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Research Article
(Araştırma Makalesi)

Rıza IŞIK [1]

R. Refika AKÇALI GIACHINO [2*]

[1] District Directorate of Agriculture and Forestry, 35980 Dikili, Izmir, Türkiye

[2] Ege University, Faculty of Agriculture, Department of Field Crops, 35100 Bornova, İzmir, Türkiye

* Corresponding author (Sorumlu yazar):

refika.giachino@ege.edu.tr.

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Performance of durum wheat landraces concerning on grain yield and spike characteristics in Bornova ecological conditions*

Bornova ekolojik koşullarında yerel makarnalık buğday çeşitlerinin tane verimi ve başak özelliklerine ilişkin performansı

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ABSTRACT

Objective: The aim of this study was to determine the grain yield and spike characteristics of durum wheat landraces collected from different regions of Türkiye under Bornova-Yakaköy conditions and to determine the best adapted varieties for the region.

Materials and Methods: In the 2021-2022 growing season, the trial was carried out with three replications according to the randomized blocks trial design in Yakaköy conditions of İzmir/Bornova district. Nine local durum wheat varieties and three standard varieties were used as material. Within the scope of the study, heading time, maturity time, spike length, spike weight, number of spikelet per spike, number of grains per spike, grain weight per spike, spike harvest index and grain yield properties were investigated.

Results: Statistically significant differences were found between the landraces and the standard varieties for all traits except spike harvest index. Regarding heading times and spike length, it was observed that the local landraces exhibited higher values than the standard varieties. In terms of spike weight, Akpüsen landrace exhibited 22.7% higher mean value than the standard varieties. The local landraces exhibited a 53% decrease in grain yield compared to the standard varieties.

Conclusion: Akpüsen, Şahman, Kunduru and Sarı Bursa varieties had differences in terms of yield by giving higher values than both the landrace average and the general average.

ÖZ

Amaç: Bu çalışma ile Türkiye'nin çeşitli bölgelerinden toplanmış yerel makarnalık buğday çeşitlerinin Bornova-Yakaköy koşullarındaki tane verimi ve başak özelliklerinin belirlenerek yöreye en iyi adaptasyon sağlayan çeşitlerin tespit edilmesi amaçlanmıştır.

Materyal ve Yöntem: Deneme 2021-2022 yetiştirme sezonunda İzmir/Bornova ilçesi Yakaköy koşullarında tesadüf blokları deneme desenine göre üç tekrarlamalı olarak yürütülmüştür. Denemede materyal olarak dokuz yerel makarnalık buğday çeşidi ve üç standart çeşit kullanılmıştır. Çalışma kapsamında başaklanma süresi, olgunlaşma süresi, başak uzunluğu, başak ağırlığı, başakta başakçık sayısı, başakta tane sayısı, başakta tane ağırlığı, başak hasat indeksi ve tane verimi özellikleri incelenmiştir.

Araştırma Bulguları: Başak hasat indeksi hariç tüm özellikler için yerel ve standart çeşitler arasında istatistiksel olarak önemli farklılıklar bulunmuştur. Başaklanma zamanı ve başak uzunluğu bakımından yerel çeşitlerin standart çeşitlerden daha yüksek değerlere sahip olduğu görülmüştür. Akpüsen çeşidinin başak ağırlığı ortalaması standart çeşitlerden %22,7 daha yüksek olmuştur. Yerel çeşitler, standart çeşitlere kıyasla tane veriminde %53'lük bir düşüş sergilemiştir.

Sonuç: Akpüsen, Şahman, Kunduru ve Sarı Bursa yerel çeşitleri hem yerel çeşit ortalamasından hem de genel ortalamadan daha yüksek değerler vererek verim bakımından fark yaratmıştır.

INTRODUCTION

Wheat (*Triticum* spp.) is a plant belonging to the family of Gramineae (Poaceae) (Quisenberry & Reitz, 1967). This strategic cereal species is widely cultivated worldwide. Wheat is a rich source of nutrients and plays an important role in the nutrition and trade of many countries. It is also used in animal nutrition and industry (Pala et al., 2018; Kılıç et al., 2022). Durum wheat (*Triticum turgidum* L. var. *durum* Desf.) is the most important cultivated tetraploid (2n = 4x = 28, AABB) wheat species, with a limited distribution across the globe. It plays a significant role in global trade. Durum wheat is cultivated on approximately 14 million hectares worldwide, with an annual production of 34.5 million tons of grain (2022-2023) (International Grains Council (IGC), 2024). The area under durum wheat cultivation represents approximately 6.2 percent of the total area under wheat cultivation and 4.5 percent of the total wheat production (Blanco, 2024). The countries that produce the majority of durum wheat are the European Union, Canada, Türkiye, Algeria, Morocco, the United States, Mexico, China and India. The European Union is the first producer of durum wheat with more than 7.5 million tons of grain, with Italy playing a leading role. Canada is the most important exporter in the world durum wheat market, as it exports most of its production. The European Union is among not only the major producers and exporters, but also the most important consumer (Anonymous, 2024a; Blanco, 2024). In Türkiye, durum wheat cultivation area is 1.26 million hectares with a production of 4.3 million tons (TUIK, 2024). Currently, durum wheat accounts for about 16% of the total national wheat area and about 10% of the global durum wheat area (International Grains Council, 2022; Martínez-Moreno et al., 2022). Türkiye's durum production increased by 15% to 4.3 million tons in 2023/24, turning Türkiye from a net importer of durum into a major exporter (Anonymous, 2024b). With record durum wheat production at a time of limited supply, Türkiye has emerged as a major player in international grain markets. As a result, Türkiye's durum exports are estimated to reach 1.7 million tons (Stratégie Grains, 2024).

Wheat was cultivated approximately 12,000 years ago in the region called 'Fertile Crescent', which includes Türkiye, and spread all over the world from Anatolia (Salamini et al., 2002). In this sense, Türkiye is a very important gene center that hosts the wild relatives of wheat in the primary and secondary gene pool (Karagöz, 2014). As a result of natural evolution and hybridization from the wild relatives of wheat in Anatolia and selection by humans, varieties suitable for local needs have started to emerge. Local wheat varieties are the genotypes that are developed by farmers using traditional methods and have adapted to a certain region with the effect of natural selection (Zencirci, 2018). These local wheats were intensively cultivated until the 20th century. The cultivation areas of local wheat varieties decreased rapidly and almost disappeared, especially after the widespread use of new high-yielding, short-length breeding varieties (Green Revolution). Although certain local wheat landraces exhibit considerable potential in terms of traits such as adaptability, quality, flavor and aroma, their grain yield is comparatively limited in comparison to those of commercial varieties. In the present era, the yield and net income per unit area of traditional local wheat varieties are unable to compete with those of cultivated varieties. However, in recent years, there has been a notable increase in interest and demand for local wheat landraces and products derived from them on a global scale, including in Türkiye. This offers a promising opportunity for local wheats. Local landraces are cultivated using traditional methods on a limited number of small-scale family farms, often in unfavorable environmental conditions. The significance of genetic materials is growing annually on a global scale, with a particular focus on the protection of gene resources, particularly local populations. Local wheat landraces, which are estimated to be cultivated in less than 1% of the total wheat cultivation area of Türkiye (Mazid et al., 2009), are also of significance in terms of creating genetic resources, particularly for breeding studies. Indeed, numerous researchers have asserted that local landraces possess considerable potential for use in breeding studies (Zanatta et al., 1996, 1998; Jaradat, 2012). The conservation of wheat diversity is possible by protecting the wild relatives of wheat and old local landraces. This is only possible if the necessary conservation measures are taken with the participation and co-operation of all interest groups. In order to ensure the sustainability of local landraces, the efforts should be encouraged by farmers to protect local

landraces that are disappearing with the widespread use of modern wheat varieties. It is of great importance to determine the beneficial characteristics and potentials of local wheat varieties that can be used in wheat breeding programs and to grow those that are well adapted to regions with global climate change with sustainable practices in ecological conditions. The objective of this study was to determine the performance of the local wheat varieties in Bornova-Yakaköy conditions and to identify the varieties that provide the best adaptation to the region. The aim was to characterize nine local durum wheat varieties and three standard varieties, collected from different locations, in terms of some spike characteristics and grain yield.

MATERIALS and METHODS

Plant Material

The plant material of the study consisted of nine durum wheat landraces collected from different regions of Türkiye (Table 1) and three varieties obtained from the Aegean Agricultural Research Institute. These registered varieties were used as standards. Although Ağ Buğday and Yazlık Adana local varieties are classified as 'bread' wheat (*Triticum aestivum* subsp. *aestivum*), they are used for various purposes, including pasta production in certain regions. The research was conducted in 2021-22 growing season in Bornova Natural Agriculture Center and Farm Area (Yakaköy/Bornova). The area, where the experiment was established, is at the coordinates of 38°50'08'' north latitude and 27°18'09'' east longitude, and its altitude is approximately 320 meters above sea level.

Table 1. Durum wheat genotypes used in the experiment

Çizelge 1. *Denemede kullanılan makarnalık buğday genotipleri*

Genotypes		Source
Karaburun Sarı Buğday	Landrace	İzmir
Sarı Bursa	Landrace	Balıkesir
Ağ Buğday	Landrace	Yozgat
Kunduru	Landrace	Yozgat
Yozgat Sarı Buğday	Landrace	Yozgat
Şahman	Landrace	Yozgat
Yazlık Adana	Landrace	Adana
Koca Buğday	Landrace	Denizli
Akpüsen	Landrace	Manisa
Şölen	Standard Variety	AARI
Poyraz	Standard Variety	AARI
Alatay	Standard Variety	AARI

*AARI: Aegean Agricultural Research Institute.

Method

In the research, field experiments were conducted according to the randomized block design with three replications. The plot size of the experiments was 1.20 m x 5 m = 6 m^2 at harvest, sown as 6 rows with 20 cm row spacing. The sowing norm was 500 seeds m^{-2} and the seeds were sown by hand at a depth of 3-4 cm. In the research, sowing was carried out on 13 November 2021. No fertilizer was applied before and after sowing. In addition, the trial area was entirely dependent on natural precipitation, with no supplementary irrigation employed. When the plants reached harvest maturity, they were harvested by hand and threshed with a threshing machine on 25 June 2022. Heading times, maturity time, spike length, spike weight, spike weight, number of spikelet in spike, number of grains in spike, grain weight in spike, spike harvest index and grain yield per hectare were determined according to the method described by Akkaya & Akten (1985) and Pask et al. (2012). Statistical analyses were performed using SPSS V.22 software. The differences between the means were determined according to the least significant difference (LSD) test.

Some physical and chemical properties of the soils of the research area are given in Table 2, and the average climatic data for 2021-2022 and long years are given in Table 3.

According to the soil analyses carried out in the laboratories of Ege University, Faculty of Agriculture, Department of Soil, the soils of the research area have clayey-loamy texture, medium alkaline character and low salt content. Organic matter content of the soils is sufficient and lime content is high (Table 2).

Table 2. Some physical and chemical properties of soil of the trial area

Çizelge 2. *Deneme alanı toprağının bazı fiziksel ve kimyasal özellikleri*

Depth (cm)	0-30
Soil reaction (pH)	8.1 (medium alkaline)
Salinity (%)	0.05 (Unsalted)
Lime ($CaCO_3$) (%)	22.1 (Very Calcareous)
Sand (%)	44.96
Mile (%)	28
Clay (%)	27.04
Soil structure	Clay-Loam
Organic matter (%)	3.22 (Adequate)
Total N (%)	0.319 (Excess)
Available Phosphorus (P)	15.6 (Adequate)

Table 3. Climatic data of Bornova/Yakaköy district where the experiment was conducted

Çizelge 3. *Denemenin yürütüldüğü Bornova/Yakaköy'e ait iklim verileri*

	Temperature (℃)		Precipitation (mm)		Relative Humidity (%)	
Months/Years	2021-2022	Long Years	2021-2022	Long Years	2021-2022	Long Years
October	15.4	16.8	47.0	50.6	68.3	68.9
November	12.9	12.1	63.4	61.5	80.8	76.1
December	8.0	7.4	225.0	104.2	92.8	83.8
January	4.5	6.0	68.4	186.2	81.3	84.3
February	7.0	8.1	130.6	94.6	85.0	80.3
March	5.3	10.2	26.0	89.0	64.6	73.7
April	14.8	14.1	29.1	46.4	61.9	64.2
May	19.7	19.1	7.9	41.5	50.2	59.3
June	24,2	23.0	19.7	55.1	49.6	58.2
Average	12.4	12.4	617*	729.0*	70.5	72.05

General Directorate of Meteorology, *: Total value.

RESULTS and DISCUSSION

In this study, conducted in Bornova/Yakaköy arid conditions, the analysis of variance results of the mean squares of nine landraces and three standard durum wheat varieties for heading time, maturity time, spike length, spike weight, number of spikelet in spike, number of grains in spike, grain weight in spike, spike harvest index and grain yield are shown in Table 4. The findings of the variance analysis of the collected data demonstrated that there were significant differences at $p<0.05$ and $p<0.01$among the varieties for all traits, with the exception of spike harvest index. The mean of the analyzed traits and the groups formed are given in Table 5.

Table 4. Results of variance analysis for all examined traits in durum wheat genotypes

Çizelge 4. *Makarnalık buğday genotiplerinde incelenen bütün özelliklere ait varyans analiz sonuçları*

Source of Variation	DF	Heading Times	Maturity Times	Spike Length	Spike Weight	Number of Spikelet in spike	Number of grains in spike	Grain weight in spike	Spike harvest index	Grain yield
Genotype	11	92.364	113.785	3.243	1.539	29.922	226.523	0.884	47.303	11240.575
Repetition	2	33.583	1.361	0.090	0.036	1.157	8.396	0.013	10.428	3316.021
Error	22	29.492	1.967	0.255	0.012	3.309	3.992	0.011	46.354	4002.264
General	35	49.486	37.075	1.184	0.493	11.550	74.182	0.285	44.599	6237.948
F value		3.132**	7.842**	12.725**	129.433**	9.043**	56.741**	81.007**	1.020ns	2.809*
Coefficient Variation (%)		4.42	3.61	7.6	6.1	11.2	6.8	8.2	10.0	33.2

*: p<0.05; **: p<0.01; ns: not significant; DF: degrees of freedom.

Days to heading (days)

When the heading times of durum wheats used in the study were analyzed, significant differences were found among the genotypes at p<0.01 level and with a coefficient of variation of 4.42% (Table 4). While the heading time of the genotypes varied between 114 days and 132 days, the general average was found to be 123 days. The durum wheat genotypes formed six different groups (Table 5).

Among the landraces, the highest heading time was 132 days for Koca Buğday, followed by Kunduru with 129 days, Yozgat Sarı Buğday and Akpüsen with 127 days. The trial results indicated that all landraces, with the exception of two (Yazlık Adana and Karaburun Sarı Buğday), exhibited a higher number of days to heading than the average of the control varieties (118.6 days). Days to heading of other landraces were between these. The average heading time was found to be 124.5 days (Table 5).

Among the standard varieties, Poyraz exhibited the highest heading time, with an average of 119.7 days, followed by Alatay with an average of 119 days. The lowest heading time was observed in Şölen, with an average of 117 days. The mean heading time was 118.6 days (Table 5). Koca Buğday, Kunduru, Akpüsen, Yozgat Sarı, Şahman, Ağ Buğday, Sarı Bursa exhibited a later heading than the standard varieties (Şölen, Poyraz, Alatay). Table 5 indicates that the average heading time of the landraces is above the general average, while the standard varieties are below the general average. Öner & Kendal (2022) conducted a study on durum wheat landraces in Mardin, which revealed that heading time varied between 93 and 124 days. The observed variation in durum wheat heading time can be attributed to the climatic conditions in the region where the crop is grown, as well as the genetic structure. The heading of wheat spikes at an early-stage results in a prolongation of the grain-filling period, which allows for the completion of heading before the extreme heat of the following periods and an early transition to the grain-filling period, which increases grain yield (Balkan, 2006).

Days to maturity

Maturation time (days) is calculated as the number of days between the date when the spike emerges from the flag leaf sheath in approximately 75% of the plants in the plot and the date when the spike, flag leaf node and leaves turn yellow. When the maturity time data of the wheat genotypes used in the trial area are examined, the significant differences were observed between the genotypes at p<0.01 level and a coefficient of variation of 3.61% (Table 4). While the maturity time of the genotypes varied between 29.3 days and 45.3 days, the general average was found to be 38.8 days. The durum wheat varieties formed eight different groups (Table 5). It is thought that the amount of precipitation in the 2021-2022 vegetation period, especially in March, April and May, was significantly lower than the long-term average, which would affect early maturity.

Among the landraces, Yazlık Adana had the highest maturity time with 45.3 days, followed by Karaburun Sarı with 45 days, and Ağ Buğday with 41.1 days. The lowest maturity time was found to be Yozgat Sarı, 29.3 days. The average maturity time of landraces was observed to be 37 days (Table 5).

Among the standard wheat varieties, Şölen had the highest maturity time with 44.3 days, followed by Alatay with an average of 44 days. The lowest maturity time among the varieties was determined as 43.7 days in Poyraz. The average maturity time of the standard varieties was determined as 44 days (Table 5).

Yazlık Adana and Karaburun Sarı matured later than both other landraces and the standard varieties (Şölen, Poyraz, Alatay). In addition, these two varieties are the earliest to head. Demir (1983), Genç et al. (1993) and Bilgin & Korkut (2005) stated that early heading genotypes would have longer heading-maturation times. Blum (2017) posited that early-headed varieties are less susceptible to drought damage, particularly during the latter stages of the drought period.

Table 5. The mean values and formed groups for the measured traits

Çizelge 5. *İncelenen özelliklere ilişkin ortalama değerler ve oluşan gruplar*

Landraces	Heading	Maturity	Spike	Spike	Number of	Number of	Grain	Spike	Grain
Karaburun Sarı	117.0 *e*	45.0 *a*	7.3 *cd*	2.3 *bc*	18.6 *b*	36.8 *b*	1.6 *cde*	68.5	1388 *cd*
Sarı Bursa	124.7 *c*	40.3 *d*	6.7 *de*	2.1 *c*	17.1 *b*	33.0 *cd*	1.5 *de*	67.2	1925 *bcd*
Ağ Buğday	124.7 *c*	41.1 *c*	5.8 *fgh*	0.6 *f*	10.1 *e*	15.6 *g*	0.5 *h*	67.5	1158 *d*
Kunduru	129.0 *a*	32.3 *f*	8.2 *ab*	0.9 *e*	13.4 *cd*	17.8 *g*	0.7 *g*	61.8	1933 *bcd*
Yozgat Sarı	127.0 *b*	29.3 *k*	6.6 *def*	2.4 *b*	17.0 *b*	30.0 *de*	1.7 *bc*	65.0	1708 *bcd*
Şahman	125.0 *c*	37.3 *e*	7.5 *bc*	1.0 *e*	11.9 *de*	18.8 *g*	0.7 *g*	70.2	2158 *bcd*
Yazlık Adana	114.0 *f*	45.3 *a*	8.6 *a*	1.0 *e*	22.1 *a*	25.4 *f*	0.6 *gh*	64.1	1129 *d*
Koca Buğday	132.0 *a*	32.0 *f*	6.5 *defg*	1.9 *d*	17.8 *b*	29.2 *e*	1.4 *e*	65.2	1479 *bcd*
Akpüsen	127.0 *b*	30.7 *g*	5.7 *gh*	2.7 a	16.7 *b*	44.1 a	2.1 a	75.5	2281 *abc*
Standard Variety									
Şölen	117.0 *e*	44.3 *a*	5.2 *h*	2.4 *b*	17.3 *b*	34.7 *bc*	1.8 *b*	72.7	3279 *a*
Poyraz	119.7 *d*	43.7 *b*	5.9 e*fgh*	2.4 *b*	16.6 *b*	37.3 *b*	1.7 *bc*	71.2	1929 *bcd*
Alatay	119.0 *d*	44.0 *a*	6.2 *efg*	1.8 *d*	16.1 *bc*	27.7 *ef*	1.2 *f*	64.8	2521 *ab*
Av. of Landraces	124.5	37.0	7.0	1.7	16.1	27.9	1.2	67.2	1684
Avg. of Standard	118.6	44.0	5.8	2.2	16.7	33.2	1.6	69.6	2576
Overall Average	123.0	38.8	6.7	1.8	16.2	29.2	1.3	67.8	1907
LSD (0.05)	9.20	2.38	0.86	0.19	3.08	3.38	0.18	11.53	107.13

LSD: Least significant difference.

Spike length

Significant differences at the 1% level were detected between the genotypes in terms of spike length (Table 4). The genotypes varied between 5.2-8.6 cm for spike length and the trial average was calculated as 6.7 cm. A total of twelve different groups were observed among the durum wheat genotypes. Among the landraces, the longest spike length was found in Yazlık Adana with 8.6 cm, and the shortest spike length was found in Akpüsen with 5.7 cm. While the average of the landraces was 7.0 cm, the average of the standard varieties was 5.8 cm. The average spike length of the standard varieties was below the trial average. Our findings are similar to the results of Altındal & Akgün (2018). It showed that the landraces had high variation with a coefficient of variation (CV) value of 7.6%. The results obtained from the research were found to be in agreement with the values (5.5-7.3 cm) reported by Kara & Akman (2008), Başkonuş et al. (2022) (6.9-8.8 cm), and Kara et al. (2022) (6.0-7.0 cm). Spike length

has a significant effect on yield. High heritability makes this trait a valuable selection criterion for high grain yield (Satyavart et al., 2002).

Spike weight

Statistical analysis of spike weight data of the genotypes wheat used in the experiment revealed that there were significant differences among the genotypes at $p<0.01$ level and the coefficient of variation was 6.1% (Table 4). Spike weight of the genotypes varied between 0.6 g and 2.7 g and the general average was 1.8 g. The durum wheat genotypes were divided into seven different groups (Table 5). The highest spike weight was observed in Akpüsen with an average of 2.7 g. This was followed by Yozgat Sarı Buğday and Karaburun Sarı Buğday with 2.4 g and 2.3 g, respectively. The lowest spike weight was observed in Ağ Buğday with an average of 0.6 g. The average spike weight among all landraces was 1.7 g. Akpüsen had an average of 22.7% more than the standard varieties.

Among the standard varieties, Şölen (2.4 g) and Poyraz (2.4 g) have the highest value. Alatay (1.8 g) was found to have the lowest value. The average of the standard varieties was found to be 2.2 g. It was determined that the average of the standard varieties was higher than the landraces and the general average (Table 5). The study conducted by Öner & Kendal (2022) was comparable to the present study and determined the spike weight to be between 0.34 and 2.94 g. In addition, the presence of the landraces with higher spike weights than some standard varieties in our study proves that the landraces have a wide variation. Furthermore, spike weight values were reported as 0.86-1.37 g in Kırşehir by Çetin and Ayrancı (2021), 1.49-2.72 g in Şanlıurfa by Akkaya (2019), 0.81-2.19 g in Tokat by Sakin et al. (2004).

Number of spikelet in spike

Upon examination of the spikelet number data of the durum wheat genotypes utilized in the study, it was found that there were significant differences among the genotypes at $p<0.01$ level, with a coefficient of variation of 11.2% (Table 4). While the number of spikelet belonging to the genotypes varied between 10.1 and 22.1, the general average was determined to be 16.2. LSD ($p < 0.05$) test classified the durum wheat cultivars in six different groups.

Among the landraces, Yazlık Adana exhibited the highest number of spikelet (22.1), followed by Karaburun Sarı Buğday (18.6), Koca Buğday (17.8) and Sarı Bursa (17.1). It was determined that the Ağ Buğday had the lowest number of spikelet (10.1). The average number of spikelet for the landraces was determined to be 27.9 (Table 5). Among the standard varieties, Şölen had the highest spikelet count with 17.3, followed by the Poyraz with 16.6. The lowest number of spikelet was observed in Alatay, with a value of 16.1. The average number of spikelet for the standard varieties was determined to be 16.6 (Table 5). Although the average of the standard genotypes yielded higher values than the average of the landraces, Yazlık Adana, Karaburun Sarı and Koca Buğday exhibited higher values than the standards (Şölen, Poyraz, Alatay) in terms of spikelet number. The average of the local varieties is very close to the general average (Table 5).

The findings of this study are consistent with Özateş (2022), who examined local populations. The number of spikelet per spike was found to vary between 15.9 and 26.7 pieces per spike.

In the Mardin/Kızıltepe region, the number of spikelet per spike was found to range from 15.0 to 29.8 (Doğan & Çetiz, 2015). In the Kahramanmaraş region, the number of spikelet per spike was reported to be 18.0 to 24.0 (Kaya, 2020). The number of spikelet per spike was reported to be 18.0-24.0. Akan (2021) observed that the number of spikelet per spike varies between 18.15 and 22.13 in Mardin and Midyat ecological conditions. Our findings are also in agreement with the results of Öner & Kendal (2022), who observed that the highest and lowest spikelet numbers were obtained from the local varieties used in the study, indicating that local populations exhibit high variation.

Number of grains per spike

Significant differences in the number of grains per spike were revealed between the local and the standard varieties of durum wheat, with a CV of 6.8% ($P < 0.01$) (Table 4). The number of grains per spike values of the durum wheat varieties are presented in Table 5. The number of grains per spike among the genotypes ranged from 15.6 to 44.1, with a general average of 29.2. These values categorized the durum wheat varieties into nine groups.

Among the local landraces, Akpüsen exhibited the highest number of grains per spike (44.1), followed by Karaburun Sarı (36.8), Sarı Bursa (33.0), and Yozgat Sarı (30.0). The lowest value was observed in Ağ Buğday, with an average of 15.6 grains. The overall average for local wheat was determined to be 27.9. For the standard varieties, Poyraz exhibited the highest number of grains per spike, with 37.3 grains, followed by Şölen with 34.7 grains. The lowest grain was observed in the Alatay with 27.7. The average for the standard varieties was 33.2 (Table 5). Although the average number of grains per spike for the standard varieties (33.2) was 19% higher than the local landraces (27.9), the local landraces Akpüsen (44.1) and Karaburun Sarı (36.8) showed higher values than the standard varieties. Furthermore, the fact that both the highest and lowest grain numbers per spike in the study were obtained from local landraces indicated that they exhibited considerable variation. Similarly, in the study conducted by Çığ & Kahraman (2019), the average number of grains per spike for the genotypes was reported to be 28. This average was 33.4 grains for the standard varieties and 27 grains for the local varieties.

In a study conducted in Mardin province, Öner & Kendal (2022) reported that the average number of grains per spike ranged from 13.8 to 76.1. Similarly, Durmaz & Aktaş (2023) found that local varieties exhibited a range of 27.8 to 61.9 grains per spike, with an average of 42.4. Kanat (2017) observed the number of grains per spike varied between 40.1 and 45.7 grains in Viranşehir. Additionally, Mahdi (2017) reported a variation of 33.0 to 66.2 grains per spike under the environmental conditions of Konya.

The number of grains per spike is a critical parameter that directly affects the yield, and the increase in the number of grains per spike is positively reflected in the yield (Alipour et al., 2017; Karagöz & Zencirci, 2005). This trait is related to spikelet initiation, pollination, fertilization and grain formation. Environmental factors, including excessive rainfall during the flowering period, drought and extreme temperatures, can negatively impact the number of grains per spike (Farooq et al., 2011). For instance, the temperatures above 20°C between heading and anthesis can significantly reduce grain numbers per spike (Saini & Aspinall, 1982).

Grain weight per spike

Regarding the data on grain weight per ear, coefficient of variation of 8.2% was detected among local and standard varieties (Table 4). The grain weight per spike for the genotypes ranged from 0.5 g to 2.1 g, with an overall average of 1.3 g. According to the LSD (5%) test, grain weight per spike data were formed into eleven different groups among the durum wheat varieties (Table 5). Among the local landraces, Akpüsen exhibited the highest kernel weight per spike at 2.1 g, followed by Yozgat Sarı Buğday at 1.7 g and Karaburun Sarı Buğday at 1.6 g. Ağ Buğday exhibited the lowest grain weight per spike, at 0.5 g. The average grain weight per spike of the local landraces was determined to be 1.2 g (Table 5). In the standard varieties, Şölen exhibited the highest grain weight per spike at 1.8 g, followed by Poyraz at 1.7 g. Alatay exhibited the lowest grain weight among the standard varieties with 1.2 g. The average grain weight per spike was 1.6 g. Although the average grain weight per spike of the local landraces (1.2 g) was 33.3% lower than that of the control varieties (1.6 g), Akpüsen exhibited the highest grain weight with 2.1 g, and thus stood out from the other varieties. Additionally, Yozgat Sarı, Karaburun Sarı, Sarı Bursa and Koca Buğday had the values above the trial average (Table 5).

In a study conducted by Durmaz (2021) in Mardin province, the average grain weight per spike of the local varieties was found to be 1.95 g, while the average for the control varieties was 2.63 g. This

result indicates that grain weight per spike significantly influences the higher grain yield observed in modern breeding varieties compared to traditional or local varieties. According to the trial results, only four local varieties exhibited higher grain weights per spike than the control variety average (2.63 g).

Spike harvest index

The spike harvest index was calculated by dividing the weight of grains obtained from the spike by the weight of the spike itself. When the durum wheat varieties are examined in Table 4, the differences among the genotypes in terms of spike harvest index were found to be insignificant. While the spike harvest index of the genotypes varied between 61.8% and 75.5%, the general average was found to be 67.8%. Spike harvest index values created three different groups among the durum wheat landraces and the varieties. Although the average of the landraces (67.2%) gave 3% lower values than the average of the standard varieties (69.2%), Akpüsen (75.5%) stood out by being in the first group with its harvest index rate. Additionally, Şahman (70.2%) and Karaburun Sarı Buğday (68.5%) gave values above the trial average. Among the control varieties, Şölen exhibited the highest harvest index (72.7%), while Alatay exhibited the lowest (64.8%). The average harvest index was found to be 69.6% (Table 5).

Grain yield

Grain yield is the most important economic trait in wheat improvement (Wu et al., 2012). Yield is a complex quantitative trait influenced by a number of genes with low heritability (Cuthbert et al., 2008). Wheat grain yield is affected by both genetic and environmental factors. However, the effect of the environment on grain yield has been reported to be more pronounced (Erdemci et al., 2021). A significant difference was observed between the durum wheat genotypes in terms of grain yield per hectare, with a 33.2% coefficient of variation ($p<0.05$). The coefficient of variation for the grain yield trait is relatively high. This result is in agreement with that reported by other researchers in durum wheat (Arzani, 2002; Zencirci & Karagöz, 2005; Baye et al., 2020). This means that there are significant differences among the replicates. This may be due to the differences in soil homogeneity in the experimental area. It may also be due to irregular rainfall during the growing season. Coefficients of variation indicate the effects of genetic diversity and environmental variance. High CVs make it difficult to identify differences between genotypes. Coefficients of variation for grain yield were relatively high, indicating the difficulty of selection for yield improvement. Arzani (2002), in a study on grain yield performance of durum wheat germplasm under dryland and irrigated conditions, reported high CVs for grain yield at four locations (Isfahan-28.35%, Abarkoh-25.04%, Mehran-29.05%, Ilam-Dryland-32.14%). It was determined that there was a difference in yield per hectare among the durum wheat varieties, with the lowest yield being 1129 kg and the highest yield being 3279 kg. The general average yield was found to be 1907 kg. The durum wheat varieties were divided into six groups based on their grain yield. The average yield of the landraces was found to be 1684 kg, while the average yield of the standard varieties was 2576 kg (Table 5). Among the landraces, Yazlık Adana (1129 kg) exhibited the lowest yield, while Akpüsen (2281 kg) exhibited the highest. The following local landraces were observed to have data above the overall average: Şahman (2158 kg), Kunduru (1933 kg) and Sarı Bursa (1925 kg). Among the standard wheat varieties used as control, the highest grain yield per hectare was obtained from Şölen (3279 kg). The next highest yield was recorded for Alatay, with 2521 kg per hectare. The lowest yield was observed for Poyraz, with 1929 kg per hectare.

According to the average yield, the local landraces exhibited 53% lower yield than the standard varieties. Nevertheless, Akpüsen, Şahman, Kunduru and Sarı Bursa exhibited a notable difference in grain yield, with values exceeding both the local landrace average and the general average. Akpüsen, Şahman and Kunduru yielded more grain than the standard variety Poyraz. Akpüsen landrace was supplied from Manisa province in the Aegean Region. The location where the experiment was established (Yakaköy) resembles the Manisa Merkez region in terms of environmental conditions. It can be considered that this

may have an effect on the increase in yield. In this study, Akpüsen showed the closest grain yield to the two standard varieties, Şölen and Alatay. Notably, it is the only local variety to be placed in group "a" in the statistical classification. Additionally, Akpüsen, Şahman and Kunduru produced higher grain yields than the standard variety Poyraz, while Sarı Bursa was classified within the same group as Poyraz.

Despite the grain weight per spike values of the Aksüpen, Yozgat Sarı Buğday and Karaburun Sarı Buğday being close to or even higher than the standards, their grain yields fell below the standards, with the exception of the Aksüpen genotype. It can be posited that the local varieties may prove more advantageous when the potential yield is considered, based on the grain weight per spike, especially if all grains (500 seeds per m^2) germinate. While the grain weight per spike of the local landraces (except for such as Ağ Buğday and Yazlık Adana, which are in the form of bread wheat (*Triticum aestivum* subsp. *aestivum*)), are better than or similar to the standards, it is thought that this yield difference may be due to the low number of spikes per square meter due to the non germination of some seeds planted in the plots. In addition, plant lodging due to stem thinness and long plant height may also explain this difference in yield.

In their study conducted under fertilized conditions in Mardin, Durmaz & Aktaş (2023) evaluated 80 local and 10 modern varieties of durum wheat in terms of yield and its components. The findings revealed that the mean values of standard varieties ranged from 3500 kg ha^{-1} to 4560 kg ha^{-1}, while the grain yield per hectare of local varieties varied between 929.8 kg ha^{-1} and 3781 kg ha^{-1}. Öner & Kendal (2022) determined that grain yield varied between 1750 and 6169 kg ha^{-1}. Furthermore, some local populations have higher grain yield than standard varieties. These local populations have also demonstrated satisfactory results in terms of yield under drought conditions with high variation. Çığ & Karaman (2019) reported that the grain yields of local durum wheat varieties native to the Southeast Anatolia region are promising genotypes, with values close to the average of standard varieties. Furthermore, this study found that although the biological yields of local genotypes were high, the grain yields were low.

Local wheat landraces have developed specific adaptations in marginal areas with low soil fertility and stress conditions such as drought and high temperature that negatively affect grain yield. Despite this, they have a yield potential that is not very high but satisfactory compared to modern breeding varieties in these areas. Therefore, it is considered very important to protect and utilize these genetic resources (Aktaş, 2016; Kan et al., 2017; Aktaş et al., 2018).

CONCLUSIONS

Local wheat landraces are extremely important genetic resources with wide adaptability, high grain quality, and drought and heat tolerance. Some local varieties with beneficial characteristics in terms of some commercial characters, especially quality, flavor and aroma, have an important potential in terms of food safety, especially under biotic and abiotic stress conditions. The results of the study conducted in Bornova/Yakaköy indicate that there are statistically significant differences between the local landraces and the standard varieties for all traits except spike harvest index. This study revealed that wheat genotypes with different genetic potentials exhibited a wide variation in terms of the traits examined. It was observed that the local durum landraces exhibited superior characteristics in terms of spike emergence time and spike length compared to the standard genotypes. The local landraces were found to have a later spike emergence time and more winter growth characteristics than the standard varieties. Conversely, earlier genotypes were found to mature later. Although average spike weight, number of spikelet in spike, number of grains per spike, grain weight per spike and spike harvest index values were higher in the standard varieties, the local landraces gave the highest values. For spike weight, Akpüsen had an average of 22.7% more than the standard varieties. It also ranked first in terms of number of grains per spike, grain weight per spike and spike harvest index. The landraces were found to yield 53% less than the standard varieties in terms of average grain yield. However, Akpüsen, Şahman, Kunduru and Sarı Bursa varieties made a difference in terms of yield by giving higher values than both the

landrace average and the general average. The closest value to the grain yield of the two standard varieties (Şölen and Alatay) in the study was given by Akpüsen landrace. In fact, it is the only local variety in the statistical classification in group "a". Akpüsen, Şahman and Kunduru gave more grain yield than the standard variety Poyraz. Sarı Bursa is in the same group as Poyraz. Further research is required to ascertain the suitability of these landraces for cultivation in Bornova conditions and their potential for utilisation in sustainable agricultural practices.

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Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: RI, RRAG; data collection: RI; analysis and interpretation of data: RI, RRAG; statistical analysis: RRAG; visualization: RRAG; writing manuscript: RI, RRAG.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that there is no need for an ethics committee for this research.

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