SEEDLING AND ROOT WEIGHT IN DURUM WHEAT (*Triticum durum* Desf.) GENOTYPES AND ASSOCIATION WITH AGRO-PHYSIOLOGICAL PARAMETERS

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Abstract

*Durum wheat (Triticum turgidum L. var. durum) under Mediterranean conditions is frequently limited by both high temperature and drought during grain growth stages. The research was carried out in the 2017-2018 cycles, with 25 genotypes in randomized completely blocks design with 4 replications. Data on grain yield, seedling fresh weight, root fresh weight, flag leaf area, tillering number, normalized difference vegetative index, canopy temperature, chlorophyll content, days of heading, peduncle length, spike length, spikelet number per spike, number of kernel per spike, and relationships among characters were investigated. The analysis of variance revealed highly significant differences (p<0.01) among the genotypes parameters investigated except for canopy temperature. In the study, G21, G6 and G22 had higher grain yields. The largest flag leaf area was measured in G3 (31.3 cm2), followed by G9 and G3. The seedling fresh weight and root fresh weight were established at the Z25 growth stages. The highest seedling fresh weight was determined in G23, followed by G19 and G18. Genotypes G5 and G8 had the highest root fresh weight. G15 had the highest tillering capacity. The longest spike was determined in G8, the highest spikelet number per was in G10 and the kernel number per spike was in G25. The lowest canopy temperature was measured in G15 and the highest chlorophyll content was measured in G25, G19 and G23. Correlation analysis showed that there are different coefficients between the parameters examined. Flag leaf area positively correlated with grain yield. Seedling fresh weight was positively correlated with chlorophyll content (r=0.517**), peduncle length and kernel number per spike. Root fresh weight in genotypes had a positive effect on peduncle length, spike length, spikelet number per spike and kernel number per spike. A significant positive correlation was determined between the normalized difference vegetative index at Z55 with spike length (r=0.412*), and spikelet number per spike (r=0.620**). Canopy temperature measured at the heading stage had a slightly negative effect on peduncle length, spike length and spikelet number per spike. Chlorophyll content measured at the heading stage had a positive effect on peduncle length (r=0.402) and spikelet number per spike (r=0.300). Although the research was conducted under rainfed conditions, positive correlations were found between some physiological and yield components.*

Keywords: *Durum wheat, genotypes, physiological parameters, yield components*

1. INTRODUCTION

The grain yield of durum wheat (*Triticum turgidum* L. var. *durum*) under Mediterranean conditions is frequently limited by high temperatures 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 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). Agro-morphological and physiological responses under rainfed conditions can advance our understanding of the ability of crops to respond and adapt to drought-prone environments. Several agro-morphological traits such as plant height, peduncle length, number of fertile tillers per plant, spike length, number of grains per spike, thousand grains weight, and even awn length not only affect stress tolerance to limited soil moisture in wheat, but they also reveal how adaptive genotypes cope with drought via morphological changes (Liu et al., 2015). The pattern of biomass allocation is a key growth parameter of an adaptive strategy in plants, especially in drought conditions. It is strictly associated with the size and morphological construction of crop organs (Siddique et al., 1989). Plants are often subjected to periods of unfavourable conditions such as drought, high light and temperature, during their life cycle in the field. Drought is the most severe stress and the main cause of significant losses in growth, the productivity of crop plants, and finally their yields (Ludlow and Muchow, 1990).

Grain filling and its end result, the grain yield, are closely linked to several morphological, anatomical, physiological, and molecular characteristics of flag leaves (Biswal and Kohli, 2013; Sanchez-Bragado et al., 2014). Effects of flag leaf area and flag leaf area duration on spike grain yield are positive but insignificant when drought stress was not a problem in which temperature rose and rainfall decreased between the heading and physiological maturity of wheat (Tiryakioğlu, 2014). Extensive root systems have higher respiration costs for plants. While genotypic variability exists in root length under favourable conditions, the benefits of a more extensive root system are more important when plants are exposed to drying soils (Blum, 2005; Pask et al., 2012). Canopy temperature (CT) has been widely used to evaluate and select wheat in drought and hot conditions as a valuable predictor of abiotic stresses (Pask et al., 2012; Reynolds et al., 2001; Liu et al., 2022). CT has been suggested as a significant indicator for measuring agricultural responses to water shortages, high temperatures, and other environmental stresses, and it has been used to assess the drought resistance of several crops (Past et al., 2012; Reynolds et al., 2001; Anderegg et al., 2021). Canopy temperature is also negatively correlated with yield, mostly in drought and thermal conditions, and a cooler canopy is beneficial to yielding gains in these stresses (Pask et al., 2012; Reynolds et al., 2001, Monnens et al., 2022). Despite intensive durum wheat breeding programs in the last century, in-depth comprehension of the agronomic and morpho-physiological responses of wheat to drought stress is not available. Hence, agro-morphological assessments might be useful to improve the successive operations of wheat processing and transformation. In particular, the selection of cultivars resistant to drought stress and the adoption of correct agronomic treatments might prevent problems (Guerrini et al., 2020; Capelli et al., 2020).

Türkiye is considered a diversification centre of durum wheat (*Triticum durum* Desf.). Germplasm presents average diversity showing a large genetic variability. Therefore, these genotypes can be used as parents for the improvement of durum wheat. 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, 2019). During the vegetative development periods of the plant, the environmental effect may affect the seedling development and physiological activity differently. The objectives of the study were to evaluate the seedling weight of the durum wheat genotypes and response to yield, and agro-physiological parameters under rainfed conditions.

2. MATERIAL AND METHODS

The field experiment was carried out at an experimental area at Trakia Agriculture Research Institute, Edirne, Turkey. The experiment was planted during the 2017-2018 cropping cycle, the site is at an altitude of 41m, at latitude 41º 38′ 59′′ N and longitude 26º 35′ 49′′ E. The experiment was composed of 25 genotypes in a randomized completely blocks design (RCBD) with four replications. Each plot was 6 meters long and had 6 rows, spaced 0.17 meters apart. A seed rate of 500 seeds per square meter was used. Sowings of the experiment were performed by using a plot drill.

Studied Parameters

The following agronomic traits were evaluated: grain yield (GY) (kg ha^{-1}), seedling fresh weight (SFW), root fresh weight (RFW), tillering number (TN), normalized difference vegetation index (NDVI), canopy temperature Z55 (CT), chlorophyll content Z55 (SPAD), days of heading (DH), flag leaf area (FLA), peduncle length (PL), spike length (SL), spikelet number per spike (SNS) and number of kernels per spike (KNS). All traits were measured based on five randomly selected samples of each genotype during different stages from development to maturity.

Days to 50% heading **(DH):** Days to heading was recorded as the number of days from 1 January until 50% of the heads and physiological maturity in a plot.

Peduncle length **(PL)** ***(cm):*** Peduncle length was measured from the last node from the top of the plant to the rachis.

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

Number of tillers **(TN)*:*** Tiller numbers were randomly selected and then it was determined by averaging the number of tillers.

Spikelet number per spike **(SNS):** Ten heads were randomly selected before harvest. It was determined by averaging the total number of spikelets.

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

Flag leaf area **(FLA)** ***(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

Seedling fresh weight **(SFW) (g):** In the experiment, 10 seedlings from each plot were taken from a depth of 10 cm in the Z30 period. After the roots were cleaned, their fresh weights were determined without roots.

Root fresh weight **(RFW) (g):** In the experiment, 10 seedlings from each plot were taken from a depth of 10 cm in the Z30 period. After the roots were cleaned, their fresh weights were determined.

Normalized difference vegetation index **(NDVI):** It was taken at the GS55 growth stage. 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. NDVI provides the rapid ground-level measurement of crops at a resolution to characterize the canopy for leaf area index (LAI) and green area index (GAI), biomass and nutrient content. Data can be used to estimate yield prediction, biomass accumulation and growth rate, ground cover and early vigor, senescence pattern estimations, and for biotic and abiotic c stress detection (Araus, 1996; Gutierrez-Rodriguez et al., 2004; Raun et al., 2001)

Chlorophyll content **(SPAD):** Data physiological parameters were recorded for chlorophyll content and canopy temperature (Reynolds et al., 2001; Babar et al., 2006). A handheld portable SPAD-502 chlorophyll meter (Minolta) provides a convenient means of assessing relative leaf chlorophyll content. Ten flag leaves were used to take chlorophyll meter readings from each plot at the heading stage (Adamsen et al., 1999; Babar et al., 2006; Pask et al., 2012). Measurements were taken for plant growth at the Z55 development stages.

Canopy temperature **(CT):** A handheld infrared thermometer was used to measure canopy temperature CT (°C). The data were taken from the same side of each plot at a 1m distance from the edge and approximately 50cm above the canopy at an angle of 30° to the horizontal. Readings were made between 13.00 and 15.00h on sunny days (Jackson et al., 1981; Babar et al., 2006; Reynolds et al., 2012; Pask et al., 2012). Measurements were taken for plant growth at the Z55 development stages.

Yield component: peduncle length, spike length, spike number per square meter, kernel number per spike, spike weight and flag leaf area was investigated in the Edirne location (E1). Physiological parameters: normalized difference vegetative index, canopy temperature and chlorophyll content were investigated in Edirne (E1) location at heading stages (Z55).

Table 1. Monthly precipitation, mean humidity and temperature for the growing seasons from 2017 to 2018 and the long-term precipitation average

Months	Rainfall (Long-term average)	Total Rainfall (mm)	Mean humidity (%)	Temperature (°C)		
				Min.	Max.	Mean
October 2017	52.9	135.2	77.1	3.8	27.8	13.6
November 2017	72.4	71.6	75.7	-2.1	27.4	9.5
December 2017	61.7	119.6	85.1	-4.2	20.8	7.4
January 2018	48.1	55.6	88.1	-5.2	15.1	4.3
February 2018	46.9	101.8	89.5	-5.4	16.1	5.7
March 2018	52.2	145.6	88.8	-11.0	20.2	8.9
April 2018	51.0	3.0	61.3	2.6	31.7	16.6
May 2018	56.0	18.8	64.0	9.2	31.1	20.3
June 2018	41.5	148.4	66.4	11.7	34.8	22.6
Total/Mean	482.7	799.6	77.3	-11	35.9	12.1

Meteorological Conditions

Total rainfall and mean temperature in the experimental area in the 2017-2018 cycles were given in Table 1. In the experimental site in the Trachea region, the winter wheat crops were sown in late October and harvested in late June. The developmental period from the shooting to the early grain-filling stages the most extensive water requirement period for wheat crops was generally from early April to late May. Total rainfall in the 2017-2018 cropping seasons was higher than the long year. The most total precipitation that occurred in June and March was 148.4 mm and 145.6 mm, respectively. Total rainfall in April (3.0 mm) and May (18.8 mm) was very lower. Thus, for April and May 2018, the special water requirement period for wheat crops was the wettest. An average temperature value was in 12.1 °C in 2017-2018. It is possible to say that the temperature above 30 degrees in April, May and June between the shooting and grain-filling periods may adversely affect the physiological parameters and yield elements examined in the research. The average temperature value was 12.1 °C in 2017-2018. It is possible to say that the temperature above 30 degrees in April, May and June between the shooting and grain-filling periods may adversely affect the physiological parameters and yield elements examined in the research.

Statistical Analyses

The meaning of the twenty-five genotypes was compared using the least significant differences (LSD) at a probability level of p = 0.05. Data were analysed statistically for analysis of variance following the method described by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

The results of the combined analysis of variance (ANOVA) on grain yield and other measured traits indicated significant effects ($p<0.01$) for the genotypes except for canopy temperature (Table 2).

Analysis of variance over the 2017-2018 cycles revealed highly significant variation among genotypes for grain yield under rainfed conditions. The mean grain yield of the durum wheat genotypes was 6007 kg ha^{-1}. It was determined that G21, G6 and G22 have the highest yield potential compared to all other genotypes with 6875, 6865 and 6862 kg ha^{-1}, respectively (Table 3).

In the study, 10 seedlings from each plot were taken from a depth of 10 cm in the Z30 period, then the roots were cleaned and their fresh weights were determined. The highest fresh seedling weight was achieved in G23, G25 G19 and G18 genotypes. The lowest and highest seedling weights ranged from 42.6 g to 76.6 g. This difference can be explained by the genotypic character and environmental conditions. In particular, the type of development and the need for vernalization was a factor in the difference. Genotypes showed significant differences in root fresh weight varying from 4.17 g to 8.85 g. Genotypes G5 and G8 showed the highest root fresh weight than the other genotypes (Table 3).

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

Parameters	**Genotypes (G)**	
	Mean square (MS)	**F Ratio**
Seedling fresh weight (SFW)	364.382	8.573**
Root fresh weight (RFW)	6.652	7.130**
Flag leaf area (FLA)	42.320	10.963**
Grain yield (GY)	10556.10	5.052**
Days of heading (DH)	42.769	16.124**
Chlorophyll content (SPAD)	28.299	4.229**
Normalized difference vegetation index (NDVI)	0.003	7.616**
Canopy temperature (CT)	2.075	1.524ns
Peduncle length (PL)	23.978	9.944**
Spike length (SL)	2.647	14.990**
Number of tiller (TN)	0.531	6.743**
Spikelet number per spike (SNS)	24.031	21.082**
Number of kernel per spike (KNS)	102.055	7.791**

*, ** Significant at p<0.05 and p<0.01 respectively. ns: not-significantly

Under rainfed conditions, there was a significant difference among the tested genotypes in terms of tiller number (TN). In the experiment, this trait varied between 1.50 and 2.93. The mean of the tiller number was 2.16. In the study, G15, G1, G13 and G6 were the genotypes with the highest tillering ability. Flag leaf in durum wheat genotypes during the years 2017-2018 were examined and very highly significant differences were determined. In durum wheat genotypes flag leaf area varied from the lowest 16.0 cm^2 to the highest 32.3 cm^2. Genotypes G23, G13 and G15 had higher flag leaf areas (Table 3). There was high variability in spike length (SL) and peduncle length (PL) under rainfed conditions. Peduncle length varied between 24.3 cm and 36.3 cm and the average was 31.4 cm. Spike length varied between 6.37 cm and 9.58 cm and the average was 7.45 cm (Table 3).

Spikelet number per spike and kernel number per spike are other important yield components that may vary according to genotype, environment and cultural practices. The number of spikelet per spike and kernel number per spike of durum wheat genotypes were studied under rainfed conditions. The tested durum wheat genotypes in the present study revealed a high variability for spikelet number per spike (SNS) and kernel number per spike (KNS). The maximum number of spikelet per spike was noted in genotype G10 (24.1 spikelet), followed by G2 (23.6 spikelet) and G1 (23.3 spikelet). Genotypes G12 and G24 produced a minimum number of spikelet per spike meter. There was a high rate of variation in kernel number per spike in durum wheat genotypes. Kernel number per spike varied from 33.1 to 54.4 kernels. The highest kernel numbers per spike were found in genotypes G25, G13, G23 and G24. Genotype G25 was prominent from other genotypes as the best lines, with a high kernel number under rainfed conditions (Table 4).

The normalized difference vegetation index (NDVI) is widely used at ground level and from low, high altitudes to measure vegetation greenness and canopy photosynthetic size. NDVI provides rapid ground-level measurement of crops at a resolution to characterize the canopy for leaf area index (LAI) and green area index (GAI), biomass and nutrient content (Pask et al., 2012). Taking into account physiological traits, there was a high rate of variation in NDVI in durum wheat genotypes. Normalized difference vegetation index varied from the lowest 0.71 to the highest 0.81 in genotypes. The highest NDVI were scaled in genotypes G8, G17 and G20. According to canopy temperature, G15 and G9 had the lowest canopy temperature (CT), while G23, G21, G5, G6 and G4 had the highest CT. Based on chlorophyll content (SPAD), genotype G25, followed by G19 and G23 performed well, whereas G1 and G20 showed lower chlorophyll content under rainfed conditions. Earliness in genotypes is related to sowing time and temperature, as well as to vernalization requirements. Under the rainfed condition, days of heading (DH) ranged from 115.8 to 128.8 days. The mean of the value was 121.9 days and genotypes G12 and G25 showed a short time of spike appearance (Table 4). Earliness is an effective breeding strategy for enhancing yield stability in Mediterranean environments, where wheat plants are exposed to terminal drought stress (Cattivelli et al., 1994; Shavrukov et al., 2017).

Table 3. Mean grain yield and agronomic parameters of durum wheat genotypes

Genotype	GY	SFW	RFW	TN	FLA	PL	SL
G1	5579g-j	61.8cd	6.17c-h	2.65ab	21.3ghı	28.7l	8,65b
G2	5452ıj	45.2hıj	4.80ıjk	1.75jkl	21.3ghı	24.3m	8,38bc
G3	5938d-ı	54.2d-h	7.27bc	2.25c-g	27.4b	30.5g-l	7,46f-ı
G4	6653ab	44.4ıj	5.47g-k	2.15e-ı	22.9e-h	33.4bcd	7,64e-h
G5	6040b-ı	42.6j	8.85a	1.78ı-l	20.5hı	30.2h-l	7,14g-k
G6	6865a	46.2hıj	5.87d-ı	2.55a-d	25.2b-e	28.9kl	6,85jkl
G7	6248a-f	62.2cd	6.89b-f	2.03f-j	26.5bcd	32.4c-g	7,71d-g
G8	5605f-j	51.4f-j	8.81a	2.50b-e	31.3a	32.8b-f	9,58a
G9	5703e-j	51.2f-j	6.93b-e	1.60kl	27.6b	31.1e-k	7,2g-j
G10	5254j	50.6g-j	5.58e-j	2.18d-h	21.0hı	30.8f-l	7,96c-f
G11	5799d-j	49.0g-j	4.51jk	1.85h-l	25.2b-e	31.0e-k	8,26bcd
G12	6129b-h	55.9d-g	4.64ıjk	1.50l	23.9d-g	31.7d-ı	6,57kl
G13	6406a-d	60.8cde	7.58ab	2.63abc	26.9bc	34.7ab	6,42l
G14	6310a-e	60.4c-f	6.75b-g	2.23d-h	24.4c-f	29.9ı-l	6,74jkl
G15	5212j	43.7ıj	7.98ab	2.93a	20.3hı	34.5abc	8,16b-e
G16	6184b-g	62.1cd	5.20h-k	2.18d-h	22.4f-ı	29.2jkl	8,13b-e
G17	5516hıj	43.5ıj	5.12h-k	2.13e-j	22.9e-h	30.5g-l	7,07h-k
G18	6610abc	67.5abc	4.17k	1.85h-l	22.4f-ı	30.2g-l	7,26g-j
G19	6215b-g	68.7abc	5.74d-j	2.40b-f	25.3b-e	33.1b-e	6,6kl

G20	5698e-j	52.4e-ı	5.57f-j	1.95g-k	16.0j	29.5jkl	8,44bc
G21	6875a	66.0bc	4.90h-k	1.85h-l	25.9bcd	32.1d-h	6,92ı-l
G22	6862a	54.3d-h	6.96bcd	2.50b-e	26.3bcd	31.4d-j	7,09h-k
G23	5716e-j	76.6a	5.35h-k	2.25c-g	21.6ghı	36.3a	6,76jkl
G24	6007c-ı	56.3d-g	5.69d-j	1.78ı-l	21.0hı	33.6bcd	6,37l
G25	5288j	71.5ab	5.55f-j	2.50b-e	20.0ı	33.5bcd	6,94ı-l
Mean	**6007**	**55.9**	**6.09**	**2.16**	**23.6**	**31.4**	**7.45**
LSD (0.05)	64.3	9.17	1.36	0.39	2.75	2.17	0.57

GY: Grain yield (kg ha^{-1}), SFW: Seedling fresh weight (g), RFW: Root fresh weight (g), TN: Tillering number, FLA: Flag leaf area (cm^2), PL: Peduncle length (cm), SL: Spike length (cm),

Multiple environmental stresses have an impact on plant growth and development, which globally restricts agricultural productivity and output. Heat stress is a key abiotic stress that lowers wheat grain production worldwide, especially in arid, semi-arid, tropical, and sub-tropical environments (Okechukwu et al., 2016). Although physiological traits regulate the uptake, use, and distribution of resources such as carbon, water, and nutrients and finally determine growth and reproduction (Ackerly et al., 2000). Yield is the main criterion for selecting wheat varieties for dry Mediterranean environments. It has been proposed that the selection of genotypes using yield assisted by morphological and physiological traits associated with yield under drought stress is more efficient in selecting high-yielding genotypes for dry environments (González-Ribot et al., 2017).

Table 4. Mean yield component and agronomic parameters of durum wheat genotypes

Genotype	SNS	KNS	NDVI	CT	SPAD	DH
G1	23.3abc	41.9def	0.78b-f	23.0a-e	50.6h	126.0bcd
G2	23.6ab	45.4bcd	0.75f-ı	23.6abc	58.2a-d	128.8a
G3	21.1d	42.9cde	0.77def	23.9abc	54.1e-h	122.8efg
G4	19.2ef	38.0e-ı	0.78c-f	24.0abc	55.7d-g	120.3hıj
G5	19.3e	38.5e-h	0.74hıj	24.1ab	53.6fgh	119.3ıj
G6	19.0efg	35.0ghı	0.75f-ı	24.1ab	56.7c-f	120.0hıj
G7	16.8ıjk	40.9def	0.74hıj	23.6abc	55.8d-g	123.8def
G8	22.3bcd	45.4bcd	0.81a	23.5a-d	56.1d-g	124.5cde
G9	17.4h-k	37.5f-ı	0.77def	21.9de	56.4def	120.0hıj
G10	24.1a	45.4bcd	0.80abc	23.2a-d	55.3d-g	125.8bcd
G11	18.9e-h	39.1e-h	0.78a-e	23.8abc	52.5gh	121.5f-ı
G12	16.5k	33.1ı	0.74ghı	23.3a-d	57.2b-f	118.5j
G13	17.8f-k	49.8ab	0.77d-g	22.5b-e	57.5a-e	120.3hıj
G14	17.4ıjk	34.6hı	0.78c-f	23.1a-e	57.7a-e	120.8g-j
G15	22.1bcd	40.9def	0.79a-d	21.5e	57.3b-e	127.5ab
G16	22.2bcd	39.2e-h	0.78a-e	23.3a-d	56.2def	121.8fgh

G17	21.7d	40.8def	0.80ab	22.6b-e	52.5gh	126.8abc
G18	17.5g-k	39.1e-h	0.74ghı	22.8a-e	56.7c-f	119.3ıj
G19	18.2e-ı	40.5def	0.76e-h	22.4cde	60.5ab	119.3ıj
G20	22.0cd	40.0efg	0.80ab	22.9a-e	51.2h	125.8bcd
G21	17.3ıjk	36.8f-ı	0.77d-g	24.2ab	58.2a-d	120.8g-j
G22	20.8d	39.8efg	0.76d-h	22.9a-e	55.3d-g	121.3ghı
G23	17.3ıjk	48.5b	0.71j	24.4a	60.1abc	115.8k
G24	16.6jk	47.4bc	0.73ıj	23.6abc	57.0b-f	120.8g-j
G25	18.1e-j	54.4a	0.71j	23.9abc	61.1a	118.8j
Mean	**19.6**	**41.4**	**0.76**	**23.3**	**56.1**	**121.9**
LSD (0.05)	1.49	5.07	0.027	1.64	3.63	2.28

SNS: Spikelet number per spike, KNS: Kernel number per spike, NDVI: Normalized difference vegetative index, CT: Canopy temperature (°C), SPAD: Chlorophyll content, DH: days of heading

Pearson's correlation coefficients were used among grain yield and physiological and agro-morphological traits in rainfed conditions. Correlation analysis showed that there are different coefficients between the parameters examined. Flag leaf area positively correlated with grain yield. Seedling fresh weight was positively correlated with chlorophyll content (r=0.517**), peduncle length and kernel number per spike. Root fresh weight in genotypes had a positive effect on peduncle length, spike length, spikelet number per spike and kernel number per spike. A significant positive correlation was determined between the normalized difference vegetative index at Z55 with spike length (r=0.412*), and spikelet number per spike (r=0.620**). Canopy temperature measured at the heading stage had a slightly negative effect on peduncle length, spike length and spikelet number per spike. Chlorophyll content measured at the heading stage had a positive effect on peduncle length (r=0.402) and spikelet number per spike (r=0.300). Although the research was conducted under rainfed conditions, positive correlations were found between some physiological and yield components (Table 5).

Table 5. Correlation coefficients among yield component and agronomic characters

Traits	**GY**	**SFW**	**RFW**	**TN**	**NDVI**	**CT**	**SPAD**	**DH**	**FLA**	**PL**	**SL**	**SNS**
SFW	0.158											
RFW	-0.105	-0.275										
TN	-0.091	0.097	0.420									
NDVI	-0.178	-0.498	0.208	0.223								
CT	0.242	0.143	-0.197	-0.237	-0.418							
SPAD	0.118	0.517**	-0.101	0.094	-0.552	0.076						
DH	-0.504	-0.526	0.113	0.186	0.633	-0.343	-0.481					
FLA	0.365	0.030	0.343	0.086	0.159	0.001	0.139	-0.182				
PL	0.031	0.378	0.232	0.303	-0.210	-0.049	0.402	-0.479	0.162			
SL	-0.448	-0.334	0.174	0.163	0.581**	-0.053	-0.479	0.674**	-0.014	-0.351		
SNS	-0.493	-0.455	0.132	0.342	0.620**	-0.177	-0.470	0.794**	-0.233	-0.486	0.734**	

Traits	GY	SFW	RFW	TN	NDVI	CT	SPAD	DH	FLA	PL	SL	SNS
KNS	-0.494	0.324	0.112	0.335	-0.269	0.102	0.300	0.063	-0.150	0.343	0.047	0.140

Significance at *: P<0.05; **: P<0.01; GY: Grain yield (kg ha^{-1}), SFW: Seedling fresh weight (g), RFW: Root fresh weight (g), TN: Tillering number, NDVI: Normalized difference vegetative index, CT: Canopy temperature (°C), SPAD: Chlorophyll content, DH: days of heading, FLA: Flag leaf area (cm^2), PL: Peduncle length (cm), SL: Spike length (cm), SNS: Spikelet number per spike, KNS: Kernel number per spike,

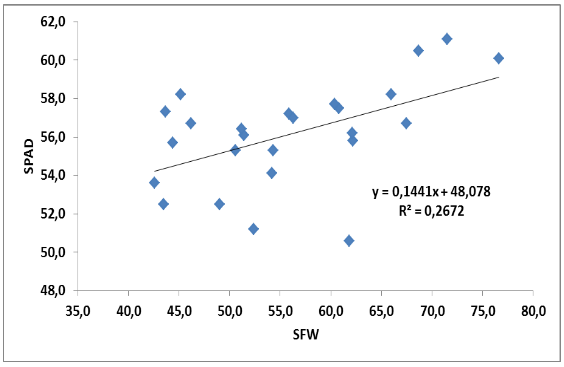

Fig 1a. Seedling fresh weight and SPAD

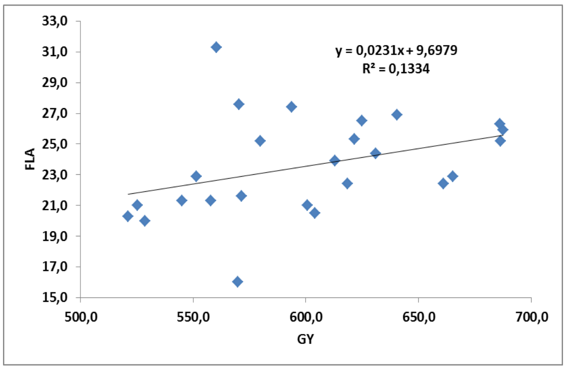

Fig 1b. Grain yield and flag leaf area

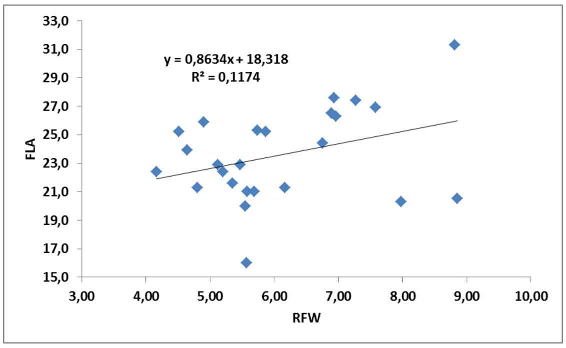

Fig 1c. Root fresh weight and flag leaf area

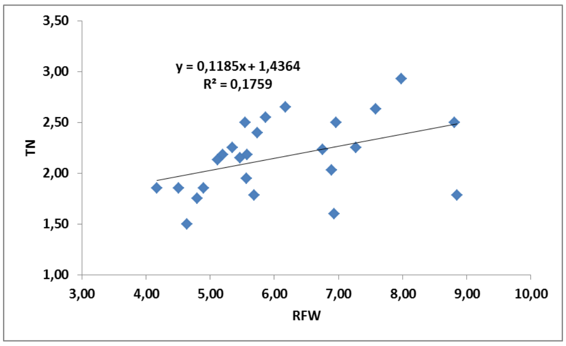

Fig 1d. Root fresh weight and tiller number

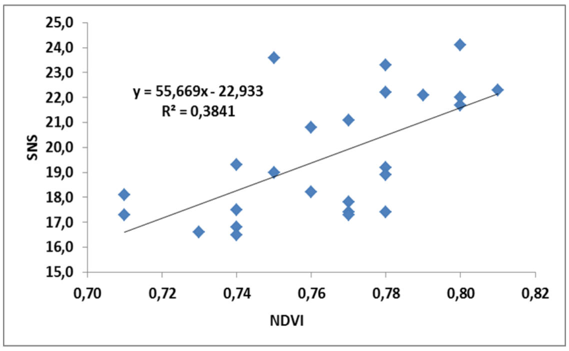

Fig 1e. NDVI and spikelet number per spike

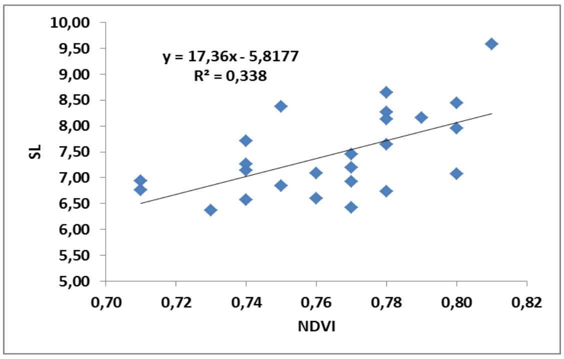

Fig 1f. NDVI and spike length

Figure 1. Relationship between grain yield and agro-physiological parameters

Pairwise relations were made between the parameters examined in the research. Seedling fresh weight is positively associated with chlorophyll content in genotypes. In the research as expected, there was a positive relation between flag leaf area with grain yield (R^2=0.133) and root fresh weight (R^2=0.117). Tiller number and root fresh weight (R^2=0.175) was positively correlated. Spike length was positively associated with NDVI (R^2=0.384). Normalized vegetation difference index and spike length were positively correlated (R^2=0.338) (Figure 1).

4. CONCLUSION

The analysis of variance revealed highly significant differences ($p<0.01$) among the genotypes parameters investigated except for canopy temperature. In the study, G21, G6 and G22 had higher grain yields. The largest flag leaf area was measured in G3 followed by G9 and G3. The highest seedling fresh weight was determined in G23, followed by G19 and G18. Genotypes G5 and G8 had the highest root fresh weight. G15 had the highest tillering capacity. The longest spike was determined in G8, the highest spikelet number per was in G10 and the kernel number per spike was in G25. The lowest canopy temperature was measured in G15 and the highest chlorophyll content was measured in G25, G19 and G23. Correlation analysis showed that there are different coefficients between the parameters examined. Flag leaf area positively correlated with grain yield. Seedling fresh weight was positively correlated with chlorophyll content, peduncle length and kernel number per spike. Root fresh weight in genotypes had a positive effect on peduncle length, spike length, spikelet number per spike and kernel number per spike. A significant positive correlation was determined between the normalized difference vegetative index at Z55 with spike length, and spikelet number per spike. Canopy temperature measured at the heading stage had a slightly negative effect on peduncle length, spike length and spikelet number per spike. Chlorophyll contents measured at the heading stage had a positive effect on peduncle length and spikelet number per spike. Although the research was conducted under rainfed conditions, positive correlations were found between some physiological and yield components. Results revealed that durum wheat genotypes were significantly varied for grain yield, agronomic and morpho-physiological traits. This resulted in considerable variation in the measured traits under rainfed conditions outstanding genotypes that should be considered for durum wheat breeding programs.

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