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Comparison of Agronomic and Physiological Parameters of Durum Wheat Local Landraces and Commercial Cultivars

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ABSTRACT

Türkiye has great variation and production experience in terms of both bread and durum wheat landraces and commercial varieties. The study was carried out to evaluate of agronomic and physiological components of durum wheat commercial cultivars and landraces under rainfed conditions. In the experiments, totally 35 durum wheat landraces and commercial varieties were investigated in the 2018-2019 cropping years in the Trakia region, Türkiye. The experiment was laid out in a randomized complete blocks design with three replications. The results of variance analysis showed significant differences ($p<0.01$) among local landraces and commercial varieties for the traits studied except for chlorophyll content. Normalised difference vegetation index (NDVI) was measured in heading stages. Landraces have the highest NDVI compared with commercial varieties. Higher canopy temperature was measured in commercial cultivars (G35, G32, G34 and G33) while lower canopy temperature was detected in landraces (G2, G15). Flag leaf area was measured at heading stages and it was found significant difference among landraces and commercial cultivars. Landraces G3, G4 and G2 had the highest flag leaf area of 42.9, 40.6 and 39.9 cm^2, respectively. Landraces had longer plant height and peduncle length than commercial varieties. The number of grains per spike and number of stomata were higher in commercial varieties and local landraces, respectively. Stomata measurements were made on samples taken from flag leaves during the heading period. Commercial varieties had higher values than landraces in terms of stomata width, height, area and perimeter. Cluster analysis clearly differentiated, commercial cultivars from the landraces based on agro-physiological data.

Keywords: Durum wheat, landraces, commercial cultivars, agro-physiological parameters

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Introduction

Türkiye is considered a diversification centre of durum wheat (*Triticum turgidum* L. var. *durum*). Germplasm presents average diversity showing a large genetic variability. If considerable variation among genotypes could be identified these can be widely used in durum wheat breeding programs (Öztürk, 2019). Durum wheat (*Triticum turgidum* L. ssp. *durum*) expresses approximately 6% of the global wheat production. The Mediterranean Basin is the most extensive durum-producing area, the customer of durum wheat products and the most important import market in the world (Royoa et al., 2020). Durum wheat Mediterranean landraces are essential resources to increase the genetic diversity of modern cultivated varieties and ensure their adaptation to regions affected by biotic and abiotic factors (Soriano et al., 2018). Wheat has been a staple crop in the Anatolian region since prehistoric times. Anatolia has hosted many agricultural cultures from the first waves of Neolithic migrations to modern times. The diversity of wheat in Anatolia is also great, as farmers have multiplied the crops and preserved them for thousands of years (Brush, 1995). New high-yield varieties of durum wheat that can compete with bread wheat varieties haven't yet been improved. Durum wheat breeding researchers also need to select well-adapted genotypes available in the region (Bilgin et al., 2008). The yield of durum wheat in the Mediterranean regions is frequently restricted by high temperatures and drought stress during grain growth stages (Garcia del Moral et al., 2003). Drought and heat are the most important abiotic stresses limiting wheat cultivation. Local varieties are tolerant to abiotic stresses and are genetic resources that can be used in breeding programs to develop genotypes resistant to stress conditions (Farooq, 2023). While Durum wheat is mainly used in the production of pasta and couscous, it is also used in the production of some other semolina products such as bulgur and unleavened bread. It is known that in the Mediterranean region, Durum wheat is mainly grown in conditions where rainfall is irregular between years and locations and during the plant growth period, thus causing yield differences (Soriano et al., 2018). Some of the morphological and physiological characteristics known to be hereditary and used in breeding programs are early development and early flowering. Early development in genotypes is generally determined by the size of the seed. This feature reduces direct evaporation of soil water by covering the soil after rapid development and increasing plant water use (Richards et al., 2011; Blum, 2011; Elazab et al., 2015). Breeding carried out according to phenological characteristics may ignore genetic characteristics. Scientists recognize that landraces and varieties represent an important group of genetic resources for the development of commercially important traits (Lopes et al., 2015).

Stomatal transpiration is the principal way of water loss in the plant. Stomata features influencing the water-use efficiency of plants are significant factors in assessing genotypes for drought stress. Reducing water loss from the leaf surface during periods of water stress is an important element of maintaining viability in drought (Bilgin et al., 2011). Stomatal characteristics such as density and size of stomata are considered to be the main determinants of the development rate and water balance in plants (Dillen et al., 2008).

Landraces were largely cultivated until the first decades of the twentieth century, being progressively abandoned from the early 1970s and replaced with improved, genetically uniform semi-dwarf cultivars as a consequence of the Green Revolution (Ortiz et al., 2007). Türkiye was one of the genetically diverse countries where landraces and commercial varieties of bread and durum wheat are widely available and produced before green revolution. Still, durum and bread wheat landraces are cultivated in rural areas of highlands where stipend farming systems are common. The experiment was carried out to evaluate agronomic and physiological parameters of durum wheat commercial cultivars and landraces under rainfed conditions.

Materials and Methods

Plant Materials and Studied Traits

During the 2018-2019 growing season, a total of 35 durum wheat landraces and commercial cultivars (Table 1) were tested in the Trakia region, Türkiye. The study was carried out under rainfed conditions at the experimental field of Trakia Agriculture Research Institute in Edirne Türkiye (41º 38´ 52´´ N and 26º 36´ 07´´ N, 40 m elevation), in a randomized complete blocks design (RCBD) with three replications. In the experiment, each plot was 2 m×3 rows, spaced 0.30 meters apart.

Parameters related to yield component and physiological were tested in each genotype using the following criteria. In the study, canopy temperature (CT), chlorophyll content (SPAD) and normalized difference vegetation index (NDVI) were taken at heading stages. Yield components such as the number of spikelet per spike, the number of kernels per spike, spike weight and spike length were determined from each genotype. Flag leaf area (FLA), days of heading (DH), plant height (PH) and peduncle length (PL) were investigated. The stomata area (STA), stomata width (STW), stomata height (STH), stomata perimeter (STP) and number of stomata (STN) were also experienced on flag leaves during the heading (Z55) period.

Normalized difference vegetation index (NDVI): It was scaled at the Z55 (Zadoks et al., 1974) period. Measurements were made using a hand-held Ntech 'Greenseeker' NDVI meter (N Tech Industries (2011) Greenseeker (Pask et al., 2012). NDVI measurements were taken from 11:00h to 14:00h, on a clear, sunny day. Measurements were taken for plant growth at Z55 development stages. Normalised difference vegetative index can be used to estimate biomass accumulation, growth rate, yield estimation, soil cover, early vigour, senescence model predictions, detection of biotic and abiotic stress factors (Araus, 1996; Gutierrez-Rodriguez et al., 2004; Pask et al., 2012).

Chlorophyll content (SPAD): For Chlorophyll content, the SPAD-502 chlorophyll meter (Minolta) was used. Chlorophyll content was measured from ten flag leaves were used to take chlorophyll meter

(SPAD) readings from each plot at the heading stage (Z55) (Adamsen et al., 1999; Babar et al., 2006; Fisher, 2001; Pask et al., 2012; Reynolds et al., 2001).

Canopy temperature (CT): The infrared thermometer was used to measure canopy temperature CT (°C). Canopy temperatures were scaled from each plot at a 1m distance from the edge and approximately 50 cm above the canopy at an angle of 30° to the horizontal. Scaled were made between 13.00 and 15.00 h on sunny and without windy days (Babar et al., 2006; Reynolds et al., 2012; Pask et al., 2012). Measurements were taken for plant growth at the Z55 development stages.

Flag leaf area (cm²): 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

Stomata width and height (µm): Stoma measurements were made on samples taken from flag leaves during the heading period. Stoma width and length were determined by taking the average of a total of 10 measurements.

Stomata area (µm²): It was determined by taking the average of the measurements made in 10 samples from the samples taken from the flag leaves.

Stomata perimeter (µm): It was determined by taking the average of the measurements made in 10 samples from the samples taken from the flag leaves.

Statistical Analyses

Data examined in the study were statistically analysed in the method described by Gomez and Gomez (1984). The averages of the parameters examined in the genotypes were determined according to the LSD test (0.05). Relationships between features were determined by Pearson correlation analysis. The cluster analysis was used to see whether the cultivars fell into groups or clusters. The cluster analysis was achieved that adopted squared Euclidian distance as a measure of dissimilarity and Ward's method as the clustering algorithm (Ward, 1963).

Meteorological Data

Total precipitation for the growing cycles from October to June was 523.4 mm. In March (7.6 mm), December (16.8 mm) and February (18.2 mm) rainfall was very low. The mean temperature was 11.6 °C and the mean humidity was 76.2% (Table 2).

Results and Discussion

The analysis of variance in the experiment is listed in Table 3. The combined analysis of variance showed significant differences (P<0.01) among durum wheat landraces and commercial cultivars for all traits except chlorophyll content (SPAD) (Table 3).

In the study, it was observed that there were significant differences between local and commercial varieties of durum wheat according to plant height, stem length and spike length. In durum wheat genotypes, plant height and stem structure are significant traits for lodging resistance. Earliness has become the most important feature against drought and heat stress in climate change. Early varieties with low vernalization requirements are less affected by drought. In the research, it has been observed that commercial varieties head earlier than local varieties. In the research, the earliest varieties were G35 with 116.0 days, G27 and G28 with 116.7 days. Long plant height is a preferred trait, especially in arid conditions. Local landraces are taller than commercial varieties. The shortest height was measured at 83.7 cm (G18) in the commercial variety, and the longest height was measured at 158 cm (G29) in the local variety. In the study, local landraces G14 had the longest peduncle (64.5 cm) and the shortest peduncle was measured for commercial cultivar G6 (28.9 cm). Spike length in genotypes may vary depending on genotype and environmental factors. In the experiments, the minimum spike length was 6.09 cm in commercial cultivar (G27). The maximum spike length was 9.10 cm in commercial cultivar (G17) and 9.05 cm in local landraces G1 (Table 4).

The number of spikelet per spike (SNM) and the number of kernels per spike (KNS) are essential yield parameters associated with grain yield. Parameters SNM and KNS may also vary based on genotype and environmental factors. The number spikelet per spike varied from 16.5 to 21.9. Commercial cultivar G26 and local landraces G15 had a higher spikelet number per spike. The number kernel per spike of durum wheat genotypes was examined and it was found a significant difference among genotypes (Table 3). More spikes were counted in commercial varieties. The maximum kernel number per spike was noted in genotype G26 (59.2), followed by G21 (57.3), G28 (52.8) and G22 (52.4). Local landraces G8 produced a minimum kernel number per spike (31.8). Differences in spike weight were determined between commercial and local varieties. The heaviest spike was measured at 3.88 g in the local variety G1. The smallest spike weight was determined in the local variety G7, with 1.99 g (Table 4).

Flag leaf areas in durum wheat landraces and commercial cultivars were tested and it was found differences in genotypes. In the study, the flag leaf area of local varieties was larger than commercial varieties. The largest flag leaf area was measured in G3 (42.9 cm^2), G4 (40.6 cm^2) and G2 (39.9 cm^2) local varieties. The smallest flag leaf area was measured in G27 (15.9 cm^2) and G28 (18.7 cm^2) commercial varieties (Table 4).

There was significant variation ($p<0.01$) in chlorophyll content (SPAD) of the durum wheat landraces and commercial cultivars. The highest chlorophyll content was 60.9 in G23 and 60.4 in G27 commercial cultivars. Chlorophyll content in durum wheat landraces varied from 53.2 (G8) to 58.8 (G3). Under drought and heat stress conditions canopy temperature is related to yield. The lowest canopy temperature was 22.1°C in G2 and 22.4°C in G15. Lower canopy temperature was measured in local varieties. The normalized difference vegetation index is widely utilised for estimating the rapid ground level of crops, canopy for leaf area index, green area index, biomass and nutrient content (Pask et al., 2012). The high rate of variation in normalised difference vegetation index in durum wheat landraces and commercial cultivars. Normalized difference vegetation index varied from the lowest 0.60 to the highest 0.81 in genotypes. The highest NDVI were determined in genotypes G13, G14, G16, G23 and G26 (Table 5). The results of the study explained differences among durum wheat genotypes according to measured stoma characteristics. It was determined that commercial varieties had wider stomata than local varieties in terms of stoma width, length, area and perimeter. The largest stoma width was measured in G15 and G25, and the longest stoma was measured in G23 and G16. While G23 had the widest stoma, the smallest stoma area was determined in G1. It was determined that local varieties had more stomatal numbers than commercial varieties (Table 5).

Durum wheat local landraces and commercial cultivars were tested for 16 parameters and a wide difference was found for the parameters studied. The cluster analysis was performed and 35 durum wheat genotypes were grouped into 7 clusters based on Ward's method. It has been determined that most of the local landraces are in the first three groups. While Fırat93 (G28) and Harran95 (G29) varieties were the closest to each other according to the examined parameters, G1 and Ankara98 (G25) were the most distant genotypes. The first group of cluster 7 genotypes and the second and third groups of cluster 3 genotypes are located. The fourth group of cluster 9 cultivars, the seventh group of cluster 6 cultivars, and the last group of cluster 5 commercial durum wheat cultivars are located (Figure 1).

Correlation coefficients among studied parameters were established by Pearson's correlation analysis (Table 6). Days to heading were positively correlated with plant height, peduncle length, spike length, spikelet number per spike, normalised difference vegetative index and flag leaf area. A positive correlation was found among plant height with peduncle length, spike length, normalised difference vegetative index, flag leaf area and number of stomata. There was a positive relation between peduncle lengths with spike length, normalised difference vegetative index, flag leaf area and number of stomata. Canopy temperature was negatively correlated with days to heading, peduncle length, plant height, spike length, number of spikelet and normalised difference vegetative index. Flag leaf area positively correlated with days of heading, plant height, peduncle length, spike length, number of spikelet and normalised difference vegetative index. Stomata number in genotypes was positively correlated with days of heading, plant height, peduncle length, spike length and normalised difference vegetative index.

Conclusions

It was observed that there were significant differences between commercial varieties and local landraces in the parameters examined in the study. The higher value of flag leaf area, plant height and normalised difference vegetation index was determined in local landraces. This result showed the importance of using local varieties in breeding studies, especially since flag leaf area and normalised difference vegetation index values are positively related to yield. The fact that local landraces have low canopy temperatures has shown the importance of using breeding studies for drought tolerance. The stomata density in genotypes was higher in local landraces than the commercial cultivars. It was determined that commercial varieties had wider stomata in terms of values such as stoma width, length and area. According to cluster analysis, it was determined that the commercial varieties examined in the research differed from the local varieties. It will be useful to use local varieties in breeding studies due to some of their superior agronomic properties.

Table 1. Local landraces and cultivars durum wheat genotypes investigated in the study.

Genotype No	Landraces	Genotype No	Commercial Cultivars	Genotype No	Commercial Cultivars
G1	Yerli/Bağacak	G16	Ergene	G31	Sarı çanak 98
G2	Sevinç	G17	Tunca 79	G32	Fuatbey 2000
G3	Kızıl Buğday	G18	Gökgöl 79	G33	Balcalı 2000
G4	Cafari	G19	Çakmak 79	G34	Zenit
G5	Gedifla	G20	Kunduru 1149	G35	Svevo
G6	Menceki	G21	Mirzabey 2000		
G7	Hacıhalil	G22	Kızıltan 91		
G8	Sorgül	G23	Eminbey		
G9	Beyaziye	G24	Çeşit-1252		
G10	Devedişi	G25	Ankara 98		
G11	Bağacak	G26	Selçuklu-97		
G12	İskenderi	G27	Ege 88		
G13	Karabaşak	G28	Fırat-93		
G14	Karakılçık	G29	Harran 95		
G15	Akbaşak	G30	G30		

Table 2. Climate data in Edirne location experimental area in 2018-2019 growing year.

Months	Long Term Rainfall (mm)	Annual Rainfall (mm)	Mean Humidity (%)	Temperature (°C)		
				Min.	Max.	Mean
October 2018	52.9	32.6	74.2	1.6	24.8	15.7
November 2018	72.4	208.8	81.8	-2.9	23.2	9.8
December 2018	61.7	16.8	86.7	-4.5	16.5	3.9
January 2019	48.1	82.4	85.7	-9.4	16.1	4.1
February 2019	46.9	18.2	76.5	-5.5	16.8	5.6
March 2019	52.2	7.6	68.6	-1.9	23.2	9.8
April 2019	51.0	60.4	72.8	-0.3	25.8	12.4
May 2019	56.0	63.4	75.1	3.8	32.2	18.2
June 2019	41.5	33.2	64.8	19.8	36.2	24.5
Total/Mean	482.7	523.4	76.2	0.1	23.9	11.6

Table 3. Mean square and F ratio for parameters investigated in durum wheat genotypes.

Parameters	Genotypes (G)	
	Mean square (MS)	F Ratio
Days of heading (DH)	77.7171**	70.472
Plant height (PH)	2063.745**	66.001
Peduncle length (PL)	269.215**	15.708
Spike length (SL)	2.382**	9.790
Spikelet number per spike (SNS)	5.366**	5.256
Number of kernel per spike (KNS)	90.402**	3.393
Spike weight (SW)	0.6763**	4.604
Normalized difference vegetation index (NDVI)	0.013**	2.654
Chlorophyll content (SPAD)	12.186	1.406
Canopy temperature (CT)	4.148**	2.061
Flag leaf area (FLA)	108.437**	12.533
Stomata width (STW)	25.720**	7.726
Stomata height (STH)	12.420**	4.869
Stomata area (STA)	36799.867**	7.836
Stomata perimeter (STP)	139.877**	8.546

Table 4. Mean value of the durum wheat landraces and commercial cultivars for parameters.

Genotype	DH	PH	PL	SL	SNS	KNS	SW	FLA
G1	127.7fg	155.7ab	60.3ab	9.05a	19.8b-e	48.9c-h	3.88a	35.2c-f
G2	127.3fg	158.0a	55.7b-e	8.62a-d	19.3b-f	46.9c-l	3.45abc	39.9abc
G3	130.0b-e	110.7h	48.6f-ı	6.84k-n	18.3e-ı	41.1g-m	2.85c-ı	42.9a
G4	128.3ef	115.7gh	49.5e-h	6.84k-n	19.5b-f	41.6f-m	2.64d-j	40.6ab
G5	119.7ı	88.3j-n	33.1nop	6.37mn	17.8f-j	45.3d-l	2.47g-k	24.2p-s
G6	130.7a-d	136.7c	54.9b-f	7.91d-ı	19.1b-f	42.9e-m	3.07b-g	35.2c-f
G7	129.7cde	132.0cde	53.5c-f	6.69k-n	17.4g-j	39.5j-m	1.99k	29.4h-n
G8	126.3gh	124.7efg	46.7h-j	6.59lmn	17.0ıj	35.1m	2.10jk	28.6j-p
G9	130.3bcd	127.0def	53.8b-f	7.71e-j	17.9f-j	44.8d-l	2.86c-ı	31.1f-l
G10	131.7ab	146.7b	58.0a-d	8.19b-g	18.6e-ı	40.9h-m	3.13b-f	33.0d-j
G11	131.7ab	119.7fgh	56.1b-e	7.04j-m	16.5j	40.4ı-m	2.28h-k	31.4f-k
G12	131.0abc	135.0cd	51.5d-g	8.33a-e	19.7b-e	47.3c-l	2.87c-ı	34.0d-h
G13	130.7a-d	153.3ab	49.5e-h	8.03c-h	18.4e-ı	39.0lm	2.34h-k	34.2d-g
G14	131.0abc	154.7ab	64.5a	8.63a-d	20.8ab	48.4c-ı	3.38abc	36.4b-e
G15	132.3a	150.0ab	59.2abc	8.33a-e	21.7a	46.5c-l	3.24bcd	37.1bcd
G16	127.3fg	92.0ı-l	35.8l-o	8.00c-h	19.6b-e	41.8f-m	2.40h-k	24.1p-s

Continuing Table 4

Genotype	DH	PH	PL	SL	SNS	KNS	SW	FLA
G17	128.3ef	88.7j-n	36.8l-o	9.10a	20.4abc	47.9c-j	2.60e-k	32.3e-k
G18	125.3h	83.7lmn	35.2m-p	8.23b-f	18.7d-h	41.1g-m	2.26ıjk	32.2e-k
G19	128.3ef	90.0ı-n	42.5ı-k	7.41g-k	18.4e-ı	49.7b-f	2.31h-k	26.4l-s
G20	131.3abc	136.3c	56.2bcd	7.81e-j	18.7d-h	45.5c-l	3.08b-g	33.7d-ı
G21	131.0abc	91.0ı-m	41.7j-m	8.91ab	20.4abc	57.3ab	3.11b-f	30.1g-m
G22	130.3bcd	98.7ı	43.6h-k	8.05c-h	19.0c-g	49.0b-h	2.52f-k	22.6st
G23	127.7fg	90.0ı-n	41.0j-m	8.01c-h	20.3a-d	53.8abc	3.14b-f	25.3m-s
G24	126.0gh	93.3ıjk	38.7k-n	8.74abc	18.9c-g	48.2c-ı	2.60e-k	23.7qrs
G25	125.3h	95.3ıj	41.5j-m	7.46f-k	19.2b-f	50.9a-e	3.12b-f	29.0ı-o
G26	130.3bcd	90.0ı-n	37.7k-o	8.32a-e	21.9a	59.2a	2.68d-j	30.5f-l
G27	116.7k	85.7k-n	35.4m-p	6.09n	17.8f-j	52.4a-d	2.89c-h	15.9u
G28	116.7k	91.7ı-m	40.1j-m	7.13ı-m	19.3b-f	52.8a-d	3.47abc	18.7tu
G29	119.0ıj	88.0j-n	37.9k-o	6.75k-n	18.4e-ı	49.9b-f	3.55ab	25.3n-s
G30	129.0def	86.3j-n	38.6k-n	7.28h-l	19.5b-f	49.3b-g	2.21jk	23.2rst
G31	126.3gh	87.3j-n	28.9p	6.57lmn	17.4g-j	48.4c-ı	3.17b-e	31.4f-k
G32	120.3ı	88.7j-n	38.1k-o	6.72k-n	18.8c-g	51.9a-d	3.31abc	27.7k-r
G33	119.0ıj	89.3j-n	38.4k-n	6.18n	17.0ıj	40.9h-m	2.57e-k	28.2k-q
G34	117.3jk	81.7n	31.6op	6.66k-n	17.2hıj	39.2klm	2.10jk	24.5o-s
G35	116.0k	82.7mn	35.3m-p	6.43mn	16.5j	47.5c-k	2.59e-k	28.5j-q
Average	126.6	109.7	44.8	7.57	18.8	46.4	2.81	29.9
$LSD_{(0.05)}$	1.69	9.07	6.72	0.8	1.63	8.38	0.62	4.77

DH: Days of heading, PH: Plant height (cm), PL: Peduncle length (cm), SL: Spike length (cm), SNS: Spikelet number per spike, KNS: Kernel number per spike, SW: Spike weight (g), FLA: Flag leaf area (cm^2)

Table 5. Agro-physiological parameters of the durum wheat landraces and commercial cultivars.

Genotype	SPAD	CT	NDVI	STW	STH	STA	STP	STN
G1	55.7b-g	23.7e-j	0.77a-e	42.1lm	24.0mno	803.1q	110.4ll	16.7a
G2	55.1c-g	22.1j	0.78a-d	44.8ı-l	25.7h-o	894.3m-q	116.3jkl	13.1c-h
G3	58.8a-d	24.5b-ı	0.76a-e	41.1m	24.4l-o	809.4pq	109.9l	14.7b
G4	54.6d-g	24.2c-j	0.78a-d	43.6j-m	23.4o	807.1pq	112.6kl	13.0c-ı
G5	54.0efg	24.7b-ı	0.73a-f	45.4h-k	24.5l-o	864.3opq	116.3jkl	12.6e-j
G6	58.2a-f	24.6b-ı	0.79abc	41.9lm	24.5l-o	803.0q	110.0l	16.7a
G7	56.2a-g	25.2a-h	0.76a-f	43.2klm	27.7b-j	917.3l-p	116.3jkl	12.6e-j
G8	53.2g	25.7a-f	0.79abc	50.7a-d	26.6e-m	1052.9c-ı	129.7a-e	11.6h-l
G9	55.4c-g	24.5b-ı	0.81ab	49.6b-e	25.2j-o	967.9g-o	124.0e-ı	14.7b
G10	54.2d-g	23.4f-j	0.79ab	46.2f-j	24.5l-o	889.5m-q	117.7ıjk	16.6a
G11	55.6c-g	24.8b-h	0.80ab	45.8g-k	26.9d-l	944.9ı-o	119.6hıj	14.7b
G12	57.9a-g	24.0d-j	0.79abc	45.9g-k	24.8k-o	882.7n-q	117.9ıjk	14.3bc
G13	58.6a-e	24.1d-j	0.81a	48.6d-g	23.9no	917.2l-p	122.3g-j	11.1jkl
G14	55.6c-g	23.2hıj	0.81a	46.1f-k	25.3ı-o	915.4l-p	119.2h-k	12.8c-ı
G15	56.9a-g	22.4ıj	0.78a-d	52.5a	28.8b-f	1160.6abc	134.8ab	11.9g-l
G16	57.5a-g	23.3g-j	0.81a	45.7h-k	30.1ab	1037.3d-k	122.9f-j	12.3f-k
G17	53.5fg	25.5a-h	0.77a-e	46.3f-j	28.5b-g	994.2e-n	121.9g-j	13.0c-h
G18	55.1c-g	23.4f-j	0.77a-e	48.1d-h	27.4c-k	1022.6e-l	124.5d-h	12.6e-j
G19	58.2a-f	24.1d-j	0.80ab	47.8d-h	29.3bcd	1103.8b-e	127.0c-g	14.2bcd
G20	59.8abc	23.2hıj	0.80ab	51.9ac	26.8d-l	1078.6b-g	130.8a-d	13.7b-f
G21	57.3a-g	24.8b-h	0.80ab	49.2b-e	28.1b-h	1065.1c-h	127.7c-g	13.5b-g
G22	59.5abc	24.0d-j	0.79abc	46.2f-j	26.6e-m	939.6j-o	119.3hıj	14.1b-e
G23	60.9a	25.4a-h	0.81ab	51.6abc	32.3a	1243.1a	136.3a	12.8c-ı
G24	56.6a-g	25.7a-f	0.79ab	48.9c-f	29.1b-e	1090.0b-f	128.9b-f	12.6e-j
G25	56.6a-g	25.3a-h	0.78a-d	52.2ab	27.8b-ı	1141.6a-d	132.4abc	11.8h-l
G26	58.1a-f	24.4b-ı	0.81ab	50.5a-d	26.1g-n	1040.7d-j	127.7c-g	13.4b-g
G27	60.4ab	25.9a-e	0.71a-g	47.2e-ı	27.7b-j	1023.3e-l	124.1e-ı	12.7d-ı
G28	58.2a-f	25.6a-g	0.65fgh	47.0e-ı	27.6b-j	985.4f-n	122.9f-ı	10.6l
G29	57.3a-g	25.2a-h	0.67d-h	46.1f-k	26.3f-n	943.4ı-o	119.3hıj	11.5h-l
G30	58.6a-e	25.0a-h	0.70b-h	46.2f-j	28.3b-h	996.0e-m	121.4g-j	13.1c-h
G31	53.2g	25.0a-h	0.68c-h	48.1d-h	24.9k-o	928.8k-o	121.9g-j	10.8kl
G32	56.4a-g	26.7ab	0.60h	47.8d-ı	25.9h-o	944.7ı-o	122.3g-j	11.5h-l
G33	58.3a-f	26.3a-d	0.62gh	46.0f-k	26.6e-l	960.0h-o	120.1hıj	11.4ı-l
G34	56.3a-g	26.5abc	0.60h	50.5a-d	29.5bc	1177.3ab	133.2abc	11.6h-l
G35	56.6a-g	27.2a	0.66e-h	46.1f-k	25.4ı-o	886.0m-q	118.2h-k	12.3f-k
Average	56.8	24.7	0.75	47.2	26.7	978.0	122.3	13
LSD $_{(0.05)}$	4.77	2.29	0.11	2.96	2.58	111.2	6.56	3.12

SPAD: Chlorophyll content, CT: Canopy temperature (°C), NDVI: Normalized difference vegetation index (NDVI),
STW: Stomata width (μm), STH: Stomata height (μm), STA: Stomata area (μm^2), STN: Stomata number, STP: Stomata perimeter (μm)

Table 6. Coefficients of correlation among parameters investigated in durum wheat genotypes.

Traits	DH	PH	PL	SL	SNS	KNS	SW	NDVI	SPAD	CT	FLA	STA
PH	0.594**											
PL	0.651**	0.927**										
SL	0.621**	0.411*	0.410*									
SNS	0.443**	0.188	0.228	0.726**								
KNS	-0.102	-0.346*	-0.250	0.272	0.559**							
SW	-0.019	0.302	0.315	0.308	0.422*	0.507**						
NDVI	0.818**	0.498**	0.542**	0.639**	0.421*	-0.035	-0.047					
SPAD	-0.019	-0.146	-0.042	-0.021	0.181	0.354*	0.058	0.018				
CT	-0.673**	-0.647**	-0.608**	-0.589**	-0.492**	0.091	-0.242	-0.659**	0.056			
FLA	0.589**	0.657**	0.630**	0.346*	0.232	-0.310	0.224	0.390*	-0.313	-0.537**		
STA	-0.072	-0.366*	-0.313	0.098	0.197	0.263	-0.166	0.040	0.276	0.133	-0.432**	
STN	0.541**	0.429**	0.561**	0.408*	0.134	-0.047	0.156	0.496**	0.040	-0.382	0.365*	-0.393*

*, ** Significant at P<0.05 and P<0.01 respectively. DH: Days of heading, PH: Plant height (cm), PL: Peduncle length (cm), SL: Spike length (cm), SNS: Spikelet number per spike, KNS: Kernel number per spike, SW: Spike weight (g), NDVI: Normalised difference vegetative index, SPAD: Chlorophyll content, CT: Canopy temperature (°C), FLA: Flag leaf area (cm^{-2}), STA: Stomata area, STN: stomata number.

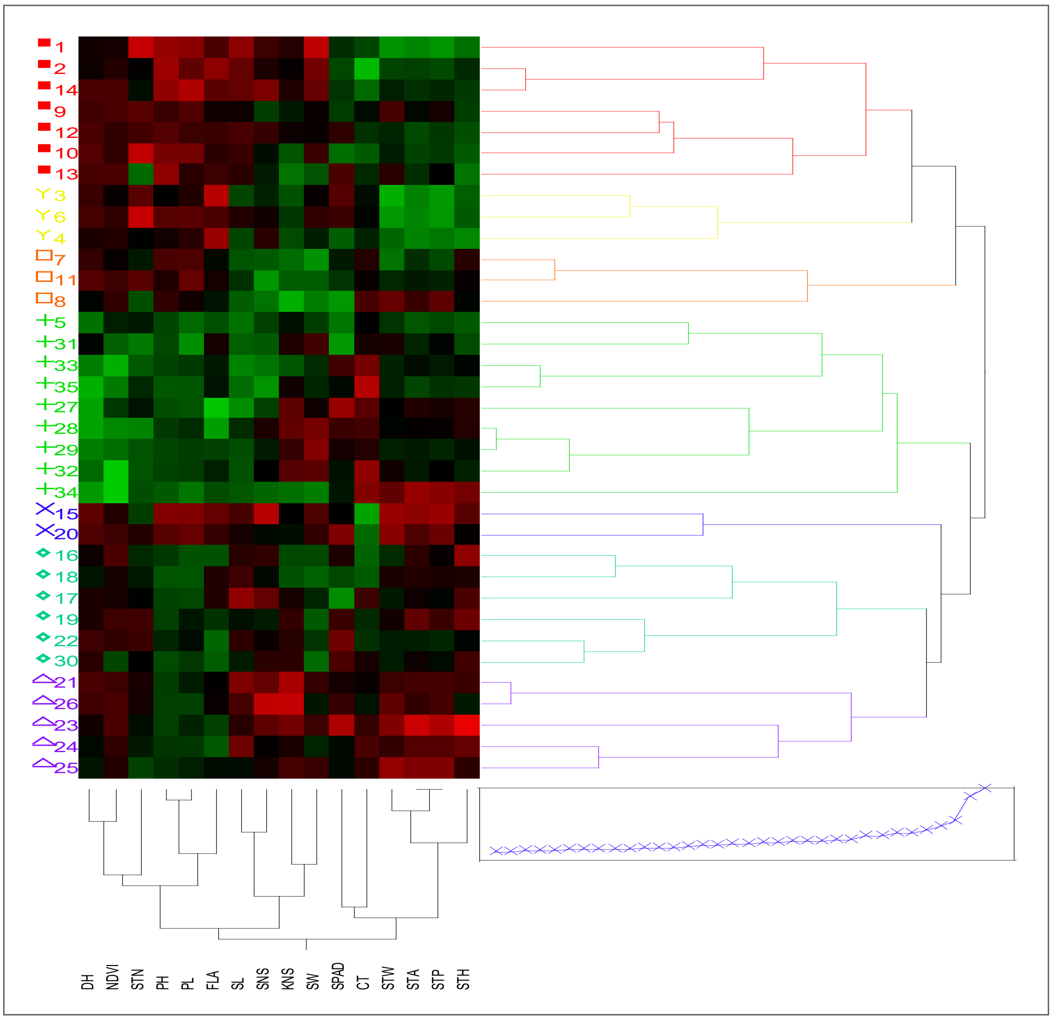

Figure 1. Cluster diagram of 35 durum wheat genotypes for parameters.

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