YIELD AND AGRONOMIC PARAMETERS IN DURUM WHEAT (*Triticum durum* L.) GENOTYPES UNDER RAINFED CONDITION

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Abstract

The experiment was carried out to asses of yield and yield components of advanced durum wheat genotypes under rainfed conditions. A total of 15 durum wheat genotypes were examined during the 2016-2017 and 2017-2018 growing cycles in the Edirne location in the Trakia region, Turkey. The experiment was conducted in a randomized complete blocks design (RCBD) with four replications. In the experiments, grain yield, days of heading, plant height, peduncle length, spike length, kernel number per spike, spikelet number per spike and flag leaf area were investigated. The results of variance analysis revealed significant differences ($p<0.01$) among genotypes and year × genotypes interaction for yield and yield component. The mean grain yield was 6675 kg ha^{-1} in 2016-2017 and 5905 kg ha^{-1} in the 2017-2018 cycles. The highest grain yield was performed by G9 (6826 kg ha^{-1}) and the lowest by G14 (6798 kg ha^{-1}). In the experiment, G4 had the longest peduncle length (34.65 cm) and G11 had the longest spike length (9.43 cm). The highest spikelet number per spike and kernel number per spike was found in G3 Genotype G15 had the highest flag leaf area (59.57 cm^2). In the study, flag leaf area in durum wheat genotypes significantly affected kernel number in spike. Tall and late maturing genotypes had higher spike length and spikelet number per spike. Grain yield was negatively correlated with spike length, days of heading and plant height. The fact that there was a different correlation between the parameters revealed the importance of genotype and environmental effects. In the study, it was found to be significant genotypes and year genotype interaction among the parameter peduncle length, spike length, kernel number per spike, spikelet number per spike and flag leaf area. Therefore, it was concluded that these parameters can be used in selection in breeding studies.

Keywords: *durum wheat, genotypes, yield component, environment effect*

1. INTRODUCTION

Turkey is considered a diversification centre of durum wheat (*Triticum durum* Desf.). Germplasm presents average diversity showing a large genetic variability. If considerable variation among genotypes could be implicated in the selection of durum wheat for the development or improvement of cultivars, developed genotypes can be widely used in breeding programs (Öztürk, 2019a). Trakia region has various environmental conditions so genotype x environment interaction is the main issue in improving high yield across variable environments. A genotype having stabile grain yield across the environment condition is very important in wheat (Öztürk, 2019b). In durum wheat, new high-yielding durum wheat varieties which can compete with bread wheat varieties haven't been improved. It is necessary that not only new durum wheat breeding researchers should be put forward but also well-adapted genotypes among presents should be selected in the region (Bilgin et al., 2008). The grain yield of durum wheat (*Triticum turgidum* L. var. *durum*) under Mediterranean conditions is frequently limited by both high temperature and drought during grain growth. Grain yield under cooler conditions was mostly determined by kernel weight, whereas the number of spikes per square meter predominantly influenced grain production in warmer environments. The number of kernels per spike had a significant contribution to grain yield, especially under drought stress conditions. Compensatory effects among yield components were almost absent in the cooler environments, probably due to the relative availability of water and nitrogen (N) during the critical phases of plant development. Contrarily, under warmer conditions, negative effects of the number of spikes per square meter were registered on both the number of kernels per spike and kernel weight (Garcia del Moral et al., 2003). Periods at such high temperatures occur frequently during grain filling in both the Mediterranean and

continental climates, and such extremes may be more frequent throughout Europe in future climates of warmer mean temperatures (Barrow and Hulme, 1996). Drought is one of the main constraints to rainfed wheat production in the Mediterranean region, where durum wheat (*Triticum turgidum* L. var *durum* Desf.) is extensively grown. Achieving genetic increases in yield in these environments has been recognized to be a difficult challenge for plant breeders while progress in yield gains has been much higher in favourable environments (Richards et al. 2002). The successful process of durum wheat breeding is based on the knowledge of characteristics of the genotypes as well as interaction genotypes and locations. Understanding the cause of genotype by environment interaction can be used to establish breeding objectives, identify ideal test conditions, and formulate recommendations for areas of optimal cultivar adaptation (Weikai and Hunt, 2001). Obtaining high-yielding genotypes of durum wheat (Triticum turgidum L. ssp. durum) for different environments, especially Mediterranean rainfed areas (rainy, cold winters and dry, hot summers), is considered difficult due to high genotype x environment interaction (Annicchiarico, 2002; Acevedo and Silva, 2007). Yield components are agronomic traits that provide an opportunity to improve yield under water stress, along with morphological and physiological traits. The yield components which together cover all the period of crop development are the number of grains per square meter and grain weight. Most studies agree that the number of grains per square meter best explains the yield (Fischer, 1973; Slafer et al., 1996, 2014). The numbers of spikes per square meter, spikelet number per spike, kernel number per spike and flag leaf area have been yield components that contributed to the grain yield of durum wheat genotypes under rainfed conditions (Öztürk, 2021). In durum wheat, if flag leaves (blade plus sheath) and ears were kept in the dark from one week after a thesis to maturity, grain weight was reduced by 22.4 % and 59.0 %, respectively (Araus et al., 1993). During the grain filling period, awns, flag leaf, first upper leaf, second upper leaf and third upper leaf are the potentially efficient photosynthetic organs in terms of economic production in wheat (Mahmood and Chowdhry, 1997).

The morphological and physiological traits reported by the literature with high heritability and used in breeding programs are early vigor and early flowering. Early vigor is determined mostly by the size of the seed. This trait increases soil coverage and plant water use, decreasing direct evaporation of soil water (Richards et al., 2011; Smith et al., 2003; Reynolds et al., 2004; Blum, 2011; Elazab et al., 2015). Early flowering which is a crucial physiological parameter provides the ability to escape terminal drought stress (Richards et al., 2001; Reynolds et al., 2007; Araus et al., 2008; Motzo et al., 2010; Blum, 2011; Crossa et al., 2016). Plant height, modern genotypes are semi-dwarfs since they carry one of the Rht genes (Sip et al., 2009), and this has been positive for grain yield, however, it has been found that greater plant height has a positive effect on yield in dry Mediterranean rainfed conditions; for this reason, it is desirable that the genotypes maintain their height in arid rainfed areas (Royo et al., 2014) compared to irrigated areas. Spike length is an important yield component due to it has more grains. Spike length may vary according to genotype, environment and cultural practices. Amount and distribution of precipitation, temperature and fertilization during ear formation are important factors for spike length (Öztürk, 2021). The objectives of this study were to evaluate the variability of grain yield and yield components of different durum wheat genotypes under rainfed conditions.

2. MATERIAL AND METHODS

The study was carried out under rainfed conditions at the experimental station of Trakia Agriculture Research Institute in Edirne of Turkey (41º 38′ 52′′ N and 26º 36′ 07′′ N, 40 m elevation). A total of 15 durum wheat genotypes were tested during 2016-2017 and the 2017-2018 growing years. The experiment was conducted in a randomized complete blocks design (RCBD) with four replications. In the experiment, each plot was 6 meters long and had 6 rows, spaced 0.17 meters apart. Using a plot drill was performed for sowing and 500 seeds per square meter were used. In the experimental data on agronomic parameters; grain yield (GY) (kg ha^{-1}), days of heading (DH), plant height (PH) (cm), peduncle length (PL) (cm), spike length (SL) (cm), number of spikelet per spike (SNS), number of kernel per spike (KNS), and flag leaf area (FLA) (cm^2) were investigated. Yield, its components,

morphological and physiological traits were evaluated in each genotype and each environment using the following criteria.

Days to 50% heading: The number of days from the date of 1 October up to the date when the tips of the spike first emerged from the main shoots on 50% of the plants in a plot.

Plant height (cm): The height of ten randomly taken plants was measured at harvest maturity from the ground level to the tip of the tallest spike in centimetres and averaged.

Peduncle length (cm): The length of ten randomly taken plants was measured at harvest maturity in centimetres and averaged.

Spike length (cm): The length often randomly taken plants was measured at harvest maturity in centimetres and averaged.

Spikelet number per spike: Ten heads were randomly selected before harvest. It was determined by averaging the total number of spikelet.

Number of kernel per spike: Ten heads were randomly selected before harvest and then it was determined by averaging the total number of the kernel.

Flag leaf area (cm^2): In the research, 10 flag leaves were randomly selected in each subplot and their length (FLL) and width (FLW) were measured by a ruler. Flag leaf area (FLA) was then calculated using the following formula (Dodig et al., 2010). FLA (cm^2) = (FLL × FLW) × 0.75

Flowering date Anthesis in Durum wheat is difficult to recognize, since the anthers of some genotypes are not visible; for this reason we measured the number of days from sowing to heading, determining this state when the 75% of the EU had the spikes completely emerged (Zadoks 59) (Zadoks et al., 1974).

Data were analyzed statistically for analysis of variance the method described by Gomez and Gomez (1984). To evaluate significant differences between genotypes, the analysis of variance (ANOVA) was performed. The differences between genotype means of parameters were tested by the L.S.D test (0.05). Letter groupings were generated by using a 5% level of significance. The regression equations were calculated according to Finlay and Wilkinson (1963), and Eberhart and Russell (1969). Regression graphs were used to predict the adaptability of genotypes and the correlations between the quality parameters were determined by Pearson's correlation analysis. The interrelation of components of the grain yield was determined by correlation analysis according to Dewey and Lu (1959).

Table 1. Climate conditions in Edirne/Institute in 2016-2017 and 2017-2018 growing year.

Months	Rainfall Long year	2016-2017			2017-2018		
		Rainfall (mm)	Humidity (%)	Mean Temp.	Rainfall (mm)	Humidity (%)	Mean Temp.
October	52.9	44.4	69.5	14.3	135.2	77.1	13.6
November	72.4	3.2	72.9	0.7	71.6	75.7	9.5
December	61.7	3.2	72.9	0.7	119.6	85.1	7.4
January	48.1	67.8	83.7	-1.9	55.6	88.1	4.3
February	46.9	43.4	80.0	5.3	101.8	89.5	5.7
March	52.2	51.0	73.0	10.2	145.6	88.8	8.9
April	51.0	65.6	63.1	12.5	3.0	61.3	16.6
May	56.0	85.0	65.4	17.9	18.8	64.0	20.3
June	41.5	44.4	74.4	21.2	148.4	66.4	22.6

Total/Mean	482.7	408.0	72.8	9.0	799.6	77.3	12.1

Accumulated rainfall for the first season was 408 mm, which occurred between October and June. In November (3.2 mm) and December (3.2 mm), rainfall was very low. The mean temperature was 9.0 ºC and the mean humidity was 72.8%. In the second season rainfall was 799.6 mm, April had very little rain (3.0 mm), thus negatively affecting the shooting phase of the plant and reducing plant height. The mean temperature was 12.1 ºC and the mean humidity was 77.3% (Table 1).

3. RESULTS AND DISCUSSION

The results of the variance analysis of the research are presented in Table 2. The combined ANOVA revealed significant differences (P<0.01 and P<0.05) among genotypes for all traits except NDVI and protein ratio (Table 2).

Table 2. Mean square and F ratio for yield, morphological and physiological parameters measured in durum wheat genotypes.

Parameters	Year (Y)		Genotypes (G)		Year×Genotypes (Y×G)	
	MS	F ratio	MS	F ratio	MS	F ratio
GY	177921.0	59.74**	9846.83	3.89**	6041.89	2.39**
PH	2193.08	300.99**	178.15	17.99**	26.97	2.72**
PL	1.72	0.28ns	32.98	11.65**	10.45	3.69**
SL	0.68	1.11ns	4.31	18.93**	0.43	1.90*
SNS	2.97	2.82ns	32.80	26.71**	5.04	4.10**
KNS	312.45	44.09**	253.58	15.18**	81.12	4.86**
FLA	4.91	0.22ns	97.99	26.52**	28.05	7.59 **
DH	1548.01	2026.48**	96.99	38.67**	9.85	3.93**

*, ** Significant at p<0.05 and p<0.01 respectively. ns: non-significant, MS: mean of square, GY: Grain yield (kg ha^{-1}), PH: Plant height (cm), PL: Peduncle length (cm), SL: Spike length (cm), SNS: Spikelet number per spike, KNS: Kernel number per spike, FLA: Flag leaf area (cm^{-2}), DH: Days of heading

Analysis of variance revealed a highly significant difference among genotypes for grain yield. The mean grain yield for 15 genotypes was 6290 kg ha^{-1}. The highest grain yield was performed by G9 (6826 kg ha^{-1}) followed by G14 (6798 kg ha^{-1}). The analysis of variance revealed highly significant differences (P<0.01) among the durum wheat genotypes for plant height, peduncle length, and spike length. Plant height and stem structure are important traits in durum wheat genotypes for lodging resistance and grain yield. Plant height varied from the lowest to 77.9 cm (G14) and the highest to 95.8 cm (G4). Peduncle length differed significantly among genotypes. In the study, G4 had the longest peduncle (34.65 cm), while the shortest peduncle was recorded for G6 (26.08 cm). Spike length may vary according to genotype, environment and cultural practices. There was a significant variation among the genotypes for spike length. In the study, the minimum spike length was 6.90 cm and the maximum was 9.43 cm. The longest spike was determined in genotypes G11 followed by G1, G5 and G4 (Table 3).

Kernel number per spike of durum wheat genotypes were studied under rainfed conditions and it was found a significant difference among genotypes and genotype × year interaction (Table 3). The maximum kernel number per spike was noted in genotype G15 (59.57), followed by G3 (48.16), and

G11 (45.08). Genotypes G13 produced a minimum kernel number per spike. Spikelet number per spike and kernel number per spike are other important yield components associated with spike length. Both parameters may vary according to genotype, environment and cultural practices such as spike length. Spikelet number per spike differed among genotypes from 17.07 to 22.88, and G3 had a higher spikelet number per spike and followed by genotype G6 and G1 (Table 3). Under the rainfed conditions, flag leaf areas in different durum wheat genotypes during the years 2016-2017 and 2017-2018 were studied and very highly significant differences were found among the genotypes and year × genotypes interaction. Flag leaf area varied from 18.58 to 30.73 cm^2, and genotypes G11 and G15 had higher flag leaf areas (Table 3). Due to the fluctuation of rainfall mid-early genotypes generally are favourable in bread wheat in the Trakia region, Turkey. Days of the heading of the genotypes ranged from 116.1 (G12) to 125.1 (G6) and the mean was 120.3 days (Table 3).

Table 3. Grain yield and yield component of the genotypes across two years

Genotype	GY	PH	PL	SL	SNS	KNS	FLA	DH
G1	6066^{d-g}	88.4^{cd}	28.89^{g}	8.72^{b}	22.28^{a}	40.73^{def}	21.09^{gh}	123.0^{c}
G2	6426^{a-e}	84.5^{e-h}	30.19^{d-g}	7.36^{gh}	19.30^{ef}	40.62^{def}	21.32^{fgh}	116.4^{f}
G3	6033^{d-g}	86.9^{de}	29.73^{efg}	8.08^{cde}	22.88^{a}	48.16^{b}	23.52^{de}	124.6^{ab}
G4	5724^{g}	95.8^{a}	34.65^{a}	8.35^{bcd}	21.89^{ab}	40.18^{d-g}	18.58^{i}	124.5^{abc}
G5	6431^{a-e}	93.1^{ab}	31.03^{cde}	8.46^{bc}	21.15^{bc}	41.81^{c-f}	19.55^{hi}	124.5^{abc}
G6	6263^{b-f}	82.9^{ghi}	26.08^{h}	8.05^{cde}	22.68^{a}	43.92^{cd}	21.99^{efg}	125.1^{a}
G7	6140^{c-g}	83.6^{f-i}	29.35^{fg}	7.92^{de}	20.40^{cd}	42.73^{cde}	26.01^{bc}	120.1^{d}
G8	6622^{abc}	86.9^{de}	33.06^{ab}	7.40^{fg}	18.86^{efg}	38.16^{fg}	23.05^{def}	118.4^{e}
G9	6826^{a}	86.3^{def}	28.90^{g}	7.00^{gh}	19.96^{de}	38.68^{efg}	22.08^{efg}	118.5^{e}
G10	6489^{a-d}	85.4^{d-g}	31.59^{bcd}	7.86^{ef}	17.74^{hi}	43.74^{cd}	27.30^{b}	117.5^{ef}
G11	5824^{fg}	90.8^{bc}	32.08^{bc}	9.43^{a}	21.99^{ab}	45.09^{bc}	30.73^{a}	123.3^{bc}
G12	6056^{d-g}	81.5^{hi}	30.86^{c-f}	7.08^{gh}	17.07^{i}	38.64^{fg}	25.45^{bc}	116.1^{f}
G13	5970^{efg}	84.3^{e-h}	30.56^{c-g}	7.97^{de}	18.11^{ghi}	36.40^{g}	24.89^{cd}	118.0^{e}
G14	6798^{a}	77.9^{j}	31.98^{bc}	6.90^{h}	17.40^{i}	39.01^{efg}	24.94^{cd}	116.3^{f}
G15	6686^{ab}	80.6^{ij}	31.78^{bcd}	6.91^{h}	18.60^{fgh}	59.57^{a}	29.81^{a}	117.6^{ef}
Average	6290	85.9	30.7	7.83	20.01	42.49	24.02	120.3
CV (%)	7.9	3.6	5.4	6.0	5.5	9.6	7.9	1.3
LSD (0.05)	49.8	3.1	1.66	0.45	1.09	4.04	1.9	1.56

GY: Grain yield (kg ha^{-1}), PH: Plant height (cm), PL: Peduncle length (cm), SL: Spike length (cm), SNS: Spikelet number per spike, KNS: Kernel number per spike, FLA: Flag leaf area (cm^{-2}), DH: Days of heading,

Table 4. Coefficients of correlation between grain yield and physiological parameters

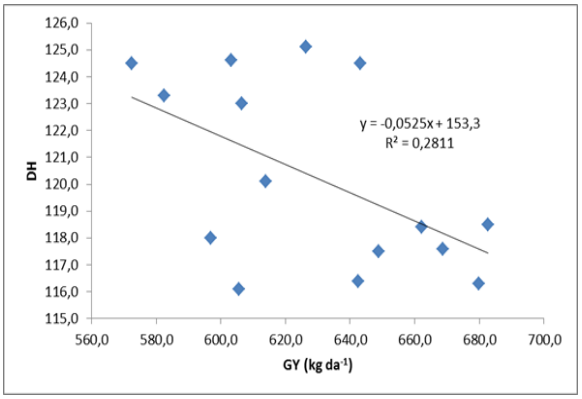
Parameter	GY	PL	SL	SNS	KNS	FLA	PH
PL	-0.084						
SL	-0.718**	-0.005					
SNS	-0.477	-0.323	0.706**				

Parameter	GY	PL	SL	SNS	KNS	FLA	PH
GNS	0.117	-0.013	-0.031	0.174			
FLA	0.054	0.119	-0.046	-0.358	0.502		
PH	-0.500	0.336	0.709**	0.608*	-0.154	-0.453	
DH	-0.530*	-0.192	0.763**	0.935**	0.141	-0.366	0.680**

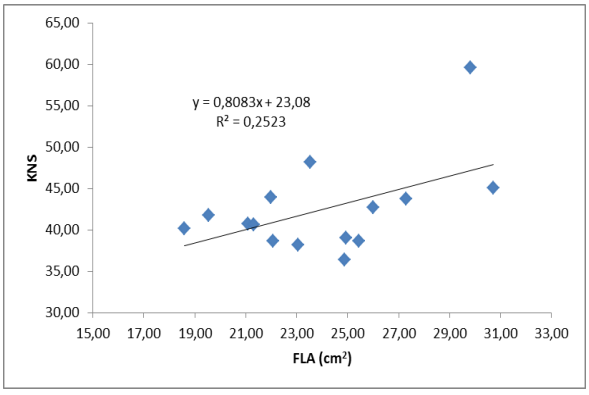
*, ** Significant at $P<0.05$ and $P<0.01$ respectively. GY: Grain yield (kg ha^{-1}), PL: Peduncle length (cm), SL: Spike length (cm), SNS: Spikelet number per spike, KNS: Kernel number per spike, FLA: Flag leaf area (cm^{-2}), DH: Days of heading, PH: Plant height (cm).

Correlation coefficients among investigated parameters were determined by Pearson's correlation analysis (Table 4). Data analysis showed that coefficients of correlation among parameters for grain yield varied. Grain yield was negatively correlated with spike length (r=-0.718**), days of heading (r=-0.530*), plant height (r=-0.500), and spikelet number per spike (r=-0.477). It was found positive relation between spike lengths with spikelet number per spike (r=0.706**), plant height (r=0.709**), and days of heading (r=0.763**). No correlation was found between grain yield with peduncle length and flag leaf area. Spikelet number per spike was positively related to plant height (r=-0.608*), and days of heading (r=-0.935**). Days of heading were also significantly positively associated with plant height (r=0.680**). Flag leaf area positively correlated with grain number per spike (r=0.502).

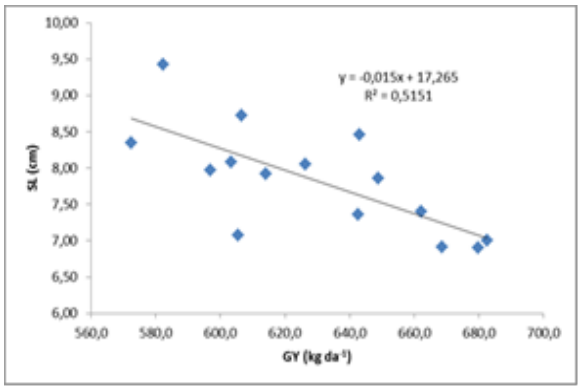
Pairwise relations of the characteristics examined in the study were also made. Linear regression was used to determine the association of grain yield, quality and physiological parameters. Flag leaf area had a positive effect on kernel number per spike (R^2=0.252) and negative relation with plant height (R^2=0.205). Days of heading (R^2=0.281) and spike length (R^2=0.515) negatively correlated with grain yield. It has been determined that the spike length is longer in late-heading genotypes. More spikelet was detected in tall genotypes (Figure 1). While higher yield was detected in early genotypes, flag leaf made a significant contribution to the increase in kernel number per spike.



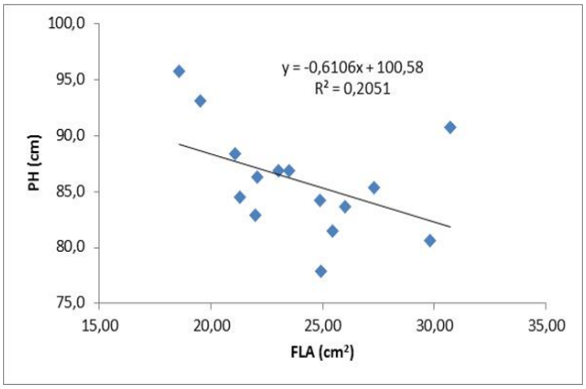
1a. Grain yield and days of heading



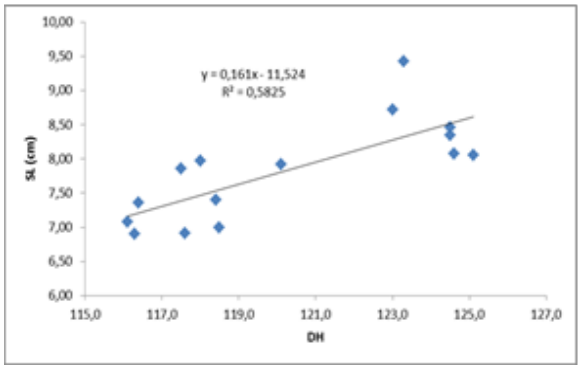
1b. Flag leaf area and kernel number per spike



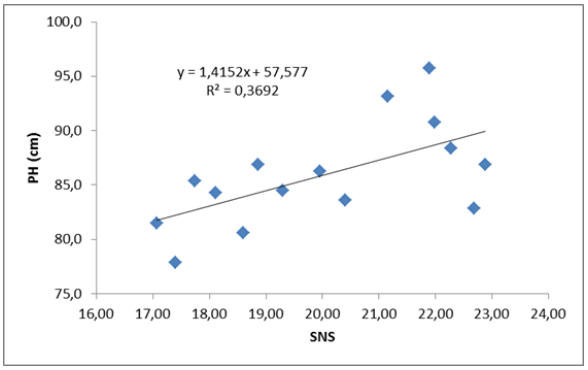
1c. Spike length and grain yield



1d. Flag leaf area and plant height



1e. Days of heading and spike length



1f. Spikelet number per spike and plant height

Fig. 1. The comparison of parameters investigated in this research

4. CONCLUSIONS

The results of variance analysis revealed significant differences among genotypes and year × genotypes interaction for yield ($p<0.01$) and yield component. The highest grain yield was performed by G9 and the lowest by G14. In the experiment, G4 had the longest peduncle length and G11 had the longest spike length. The highest spikelet number per spike and kernel number per spike were determined in genotype G3. The highest flag leaf area was determined in genotype G15. In the study, flag leaf area in durum wheat genotypes significantly affected kernel number in spike. Tall and late genotypes had higher spike length and spikelet number per spike. Grain yield was negatively correlated with spike length, days of heading and plant height. The fact that there was a different correlation between the parameters revealed the importance of genotype and environmental effects. In the study, it was found to be significant genotypes and year genotype interaction among the parameter peduncle length, spike length, kernel number per spike, flag leaf area and spikelet number per spike. Therefore, it was concluded that these parameters can be used in selection in breeding studies.

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