	54.1	48.3	43.0	49.3
No. of people in household	4.7	5.0	4.1	8.2	6.4	4.6	3.8
Market distance (km)	21.8	17.4	17.7	19.0	14.6	36.1	28.1
Total land (ha)	5.7	9.6	5.8	5.9	5.5	4.2	2.6
Total wheat area (ha)	1.3	6.2	3.5	3.3	2.4	1.8	1.2
Share of landraces in total wheat (%)	100	28.2	52.9	73.7	100	100	84.0
Percentage of farmers:							
Without education or with primary school only	95.8	95.4	90.6	90.2	100	100	92.3
Using wheat for bread	64.6	0	18.9	18.9	0	0	46.4
Using wheat for bulgur	27.1	0	26.4	14.0	0	0	46.4
Using their own seed	97.9	85.7	84.9	89.4	100	94.4	92.8
Never changing seed	79.2	57.1	5.7	0	0	0	78.6
Cleaning seed	82.1	80.9	73.6	91.2	3.3	5.5	82.1
Trying modern cultivars	0	100	64.1	52.6	3.3	0	21.4
Keeping modern cultivars	0	90.5	58.5	50.9	3.3	0	21.4
Planting by hand or spreader	100	80.9	86.8	89.5	76.7	72.2	100
Harvesting by hand	75.0	42.9	32.1	17.5	3.3	0	75
Selling grain	0	9.5	1.2	1.7	0	0	0
Selling straw	16.7	85.7	24.5	5.2	0	0	0

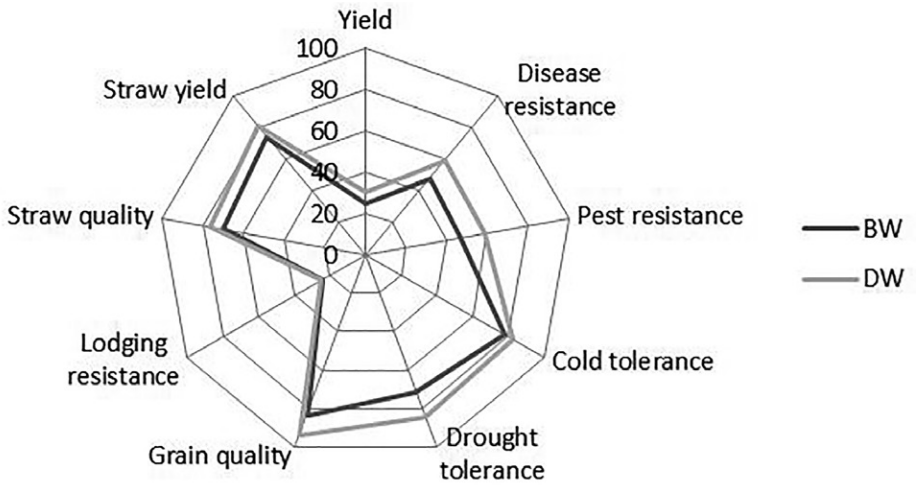

Fig. 2. Percentage of farmers' ratings of different traits of bread wheat (BW) and durum wheat (DW) landraces as good based on a survey of 1026 households in Turkey in 2009 to 2014.

diversity of landraces are presented in Table 5. It may appear that older farmers from Diyarbakır province grow more diverse landraces than relatively younger farmers from Mardin and Siirt provinces in the same region. However, relatively young farmers of Adana province also grow very diverse landraces. In Manisa province, none of the farmers grow modern cultivars; they only grow landraces, and the diversity is very high. On the other hand, in Tokat and Diyarbakır provinces, >50% of the farmers grow diverse landraces and modern cultivars side by side.

It seems that there is no clear socioeconomic premise that explains higher diversity in one province vs. the other.

On-farm diversity of wheat is of fundamental importance for sustainable production and diversity conservation. This diversity is manifested by farmer cultivation of more than one landrace, heterogeneity vs. homogeneity of landraces, or cultivation of a combination of landraces and modern cultivars. Kan et al. (2015, 2016) analyzed the current data set and concluded that except for age, none of socioeconomic factors (number of people and the labor force in the households, educational level, etc.) affected the farmers' preferences for growing wheat landraces only or both modern cultivars and landraces produced together. The share of farmers growing only landraces in the age group >50 yr old was 64.0%, while among the group of farmers younger than 50 yr old only 36.0% of growers opted for landraces only. This is another warning sign that the newer generation of farmers is more willing to try the modern cultivars, and data showed that up to 80% of those who tried were likely to keep them in the farming system.

The survey identified 99 farmers (9.7%) who cultivate more than one landrace (Table 6). These are possibly champions of wheat diversity who are keen to work with more landraces. Most of these farmers (65) maintain different wheat species probably to meet different end-use needs. The number of morphotypes found per landrace population in this group of farmers is 10% higher than that found for farmers who grow only one landrace. Interestingly, these farmers are slightly younger (52.7 yr vs. 55.3) and better educated, own substantially more land (7.6 ha vs. 5.7 ha), grow more wheat (3.3 ha vs. 2.6 ha), rely more on their own seed production (94.8 vs. 85.5%), and change seed less frequently than the group of farmers who grow only one landrace. The degree of machinery use for planting and harvesting is similar between the two groups. The farmers growing more than one landrace are better satisfied with the yield performance (32.2 vs. 23.5%), disease resistance (56.7 vs. 48.6%), and drought tolerance (75.1 vs. 70.1%) of their landraces. They are less likely to grow modern cultivars, thus preserving the landraces. These farmers have been registered in the study database and are potential entry points for programs to reinforce on-farm, in situ conservation of wheat landraces.

Overall, the underlying causes of differences in diversity among geographical regions and administrative provinces are still not clearly understood and require more in-depth analysis. Effects of elevation and biotic and abiotic stresses play an important role. Damania et al. (1996) demonstrated that Turkish durum wheat landraces were more diverse at lower elevations. A survey of 287 households in Eskişehir, Kütahya, and Uşak provinces in 1992 demonstrated that environmental heterogeneity and the risks and high cost of obtaining wheat products with the desired quality was the main reasons to maintain landraces (Brush and Meng, 1998). While considering the household determinants of wheat diversity, higher wealth, better education, and younger age were the main factors reducing on-farm diversity through incorporation of modern cultivars or cultivation of more uniform landraces. At the same time, a high probability of the household to cultivate landraces was not related to the degree of diversity of individual landraces.

Table 6. Socioeconomic characteristics of farmers growing only one wheat landrace versus farmers growing two or more landraces.

Characteristic	Farmers growing: One landrace	Farmers growing: Two or more landraces
No. of farmers	1016	99
Percentage of farmers	91.3	9.7
No. of morphotypes per landrace population	2.79	3.00
Farmers age (yr)	55.3	52.7
Percentage of farmers graduating primary school and above	68.8	73.2
No. of people in household	5.6	5.0
Total farm land (ha)	5.7	7.6
Wheat area (ha)	2.6	3.3
Share of landraces in wheat area (%)	80.4	83.1
Percentage of farmers:		
who tried modern cultivars	36.6	31.0
who kept modern cultivars	33.3	28.1
who use hand planting	64.2	65.9
who use own seed	85.5	94.8
who never change the seed	39.4	44.6
who use hand harvesting	41.3	38.9
Percentage of farmers rating the following traits as good for their landraces		
Grain yield	23.5	32.2
Disease resistance	48.6	56.7
Cold tolerance	75.9	76.0
Drought tolerance	70.1	75.1
Grain quality	85.5	88.7

Home Use of Wheat Landraces

Wheat grain in the rural areas is used for two main purposes: bread, including typical loaves and thin types, and bulgur or cracked wheat, which is cooked in water. Respectively, bread and durum wheat are normally used for these two products. Based on the survey of the farmers in the regions growing primarily bread wheat (Aegean, central Anatolia, northeastern Anatolia, and central–eastern Anatolia), its grain is mainly used for bread (64.3 to 83% of farmers; Table 7). Of the four regions dominated by durum wheat, grain in the southern coastal and eastern Mediterranean regions is mainly used for bulgur (55.5 and 87.1%, respectively). The durum grain in the central Black Sea and southeastern Anatolia regions is used for both bulgur and bread (61.1 and 83.3%, respectively). Generally, the farmers were quite flexible in dual use of their grain for bread, bulgur, and other homemade products.

Table 7. Use of bread wheat (BW) or durum wheat (DW) landraces in different regions of Turkey (percentage of farmers surveyed).

Region	End-product			Landrace quality rated as good
	Bread	Bulgur	Both	
	%			
1. Southern coastal				
DW	9.5	55.5	35.2	96.8
BW	60.0	5.0	31.7	88.3
2. Aegean				
DW	–	–	–	
BW	83.0	3.8	13.2	75.0
3. Western Black Sea				
DW	5.1	74.4	5.1	95.2
BW	45.2	33.3	4.8	97.4
4. Central Black Sea				
DW	4.2	27.8	61.1	72.2
BW	55.5	14.8	37.1	31.5
5. Central Anatolia				
DW	10.5	84.2	5.2	100.0
BW	75.4	5.3	19.3	89.6
6. Northeastern Anatolia				
DW	–	–	–	
BW	64.6	0.5	28.7	86.1
7. Southeastern Anatolia				
DW	2.4	14.3	83.3	96.3
BW	41.6	8.4	50.0	92.8
8. Central–eastern Anatolia				
DW	0	11.8	88.2	100
BW	64.3	5.1	26.5	92.6
9. Eastern Mediterranean				
DW	9.7	87.1	3.2	95.4
BW	67.7	19.3	3.0	93.6

Most of the club or compact wheat is used for dual purposes. Hulled einkorn wheat is used for bulgur in the Bolu region and for animal feed elsewhere. Emmer wheat is almost entirely used for animal feed.

The degree of satisfaction with the grain quality was not related to the end use of the landraces. Durum wheat farmers in the central Anatolia region were 100% satisfied with the grain, mostly using it for bulgur. In the southeastern Anatolia and central–eastern Anatolia regions, the durum farmers also gave very high ratings to the quality of their landraces, using them for dual purposes (bread and bulgur). Bread wheat farmers in the western Black Sea region were highly satisfied with their grain (97.4%), using it for bread and bulgur. The lowest rating of grain quality was in the central Black Sea region: 72.2 and 31.5% for bread wheat and durum wheat landraces, respectively. This may be explained by interference of modern cultivars in the rating because this region has the highest share of farmers growing both landraces and improved cultivars. This region is also characterized by high rainfall, including during the wheat maturation period, which may affect quality.

CONCLUSIONS

Despite the small total area of wheat landrace production in Turkey, the nationwide landrace distribution and diversity is significant for the global heritage of humankind, and it has now been well documented, collected, and preserved. The reduction in number of morphotypes compared with the 1920s was documented in this study and exceeded 70% in some regions. However, comparing wheat landraces of the past with those of the present demonstrated that they are evolving and very different from what they were 90 to 100 yr ago. This study suggests that long-term cultivation of wheat landraces and their exchange by farmers results in their continuous enhancement, adaptation, and creation of new genetic diversity. In situ conservation efforts in Turkey should focus on three major areas: (i) provinces with the highest diversity of landraces as identified by the number of morphotypes and Shannon diversity index (Adana, Adıyaman, Aksaray, Bitlis, Diyarbakır, Hatay, Manisa, and Tokat provinces); (ii) provinces hosting rare species like einkorn and emmer wheat (Bolu, Karabük, Kars, Kastamonu, Kütahya, Samsun, and Sinop); and (iii) provinces with the highest share of farmers growing both landraces and modern cultivars because of the likelihood of the latter replacing the former (primarily provinces of the western Black Sea and central Black Sea regions).

Future wheat landrace conservation and utilization efforts in Turkey should be directed at two targets. The first is how to conserve existing landraces and possibly expand their area and diversity. In addition to important in situ conservation practices and policies, genetic improvement of landraces and returning them to farmers may be a viable option. Modern breeding tools allow rapid selection and incorporation of desired traits while preserving the overall integrity of the landraces. Their competitiveness with modern cultivars could be improved and lead to greater and more enduring use by farmers. In 2015, the International Treaty on Plant Genetic Resources (http://www.planttreaty.org) awarded CIMMYT a project to conserve wheat landraces on farmers' fields in Turkey, Afghanistan, and Iran. The second target should be further description, classification, evaluation, and use in breeding and research programs of the tremendous diversity of the collected wheat landraces. Up to now, >1000 landrace selections have been subjected to a robust system of multilocational testing in Turkey, and superior genotypes have been identified. Having survived for so long, these landraces are highly valuable genetic resources for meeting the challenges of modern agriculture.

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