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Evaluation of Levante × Karakılçık durum wheat advanced lines for yield related and quality traits using principal component biplot analysis

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Abstract: The Karakılçık landrace is known for its quality traits, especially protein content. However, its high plant height causes lodging and yield loss, which limits the production area. A Levante × Karakılçık population developed by crossing the local Karakılçık wheat with the commercial variety Levante in order to eliminate the disadvantages of Karakılçık and adapt it to wider production areas. In the study, yield, quality, and some physiological traits were investigated in the population. The experiment was conducted in an augmented experimental design in the cropping seasons of 2021–2022 and 2022–2023. A total of 36 genotypes from Levante × Karakılçık population, parents and 2 controls were tested. The tested genotypes varied significantly for all investigated traits ($P < 0.01$). Principal component biplot analysis explained 69.3% of the variations and relationships between the traits and genotypes. Among the investigated traits, genotypes LK26, LK19 and LK3 outperformed their parents in 5 traits (spike length (SL), number of spikelets per spike (SNS), number of grain numbers per spike (GNS), protein content (PC) and wet gluten content (G)), 4 traits (SNS, grain weight per spike (GWS), GNS and PC) and 3 traits (grain yield (GY), GNS and test weight (TW)), respectively. The genotype LK3 for yield and the genotypes LK19 and LK26 for quality traits could be recommended to growers and breeders.

Keywords: Karakılçık landrace; PCA biplot; protein content; yield

Durum wheat (*Triticum turgidum* L., ssp. *durum* (Desf.), which plays an important role in global human nutrition, is a cultivated plant, rich in carbohydrates, proteins, vitamins, minerals, fibre and other phytochemicals (Harland 2015). Durum wheat is a tetraploid ($2n = 4x = 28$, AABB) wheat species produced in different regions of the world (Kabbaj et al. 2017) and 39.9 million tons of product are obtained from durum wheat over an area of approximately 16.1 million hectares corresponding to 8–10% of the world's total wheat production (Martínez-Moreno et al. 2020). Türkiye is the third largest durum wheat producer in the world with 4.2 million tonnes of durum wheat production after Canada and Italy (FAOSTAT 2022).

Wheat grain protein content and related traits are mostly determined by genotype (Hristov et al. 2010; Taheri et al. 2021), but it is also affected by environment and genotype-environment interaction (Asthir et al. 2017; Punia et al. 2019). In general, it is stated that genotype has a greater effect on quality traits, while environmental factors have a greater effect on yield traits (Guardia-Velarde et al. 2023). The genetic improvement of grain quality in durum wheat is narrow due to the limited variation of genes con-

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trolling these traits in modern durum wheat varieties (Taneva et al. 2019). To overcome this problem and improve the quality traits of durum wheat, it is still an important strategy to use durum wheat landraces in breeding programs (Kendal et al. 2019).

Durum wheat landraces have genetic diversity in many traits, making them an invaluable genetic resource. In addition, the fact that landraces have a rich diversity in rare alleles makes their use in breeding programs important (Royo et al. 2014; Kabbaj et al. 2017). The significant genetic differences in durum wheat landraces reported in previous studies indicate the existence of a great opportunity for the use of landraces as parents in breeding programs. Karakılçık is the general name of some local wheat genotypes, including both bread and pasta. Karakılçık local durum wheat genotype used in the study is consumed as bulgur, high in protein content and has a taste, especially in the Eastern Mediterranean and southern Türkiye, which is not widely grown due to its lodging problem that causes yield and quality losses.

In recent years principal component biplot analysis (PCA) has become a widely used approach to visually present the relationships between investigated traits, thus allowing the traits and genotypes to be evaluated visually (Yau 1995; Yan et al. 2007). PCA is widely used in plant breeding studies where yield and quality traits are evaluated to reduce the size of the data set without losing important information (Dhakal et al. 2020; Abdelghany et al. 2023).

Consumers' demands for quality products are increasing in the market. Since, Türkiye is the biggest exporter of both pasta and bulgur in the world (Trade Map 2022). Breeders have put effort into developing varieties that are both high in quality and yield. For this reason, to develop cultivars with superior yield and quality characteristics that could be preferred by both producers and consumers, the Karakılçık landrace was crossed with the Levante variety that grew widely. The main objective of this study was to determine non-lodging and superior genotypes in terms of both quality and yield among the population.

MATERIAL AND METHODS

This study was conducted in 2021–2022 and 2022–2023 growing seasons at the experimental field of East Mediterranean Transitional Zone Agricultural Research of Institute, located in Kahramanmaraş (between 37°38'N and 36°37'E). In the study, 36 genotypes from the Levante × Karakılçık population developed by ZD Seed R&D company and brought to the F_8 stage by the single seed descent method from a single cross using a Karakılçık genotype selected from a population and commercial cultivar Levante and 2 checks genotypes (Eminbey and Ovidio), were used as material. Karakılçık genotypes have approximately 140 cm plant height and 9 cm spike length with a high protein ratio that was used in a previous study (Yuce & Dumlupinar 2023). A detailed description was made of 60 Karakılçık genotypes deposited in the Türkiye Seed Gene Bank collected from 12 provinces across Türkiye for 29 UPOV criteria (Alkan 2022).

The experiments were carried out under rainfed conditions, and total precipitation in the 2021–2022 growing season was recorded as 555.2 mm, while it was 459.6 mm in the 2022–2023 growing season. Climate data for the experiment years and long terms are given in Table 1. The soil characteristics of the experiment site have a silt-loam and sandy-loam texture.

A total of 36 advanced lines from Levante × Karakılçık population and checks were planted in 4 blocks according to augmented experimental design in two consecutive growing seasons (Federer 2005). Each genotype was planted in 1-m length and 4 rows (550 seeds) 20 cm apart. At planting, 80 kg/ha of P_2O_5 and 80 kg per ha of nitrogen were applied as fertilizer. In addition, 70 kg/ha of nitrogen was applied to the trials at the tillering stage in the form of urea (46%) as topdressing. Herbicide (*Tribenuron-methyl* 75%) was used for weed control, while there was no pesticide usage for disease control.

The observations of the agronomic traits were taken as described by Kyratzis et al. (2022). In brief, plant height (PH, cm) (except awns) and spike length (SL, cm) were determined by measuring 10 randomly selected plants in each plot just before harvest (Zadoks 91). The number of spikelets per spike (SNS), the number of grain numbers per spike (GNS), and grain weight per spike (GWS) were determined after the harvest. In addition, thousand kernel weight (TKW, g) is determined as grams, the weight of 1 000 kernels and grain yield (GY, kg/m^2) was measured by harvesting and weighing each plot. The quality traits such as test weight (TW, kg/hL), protein content (PC, %), wet gluten content (G, %), starch (S, %), and Zeleny sedimentation (ZNS, mL) were measured using Fourier transform near infrared (FT-NIR) spectroscopy (PerkinElmer FT 9700™, PerkinElmer Inc., USA) device.

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Table 1. The average climate data of the experiment site for 2021–2022, 2022–2023 years and long terms

Months	Precipitation (mm)			Average temperature (°C)		
	2021–2022	2022–2023	long term	2021–2022	2022–2023	long term
November	14.8	65	78	12.55	12.96	11.8
December	156.8	34.8	130.6	6.4	8.77	6.9
January	126.4	57.4	124	4.25	5.55	5.2
February	74.2	67	112.2	8.18	4.83	6.7
March	116	138.4	95.1	7.17	12.05	11
April	15.6	66.6	73	17.92	14.38	15.6
May	47	30	38.8	20.41	19.9	20.6
June	4.4	0.4	8.6	26.61	25.8	25.7
Total	555.2	459.6	660.3	–	–	–
Average	–	–	–	12.9	13.0	12.9

*Meteorological data provided by East Mediterranean Transitional Zone Agricultural Research of Institute meteorological station

The data belonging to experiments were subjected to variance analysis using JMP software (Ver. 15.1, 2020), and the least significant difference (LSD) test was used to compare mean data. The significance level was determined as 5% probability unless otherwise stated. The results of the homogeneity test showed that there was no significant difference between the years ($P < 0.05$). Therefore, the statistical analysis was performed by combining the data of two years (Levene 1960). Principal component biplot analysis was conducted using mean data, and correlation coefficient calculations were performed using the JMP statistical program to determine the positive and negative correlation between all traits investigated (JMP 15.1, 2020).

RESULTS

Phenotypic and genotypic variations are of great importance in breeding programs. Based on two-year data obtained from the advanced lines of Levante × Karakılçık population and check genotypes used in the study were subjected to combined variance analysis, the mean square of genotype, year, and genotype × year interaction showed a statistically significant difference at the $P < 0.01$ level for all traits investigated (Table 2).

The average PH of the genotypes was 78.45 cm in the first year, 92.59 cm in the second year. The highest PH was obtained from the Karakılçık landrace with 130.99 cm, and the genotype LK36 was the shortest with 73.85 cm. The spike length of the genotypes was found to be 8.28 cm in the first year and 10.53 cm in the second year, with an average of 9.41 cm. The longest SL was found 10.63 cm in genotype LK20. The shortest SL was measured as 8.24 cm belonging to Ovidio cultivar. In terms of SL 22 genotypes used in the study showed superior performance than check genotypes (Table S1 in electronic supplementary material (ESM)). In the first year, the SNS of the population was 19.37, while 20.49 in the second year. The highest SNS was obtained from genotype LK20 with 21.94, while genotype LK19 followed it with 21.81. The lowest SNS was determined as 16.71 from the genotype LK31 (Table S1 in ESM). The GNS of the genotypes in the first and second years was found 55.55 and 46.45, respectively. The genotype LK19 had the highest GNS with 62.71 and the lowest one was genotype LK31 with 42.26. The average GWS of two years was measured to be 1.52 g. Ovidio standard variety had the highest value with an average GWS of 2.45 g and genotype LK24 had the lowest value with 1.14 g. Thousand kernel weight was calculated as 30.90 g in the first year, 29.27 g in the second year, and an average of two years as 30.09 g. Genotypes showed a wide variation for TKW, ranging from 45.99 g (Ovidio) to 24.01 g (genotype LK12). Genotypes numbered LK3 (34.72 g) and LK19 (33.92 g) had the highest TKW after the standard varieties Ovidio (45.99 g), Karakılçık (39.48 g), and Levante (26.58 g), respectively (Table S1 in ESM).

GY of the Levante × Karakılçık population advanced lines and standard varieties used were determined to be 0.75 kg/m^2 in the first year, while this value decreased by about 22% and was determined to be 0.59 kg/m^2 in the second year. The average GY over two years was found to be 0.67 kg/m^2. When the two-year data were examined, the highest grain yield

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Table 2. The mean squares and *F* values of genotypes (G), years (Y) and G × Y interaction

	Mean squares			*F* values		
	G	Y	G × Y	G	Y	G × Y
PH	429.33	4 328.01	32.11	513.91**	5 180.82**	38.51*
SL	0.91	109.23	1.32	753.3**	90 091.61**	1 078.24**
SNS	3.33	26.92	2.01	604.21**	4 937.22**	367.63**
GNS	45.52	1 790.83	36.93	691.4**	27 240.8**	561.9**
GWS	0.24	3.52	0.17	354.46**	5 120.84**	253.49**
TKW	82.50	57.93	20.07	832.45**	584.52**	202.54**
GY	52787.28	542 152.5	12 819.28	509.79**	5235.77**	123.80**
TW	45.65	923.02	7.89	1 047.97**	21 187.53**	181.12**
PC	4.53	132.19	2.64	1 614.02**	47 072.93**	940.62**
G	21.80	899.99	17.34	668.99**	27 616.53**	532.15*
S	11.03	89.38	2.39	2 335.98**	18 920.85**	506.30**
ZNS	30.53	838.05	17.58	647.63**	17 779.12**	373.04**

PH – plant height; SL – spike length; SNS – No. of spikelets per spike; GNS – No. of grains per spike; GWS – grain weight per spike; TKW – thousand kernel weight; GY – grain yield; TW – test weight; PC – protein content; G – wet gluten content; S – starch; ZNS – Zeleny sedimentation; *significant at 0.05 probability level ($P < 0.05$); **significant at 0.01 probability levels ($P < 0.01$)

was obtained from the Ovidio standard variety with 1.00 kg/m^2, and the lowest grain yield was obtained from the Karakılçık landrace with 0.47 kg/m^2. It was determined that genotype LK3 ranked 2nd in terms of GY and had a higher GY value than all standard varieties except Ovidio. In addition, in terms of GY, all genotypes of the Levante × Karakılçık population outperformed the Karakılçık landrace, which was one of the parents (Table S2 in ESM). The test weight of the advanced lines was 74.30 kg/hL in the first year of the research and it was 67.78 kg/hl in year two. Ovidio cultivar was the highest with 79.70 kg/hL and the genotype LK17 was the lowest 62.82 kg/hL. Genotypes LK19 and LK1 were followed by the Ovidio variety with 77.78 and 77.63 kg/hL TW values (Table S2 in ESM).

In the first year, the PC was 17.67%, and in the second year, it was 20.15%, and the mean value over two years of PC was 18.91%. The highest PC was determined in genotype LK24 with 23.46%, and the lowest PC was found in the standard variety Levante with 16.23%. A total of 20 genotypes have surpassed all standards with an impressively higher PC. It was revealed that the mean value of G was 15.5 and there was an increase in the average values in the second year compared to the first year. Genotype LK24 ranked first with 49.75% and genotype LK2 ranked last with 35.18% (Table S2 in ESM). The S content was determined to be 61.42% in the first year of the study, and 59.39% in the second year, with a slight decrease. Levante standard variety with 64.41% had the highest S, while genotype LK17 with 55.44% had the lowest. It is important to note that genotypes LK19 and LK27, along with the Ovidio standard variety, unequivocally had the highest S after the Levante variety.

Zeleny sedimentation was 73.27 mL in the first year and 79.50 mL in the second year and two years average was 76.36 mL. Genotype LK24 had the highest (86.03 mL) and the Levante standard variety had the lowest (68.41 mL) ZNS values. The study has identified 11 genotypes that exhibited significantly higher ZNS values when compared to checks.

Correlation coefficients are a statistical tool used to estimate the strength and direction of the relationship between two variables. The Spearman's correlation matrix in investigated traits (Table S3 in ESM) indicated that there was a positive and significant correlation between GY and S (r = 0.552**), GWS (r = 0.456**), TW (r = 0.452**), TKW (r = 0.425**) and GNS (r = 0.403**). On the other hand, there was a negative and significant correlation between GY and PC (r = –0.515**), ZNS (r = –0.511**), G (r = –0.459**) and SL (r = –0.365**). G was also correlated positively with PC (r = 0.920**) and ZNS (r = 0.893**). There was a positive correlation between S, TW, TKW and GWS (r = 0.711**), (r = 0.645**) and (r = 0.565**) respectively, but there was a negative correlation be-

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tween S, PC, G and ZNS (*r* = −0.921**), (*r* = −0.831**) and (*r* = −0.796**) respectively (Figure 1).

PCA is an approach that allows genotypes to be evaluated in terms of many traits and provides a better visual selection opportunity in the selection of high-performing genotypes. Figure 2 illustrates a PC biplot graph that visually shows the relationships between genotypes and traits. Twelve principal components (12 PCs) were calculated from the correlation matrix, as many as the number of investigated traits. PC biplot analysis showed that the variation was concentrated in the first two components. The PCA results based on the average values of the traits studied showed that 69.3% of the total variation was explained by PC1 and PC2. The PC1 explained 53.1% of the total variation contributed largely by S (14.19%), PC (13.26%), TW (11.85%), ZNS (10.66%) and G (10.24%), while PC2 explained 16.2% of the total variation contributed mainly by PH (30.07%), GNS (26.16%), SNS (16.45%) and SL (9.64%). When the PCA biplot graph was examined, 2 groups with a positive relationship with each other were remarkable. The first group is between PC, ZNS, and G, where there are quality traits, and the second group is between GY, GWS, S, TW, and TKW, where there are yield and yield components. Since these two groups are in opposite directions, their negative relationship is seen in Figure 2.

The results of the PC biplot analysis showed that genotypes LK3, LK2, LK1, LK19, Ovidio, and Levante were the most prominent in terms of GY, GWS, TKW, and TW. It is seen that genotypes LK24, LK23, LK15, and LK9 stood out in terms of quality traits PC, ZNS, and G. Most of the genotypes of the Levante × Karakılçık population were located close to the centre of the graph in terms of PH, while the Karakılçık landrace was separated from them due to its high PH. Since PH, GNS, and TKW have the longest vector among the traits investigated in our study, we can say that the variation among the genotypes studied for these 3 traits is wider (Figure 2).

DISCUSSION

Karakılçık is a landrace with superior quality traits besides undesirable traits such as plant height that causes lodging. To eliminate this undesirable feature of the Karakılçık landrace, the Levante × Karakılçık population was developed by crossing with the Levante commercial variety. A significant variation

	PH	SL	SNS	GNS	GWS	TKW	GY	TW	PC	G	S	ZNS
PH	1	−0.188	−0.115	−0.236	0.055	0.240	−0.103	−0.010	0.016	0.170	0.055	0.100
SL	−0.188	1	0.534	−0.236	−0.351	−0.546	−0.365	−0.481	0.016	0.524	−0.721	0.499
SNS	−0.115	0.534	1	0.312	0.106	−0.106	−0.258	−0.298	0.346	0.195	−0.325	0.284
GNS	−0.236	−0.236	0.312	1	0.699	0.250	0.403	0.189	−0.285	−0.300	0.217	−0.251
GWS	0.055	−0.351	0.106	0.699	1	0.818	0.456	0.517	−0.514	−0.387	0.565	−0.381
TKW	0.240	−0.546	−0.106	0.250	0.818	1	0.425	0.636	−0.550	−0.389	0.645	−0.391
GY	−0.103	−0.365	−0.258	0.403	0.456	0.425	1	0.452	−0.515	−0.459	0.552	−0.511
TW	−0.010	−0.481	−0.298	0.189	0.517	0.636	0.452	1	−0.687	−0.575	0.712	−0.666
PC	0.016	0.016	0.346	−0.285	−0.514	−0.550	−0.515	−0.687	1	0.920	−0.921	0.891
G	0.170	0.524	0.195	−0.300	−0.387	−0.389	−0.459	−0.575	0.920	1	−0.831	0.893
S	0.055	−0.721	−0.325	0.217	0.565	0.645	0.552	0.712	−0.921	−0.831	1	−0.796
ZNS	0.100	0.499	0.284	−0.251	−0.381	−0.391	−0.511	−0.666	0.891	0.893	−0.796	1

Not significant Positive and significant correlation Negative and significant correlation

Figure 1. The Spearman's correlation matrix in investigated traits
PH – plant height; SL – spike length; SNS – No. of spikelets per spike; GNS – No. of grains per spike; GWS – grain weight per spike; TKW – thousand kernel weight; GY – grain yield; TW – test weight; PC – protein content; G – wet gluten content; S – starch; ZNS – Zeleny sedimentation

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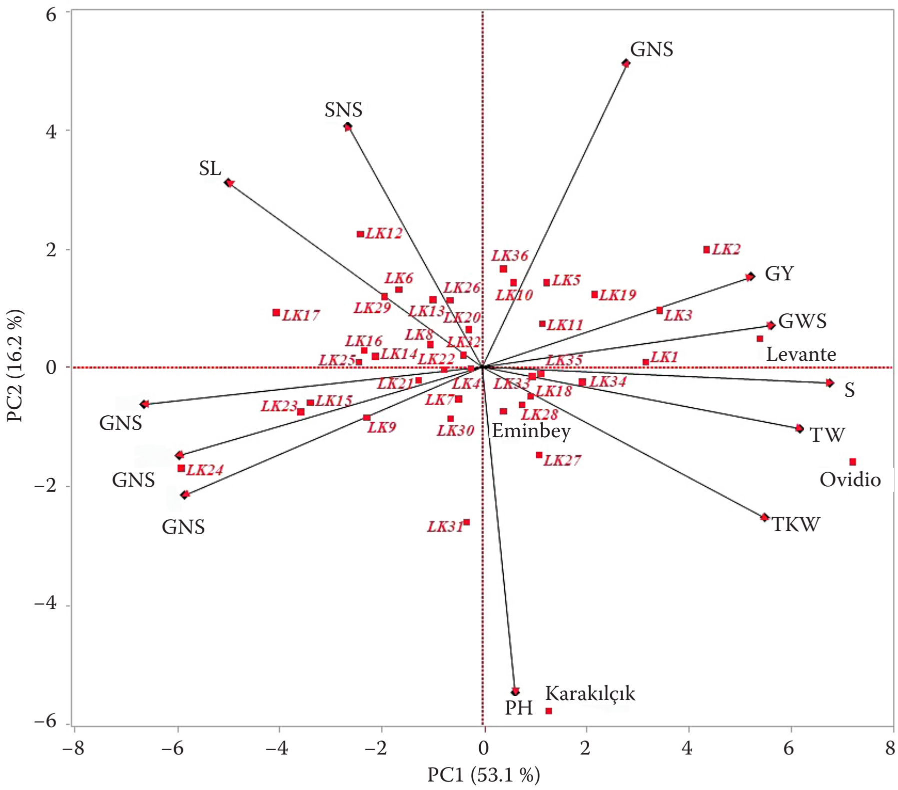

Figure 2. Biplot presentation of principal component analysis PC1 and PC2

PH – plant height; SL – spike length; SNS – No. of spikelets per spike; GNS – No. of grains per spike; GWS – grain weight per spike; TKW – thousand kernel weight; GY – grain yield; TW – test weight; PC – protein content; G – wet gluten content; S – starch; ZNS – Zeleny sedimentation

in PH (73.85–94.92 cm) was obtained among the genotypes. In particular, it has been observed that the PH (130.99 cm) of the Karakılçık landrace was decreased in the genotypes and brought to the F_8 stage, and it was determined that the genotypic influence was effective on PH. It has been reported in different studies that plant height in wheat varies depending on the genotypic structure, climate and soil conditions, and also agricultural practices (Balkan et al. 2023; Karaman et al. 2023). The fact that disadvantages of the Karakılçık landrace like plant height are not observed in Levante × Karakılçık population advanced lines may make these lines more preferable by farmers and may also make it possible to use them as material in breeding studies.

In the study, Levante × Karakılçık population advanced lines varied for SL and SNS. Bayhan et al. (2020) and Farokhzadeh et al. (2020) similarly reported variations in SL and SNS among the genotypes and years, which is similar to our results. GNS, GWS, and TKW influenced by genetic, environmental, and agricultural practices are some of the most important components of grain yield. It has been previously stated that genotype, cultural practices, and environment are effective on the morphology and physical appearance of wheat genotypes. For this reason, it has been observed that the results of studies conducted with wheat genotypes used in different studies have shown diversity in quality, agronomic, and morphological characteristics (Pignone et al. 2015; Bayhan et al. 2020; Karaman et al. 2023).

Our findings show the effects of climate conditions on the yield and quality characteristics of Levante × Karakılçık population advanced lines. Precipitation is an important part of climate conditions and seriously affects yield and quality. In previous work, Bassi and Sanchez-Garcia (2017) indicated genetic and environmental influences on the GY of wheat. In our results, it was observed that there was a decrease of approximately 22% in average grain yield in the first year compared to the second year. The amount of total precipitation was different between the years in our study. The decrease in total precipitation resulted in a decrease in TW, TKW, GNS, GWS, and S and, therefore, a decrease in grain yield. Our

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findings showed that environmental factors have serious effects on yield and yield components. It was observed that the effect of environmental factors is greater than the effect of genotype on yield and yield components. Similarly, Guardia-Velarde et al. (2023) and Mohammadi et al. (2023) reported that environmental effects have a higher impact on yield and yield components. All genotypes of the Levante × Karakılçık population used in our study showed a wide variation in terms of all quality traits investigated. In previous studies conducted on durum wheat quality traits, many researchers have reported a wide genetic diversity in quality traits (Punia et al. 2019; Taheri et al. 2021; Dagnaw et al. 2023). Kendal et al. (2019), Taneva et al. (2019) and Balkan et al. (2023) also reported the mean PC of wheat genotypes was 15.31, 15.14, and 14.79% respectively. In addition, the mean value of G was reported as 28.68% by Taneva et al. (2019), 38.58% by Mutwali et al. (2016), and 32.5% by Kaya and Akcura (2014). The mean value of ZNS was also reported as 54.3 mL by Kahriman and Egesel (2011). Climate significantly affected quality characteristics like PC, G, and ZNS. The decrease in precipitation in the second year caused a significant increase in PC, G, and ZNS among the lines of the Levante × Karakılçık population. Our findings in terms of PC, G, and ZNS were found to have higher mean values than previously reported findings. Although the increase in PC, G, and Z seems to be positive, this increase can be explained by the proportional increase in these quality traits due to the decrease in the starch contained in the grains as a result of the weak grains. The results of previous studies also support our findings (Kiliç & Yağbasanlar 2010; Morari et al. 2018; Doruk-Kahraman & Gökmen 2023; Karaman et al. 2023).

Previous studies have shown that GY can be increased by increasing traits directly related to yield, such as SNS, GNS, and GWS (Gaju et al. 2009; Liu et al. 2018). Our results in terms of SNS, GNS, and GWS were similar to the results found in other studies (Bayhan et al. 2020). It was determined that our study also found a positive relationship between SL and SNS, and a negative relationship between SL and GNS, GWS, and TKW. It is thought that the greatest reason for the decrease in GNS, GWS, and TKW, which are effective on yield, despite the increase in SL and SNS is the number of fertilized flowers. Because the number of fertile flowers in the spike has the greatest effect on the number of grains per spike (Prieto et al. 2018). It has been found in the results that there was a positive relationship between PC, G, and ZNS, but a negative relationship between S and these characteristics. Our findings are consistent with previous studies (Taheri et al. 2021; Demirel et al. 2023). In addition, it has been found that there was a negative relationship between PC, G, and ZNS with GY, but a positive relationship between S and TW with GY. The strong inverse relationship between GY and quality traits that we observed in our study has been demonstrated by other authors in various studies (Feil 1997; Kadkol et al. 2023). The difficulty of maximizing both quality and grain yield traits due to the inverse correlation between grain yield and quality traits, as in our study, has also been recognized by other authors (Clarke et al. 2009; Amiri et al. 2018; Taheri et al. 2021).

The principal component biplot analysis might be used reliably and ensures a description of a reasonable size (≥ 50%) of the entire diversity (Yan et al. 2000; Kendal et al. 2016). Güngör et al. (2022) indicated a 60.9% of the total variation of PC1 + PC2. In the current study, the relationships among the 12 traits were investigated visually in the study with PC biplot analysis that exhibited the superior lines and traits to be used in the selection for durum wheat. The PC Biplot analysis separated the best-performing genotypes for investigated traits. Thus, hopeful genotypes for grain yield and quality traits were determined. In previous works, researchers have used the PC biplot analysis approach to explain correlation, and variation and to determine relevant genotypes with the traits (Bai et al. 2018; Al-Ashkar et al. 2019; Güngör et al. 2021).

CONCLUSION

In the current study, the Levante × Karakılçık durum wheat advanced lines developed to improve desired traits were investigated for some agronomic and quality traits. Advanced lines performed better for most traits than their parents. It is concluded that LK3, LK19 and LK26 are outstanding genotypes promising for grain yield and protein content and might be released as cultivars and produced by farmers. It is also suggested that those advanced lines might be used in bulgur industry with high bulgur yield.

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