ROOT AND SEEDLING WEIGHT OF BREAD WHEAT (*Triticum aestivum* L.) GENOTYPES AND RELATION WITH PHYSIOLOGICAL PARAMETERS

İrfan Öztürk

Trakya Agricultural Research Institute, Edirne, Turkey

Abstract

*An experiment was carried out to assess of root weight and seedling weight of advanced bread wheat genotypes and relation with yield and physiological parameters. A total of 25 bread wheat genotypes were tested during 2017-2018 growing year in Edirne location in Trakia region, Turkey. The experiment was conducted in a randomized complete blocks design (RCBD) with four replications. Grain yield, biomass, canopy temperature, chlorophyll content, seedling fresh and dry weight, root fresh and dry weight were investigated. The mean grain yield for four locations was 6161 kg ha^{-1}. The highest grain yield performed by cultivar Köprü (7781 kg ha^{-1}) and the lowest by G9 (6124 kg ha^{-1}). The mean values of the genotypes were varied from 42.6 to 51.2 for chlorophyll content and G4 had higher chlorophyll content. Canopy temperature and biomass (NDVI) was measured at heading (Z55), and anthesis stages (Z69) of the genotypes. Biomass was scaled at three growth stages and there were significant differences (P<0.01) among genotypes and G16 had higher biomass. Roots of the plant were removed from a depth of 15 cm in the period of the Z25 growth stage. There were significant differences among genotypes for seedling weight and root weight. Root fresh weight was varied from 3.25 g (Selimiye) to 6.77 g (G13) and, the mean was 4.49 g. The mean seedling dry weight of the genotypes was 1.71 g, the lowest was 0.99 g (Selimiye) and the highest was 3.15 g (G13).Root weight positively affected grain yield. It was found a slightly significant positive correlation between roots fresh and dry weight with grain yield. There was a slight positive relation with seedling fresh weight and seedling dry weight with biomass (NDVI) at Z55 and Z69 growth stages. There was a negative slight relation with seedling dry weight and canopy temperature at Z55 and Z69 growth stages. Grain yield was also significantly positively associated with chlorophyll content at Z55 (r=0.555**) and, negatively correlated with canopy temperature at Z45 (r=-0.534**). Results showed that seedling and root weight and physiological parameters such as chlorophyll content and canopy temperature could be used in selection in bread wheat for yield potential.*

Key words: *bread wheat, genotypes, root and seedling weight, physiological parameters*

1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is economically one of the most important cereal crops in the world. Genetic improvement in wheat yields in dry areas has not been as easy as in more favorable environments or where water is not a limiting factor (Richards et al., 2001). Wheat root systems may not be optimal for the acquisition of resources, especially to access subsoil water, due to excessive root lengths in surface layers and inadequate root lengths at depth. The root length sufficient to acquire water and nitrogen resources is 0.1 to 1 cm/cm^2 (Van Noordwijk, 1983). The large proportion of root dry weight in the topsoil layer (0-15 cm) thus most likely represents a general genotypic tendency for roots to be concentrated in the upper layer, rather than an environmental influence. In current cropping environments, the inefficiency of root systems is resulting in high density and clumping of roots, consequently, water-stressed crop plants are leaving large amounts of available water in the subsoil at maturity (Passioura, 1983). In modern wheat crops root length density in many soil layers exceeds that needed for uptake of water and important nutrients, with common values for wheat varying between 3 and 6 cm/cm^3 in the plough layer with less than 1 cm/cm^3 being found below 40 cm (Hoad et al., 2004). A more even distribution of roots down the soil profile would reduce the path length for subsoil water to reach the plant, with the potential to increase plant biomass and harvest index with this extra supply of water (Passioura, 1983). Increased early vigour leads to faster,

deeper root growth and more adventitious roots in the top soil thus improving water and nutrient use and reducing evaporative losses from the top soil (Richards et al., 2001). Generally, 70% of the total root volume is found in the top 0-30 cm soil layer, where most nutrients are present in the majority of the agricultural soils (Manske and Vlek, 2002). Under soil water deficit, crop water extraction depends on root distribution and depth (Dardanelli et al., 2004). Deeper roots can extract more water from depth thus avoiding water deficits at critical growth stages resulting in higher harvest indices and reduced water loss by deep drainage (Ludlow and Muchow, 1990).

The understanding of the physiological and genetic adaptive mechanisms controlling drought tolerance is a crucial aspect in plant biology. The response of root growth to water deficit conditions is one aspect contributing greatly to drought tolerance. However, root morphology studies suffered from the difficulty in working with roots and from the absence of simple and fast tools to evaluate root traits on a large number of plants. Consequently, studies of genetic variability of root characteristics are scarce. Most of the experiments have been done on adventitious roots for which differences between cultivars have been observed in some cereals and grasses (Yadav and Sharma, 1982). Roots comprise close to half total wheat plant biomass and are critically involved in water uptake and nutrient supply. Despite their crucial role, less attention has been given to roots compared to more easily assessable above-ground traits. Drought is the most common crop stress globally and characters that improve water-use-efficiency (WUE) such as subsoil water extraction by roots can be enhanced through agronomic management or plant breeding to increase yield. However, the benefits depend on the seasonal pattern of water availability as influenced by rainfall distribution, soil type and management (Lilley and Kirkegaard, 2011). Drought is the most abiotic stress factor limiting crop productivity. This is particularly true in the Mediterranean region. In this area, the climate is characterised by erratic and unpredictable precipitations. As water available for agricultural uses become more restrictive, the release of drought-tolerant genotypes will become increasingly important (Loss and Siddique, 1999; Grando and Ceccarelli, 1995). Drought is the most important abiotic stress factor limiting production in bread wheat and in arid conditions root development determines the response of the genotypes (Öztürk and Korkut, 2018a). The root structure, which is a very important factor in arid conditions in bread wheat, may vary depending on environmental and genetic factors. Root weight of some bread wheat genotypes varies under different drought stress condition. The increase of root weight in genotypes promote the chlorophyll content in the flag leaves during pre-emergence and grain filling periods. Increasing in root weight reduced the canopy temperature under all drought stress applications (Öztürk and Korkut, 2018b). Therefore, the objective of this study was to investigate seedling root weight and seedling weight of bread wheat genotypes and relation with yield and physiological parameters under rainfed environment conditions.

2. MATERIAL AND METHODS

The experiment was conducted in a randomized complete block design (RCBD) with four replications in the 2017-2018 growing season in the Trakia region, Turkey. A total of 25 bread wheat genotypes were tested at four environments condition but the data investigated in Edirne location in the Trakia region. In the experiment, each plot was 6 meters long and had 6 rows, spaced 0.17 meters apart. Using a plot drill performed sowing and 500 seeds per square meter were used. Seedlings were removed at GS25 growth stages and weighted for seedling fresh weight and root fresh weight. For root fresh weight firstly root washed and then weighted. After that seedling and root were oven-dried at 70^{o}C to obtain the dry weight.

A handheld portable SPAD-502 chlorophyll meter (Minolta) was used to estimate chlorophyll content (SPAD). This instrument 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 (Z55). Chlorophyll meter data were taken on the same day or the closest possible day coinciding with the spectral reflectance measurements (Adamsen et al., 1999; Babar at al., 2006; Pask et al., 2012). A handheld infrared thermometer, with a field view of 2.5°C, was used to measure CT (°C). The data

were taken from the same side of each plot at 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. To avoid the effect of soil temperature on the CT, the data were taken when the infrared thermometer viewed no soil because of high leaf coverage areas (Jackson et al., 1981; Babar et al., 2006; Reynolds et al., 2012; Pask et al., 2012). Biomass (NDVI) was taken at GS55, and GS69 growth stage (Pask et al., 2012). Chlorophyll content (SPAD) and canopy temperature (^oC) were taken at GS55 and GS69 growth stages. Also, grain yield (kg ha^{-1}), days of heading, plant height (cm) were investigated. The Zadoks Decimal Code (Z) was used to describe plant growth stages of cereals (Zadoks et al., 1974).

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. Data were analyzed statistically for analysis of variance the method described by Gomez and Gomez (1984). The significance of differences among means was compared by using the L.S.D test (Kalaycı, 2005). 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.

3. RESULTS AND DISCUSSION

The analysis of variance for yield and root and seedling weight and physiological parameters were performed and given in Table 1, Table 2 and Table 3. The results of variance analysis showed that there were significant differences (P<0.01) among genotypes for root, and seedling weight (Table 1), biomass (NDVI) (Table 2), grain yield, and chlorophyll content (SPAD) (Table 3).

Analysis of variance revealed a highly significant difference among genotypes for grain yield. The mean grain yield for 25 genotypes was 7172 kg ha^{-1}. The highest grain yield performed by cv Köprü (7781 kg ha^{-1}) and the lowest G9 (6124 kg ha^{-1}) (Table 4).

Table 1. Combined analysis of variance for 25 genotypes for root and seedling weight

Source of variation	DF	RDW		RFW		SDW		SFW	
		MS	F value	MS	F value	MS	F value	MS	F value
Replication (R)	3	0.153	1.694	2.061	2.950*	15.555	1.804	135.876	1.494
Genotype (G)	24	0.748	8.260**	3.372	4.826**	42.003	4.870**	564.034	6.203**
Error	72	0.091		0.698		8.624		90.924	

Significant at * *P*<0.05 and ** *P*<0.01 levels, respectively. DF: Degrees of freedom; RDW: Root dry weight; RFW: Root fresh weight; SDW: Seedling dry weight; SFW: Seedling fresh weight

Table 2. Combined analysis of variance for 25 bread wheat genotypes based on physiological parameters

Source of variation	DF	NDVI (Z55)		NDVI (Z69)		CT (Z55)		CT (Z69)	
		MS	F value	MS	F value	MS	F value	MS	F value
Replication (R)	3	0.013	5.899**	0.005	3.128*	46.270	47.502**	31.260	28.161*
Genotype (G)	24	0.011	4.806**	0.005	3.281**	0.811	0.832	1.529	1.378
Error	72	0.002		0.002		0.974		1.110	

Significant at * *P*<0.05 and ** *P*<0.01 levels, respectively. DF: Degrees of freedom, NDVI: Biomass, CT: Canopy temperature (°C), Z: Zadoks scale

Table 3. Combined analysis of variance for 25 bread wheat genotypes for yield and physiological parameters

Source of variation	DF	GY		SPAD (Z55)		DH	
		MS	F value	MS	F value	MS	F value
Replication (R)	3	3115.56	1.418	23.018	3.350*	0.117	0.015
Genotype (G)	24	7403.17	3.369**	17.417	2.535**	9.833	1.405
Error	72	2197.38		6.870		7.797	

Significant at * *P*<0.05 and ** *P*<0.01 levels, respectively. DF: Degrees of freedom, GY: Grain yield; SPAD: Chlorophyll content, DH: Days of heading, Z: Zadoks scale

Roots of the ten plants were removed from a depth of 15 cm in the period of the Z25 growth stage, the root of plants washed and then weighted for fresh weight. There were significant differences among genotypes for root fresh and dry weight. Root fresh weight was varied among genotypes from 3.25 g to 6.77 g and, the mean was 4.49 g. The fresh weight of root was weighted maximum in G13 (6.77 g), G11 (6.24 g), and G24 (6.08 g). Root dry weight was varied among genotypes from 0.99 g to 3.15 g and, the mean was 1.71 g. The highest root dry weight was found in G13 (3.15 g), G24 (2.36 g), G17 (2.18 g) (Table 4).

Ten plants at the seedling stage were removed in the period of the Z25 growth stage and then weighted for seedling fresh weight. There were significant differences among genotypes for seedling fresh and dry weight. The mean ten seedlings fresh weight of the genotypes was 58.43 g. The lowest value was 40.08 g and the highest of 76.80 g were recorded. The highest seedling fresh weight was weighted for G9 (76.80 g), G13 (75.49 g), and G14 (74.21 g) while lowest in G12 (40.08 g) (Table 4). The mean seedling dry weight of the genotypes was 14.55 g, the lowest was 8.70 g and the highest was 20.68 g. The highest seedling dry weight was weighted for G17 (20.68 g), G22 (19.96 g), while lowest in Selimiye (8.70 g) and G12 (9.89 g) (Table 4).

The adaptation strategies of the plants to drought stress include drought escape, drought avoidance, and drought tolerance. Therefore, early maturity has been known as a major drought escaping mechanism, particularly in terminal drought stresses (Levitt, 1980; Chaves et al., 2002). Due to the fluctuation of rainfall mid-early genotypes generally are favorable in bread wheat in the Trakia region. Days of heading of the genotypes ranged from 110.5 to 117.8 and the mean value was 113.8 days. Early genotypes were Gelibolu, Köprü, Saban, and G2, while late maturating G9 (Table 5). Apparently, morpho-physiological traits for growth and development have the greatest impact on the adaptation of plants to the target environments with the aim of achieving maximum productivity. Selection criteria based on morphological, physiological, and biochemical traits have been suggested for screening drought tolerance in wheat (Araus et al., 2002). Chlorophyll content (SPAD) was measured at the heading stage (Z55) of the genotypes. The chlorophyll content was also significantly different among 25 genotypes. The mean chlorophyll content of the genotypes was varied from 42.6 to 51.2 at the heading stage. The highest chlorophyll content was determined in G4 (51.2), G24 (50.7), and cultivar Köprü (50.0) while the lowest in G9 (42.6) (Table 5).

Table 4. Mean yield, root and seedling dry and fresh weight of genotypes in 2017-2018 cycles

No	Genotype	GY	RFW	RDW	SFW	SDW
1	Pehlivan	7704 a	3.43 ıj	1.48 fg	55.32 e-h	12.66 f-j
2	G2	6765 def	4.52 d-ı	1.49 fg	52.01 e-j	12.05 g-j
3	G3	7295 a-d	3.77 g-j	1.46 fg	50.02 f-j	12.66 f-j
4	G4	7610 ab	3.69 g-j	1.72 ef	49.88 f-j	15.04 c-g
5	Selimiye	6990 b-e	3.25 j	0.99 h	40.93 ıj	8.70 j
6	G6	7474 abc	4.06 f-j	1.55 f	46.40 g-j	10.91 g-j
7	G7	6593 ef	4.02 f-j	1.73 def	48.19 f-j	10.70 hıj
8	G8	6879 cde	3.6 hıj	1.38 fgh	59.26 c-g	14.69 c-h
9	G9	6124 f	4.09 e-j	1.61 f	76.80 a	18.11 abc
10	Gelibolu	7543 ab	4.03 f-j	1.55 f	49.43 f-j	13.72 d-ı
11	G11	6864 cde	6.24 ab	2.15 bcd	72.50 abc	17.49 a-d
12	G12	6715 def	3.91 f-j	1.41 fgh	40.08 j	9.89 ıj
13	G13	7354 a-d	6.77 a	3.15 a	75.49 a	17.03 a-d
14	G14	6560 ef	5.00 c-f	1.68 f	74.21 a	17.30 a-d
15	Saban	7576 ab	4.58 d-ı	1.78 c-f	64.65 a-e	17.32 a-d
16	G16	7142 a-e	3.33 j	1.11 gh	49.24 f-j	11.65 g-j
17	G17	7210 a-e	5.25 b-e	2.18 bc	73.80 a	20.68 a
18	G18	7259 a-d	4.37 d-j	1.69 f	50.30 f-j	13.35 d-ı
19	G19	7511 abc	5.40 bcd	2.12 b-e	57.30 d-h	13.54 d-ı
20	Köprü	7781 a	4.07 f-j	1.55 f	45.80 hıj	12.81 e-j
21	G21	7702 a	4.84 d-g	1.74 def	60.17 b-f	16.34 b-f
22	G22	6782 def	4.27 d-j	1.65 f	72.91 ab	19.96 ab
23	G23	7554 ab	5.04 c-f	1.75 c-f	71.77 abc	16.87 a-e
24	G24	7329 a-d	6.08 abc	2.36 b	70.36 a-d	18.36 abc
25	G25	6992 b-e	4.67 d-h	1.46 fg	53.92 e-ı	11.90 g-j
	Mean	7172	4.49	1.71	58.43	14.55
	CV (%)	6.5	18.48	17.5	16.3	20.15
	LSD (0.05)	65.8	1.17	0.42	13.41	4.12
	F	3.36**	4.83**	8.26**	6.20**	4.87**

**: $P<0.01$, *: $P<0.05$, GY: Grain yield (kg ha^{-1}), DH: Days of heading, SPAD: Chlorophyll content, NDVI: Biomass, RFW: Root fresh weight (g), RDW: Root dry weight (g), SFW: Seedling fresh weight (g), SDW: Seedling dry weight (g), Z: Zadoks

Biomass (NDVI) was measured at heading (Z55), and late stages of anthesis (Z69) of the genotypes. There were significant differences (P<0.01) among genotypes for biomass. The highest biomass (NDVI) at Z55 growth stage was determined in G16 (0.80) while lowest in G25 (0.68) and Gelibolu (0.68) cultivar (Table 5). The highest biomass (NDVI) at Z69 growth stage was determined in G16 (0.81) and G21 (0.81) while the lowest in G14 (0.66) (Table 5).

Canopy temperature was measured at heading (Z55), and late stages of anthesis (Z69) of the genotypes. With regard to canopy temperature (CT), line G13 had the highest CT of 32.73ºC under rainfed condition at Z55 growth stage. On the other hand, genotype G17 (30.15ºC), G21 (30.65ºC), and Gelibolu (30.83ºC) had the lowest canopy temperature. The lowest canopy temperature was determined in G14 (31.08ºC) at Z69 growth stage while the highest in cultivar Saban (32.63ºC) and G18 (32.58ºC) (Table 5).

Table 5. Mean performance of genotypes for physiological parameters in 2017-2018 cycles

No	Genotype	DH	SPAD (Z55)	NDVI (Z55)	NDVI (Z69)	CT (Z55)	CT (Z69)
1	Pehlivan	114.5 a-e	46.5 c-g	0.71 g-l	0.78 abc	31.50 a-f	31.73 ab
2	G2	114.0 a-f	46.2 d-h	0.75 b-g	0.74 b-e	32.23 abc	32.33 ab
3	G3	114.3 a-f	48.8 a-f	0.71 h-l	0.74 b-e	32.10 a-d	32.05 ab
4	G4	115.3 a-d	51.2 a	0.74 b-h	0.75 a-d	31.70 a-e	31.35 ab
5	Selimiye	114.3 a-f	48.3 a-f	0.68 jkl	0.75 bcd	31.80 a-e	32.43 ab
6	G6	114.0 a-f	49.8 a-e	0.72 e-j	0.74 b-e	30.88 c-f	32.30 ab
7	G7	115.0 a-e	47.2 b-g	0.73 c-ı	0.79 ab	31.08 b-f	31.18 b
8	G8	115.3 a-d	46.2 e-h	0.76 a-e	0.77 a-d	32.40 ab	31.28 ab
9	G9	117.8 a	42.6 h	0.77 abc	0.79 ab	31.23 b-f	31.98 ab
10	Gelibolu	110.5 f	49.8 a-e	0.68 kl	0.69 ef	30.83 c-f	31.73 ab
11	G11	113.3 b-f	48.5 a-f	0.76 a-d	0.78 abc	31.90 a-e	32.28 ab
12	G12	113.5 b-f	46.1 fgh	0.77 ab	0.79 ab	31.23 b-f	32.25 ab
13	G13	114.0 a-f	44.3 gh	0.74 b-h	0.73 cde	32.73 a	31.80 ab
14	G14	112.0 b-f	47.2 b-g	0.72 f-k	0.66 f	31.05 b-f	31.08 b
15	Saban	111.8 c-f	49.9 a-d	0.76 a-f	0.79 ab	31.60 a-f	32.63 a
16	G16	112.3 b-f	48.3 a-f	0.80 a	0.81 a	31.45 a-f	31.35 ab
17	G17	113.8 b-f	48.9 a-f	0.77 ab	0.78 abc	30.15 f	31.53 ab
18	G18	113.5 b-f	46.1 e-h	0.75 b-h	0.78 abc	31.55 a-f	32.58 a
19	G19	115.0 a-e	45.7 fgh	0.73 d-ı	0.73 cde	31.83 a-e	31.95 ab
20	Köprü	111.5 def	50.0 abc	0.75 b-h	0.75 bcd	31.25 a-f	31.98 ab
21	G21	115.8 ab	47.3 b-g	0.77 ab	0.81 a	30.43 ef	31.60 ab
22	G22	111.3 ef	45.9 fgh	0.69 ı-l	0.72 de	31.55 a-f	32.25 ab
23	G23	115.3 a-d	47.5 b-g	0.75 b-h	0.74 b-e	30.65 def	32.25 ab
24	G24	115.5 abc	50.7 ab	0.75 b-h	0.75 bcd	31.78 a-e	32.15 ab
25	G25	113.3 b-f	45.7 fgh	0.68 l	0.72 de	32.10 a-d	32.33 ab
	Mean	113.8	47.55	0.74	0.75	31.47	31.93
	CV (%)	2.45	5.51	3.93	5.04	3.34	3.06
	LSD (0.05)	3.92	3.68	0.042	0.053	1.48	1.38
	F	1.41ns	2.54**	4.71**	3.28**	1.38ns	0.83ns

**: $P<0.01$, *: $P<0.05$, DH: Days of heading, SPAD: Chlorophyll content, NDVI: Biomass, CT: Canopy temperature (ºC), Z: Zadoks

Correlation coefficients among investigated parameters were determined by Pearson's correlation analysis (Table 6). Data analysis showed that coefficients of correlation among parameters varied, as expected, according to genotypic differences. Root fresh and dry weight positively affected grain yield and it was found a slightly positive correlation between roots fresh and dry weight with grain yield. Root fresh weight and root dry weight was also slightly positively correlated with biomass (NDVI) at Z55 growth stages. There was a slightly positive relation with seedling fresh weight and seedling dry weight with biomass (NDVI) at Z55 (r=0.206) and Z69 (r=0.249) growth stages. No correlation was found between seedling fresh and dry weight with canopy temperature. Although there is no relationship between grain yield and root fresh weight, a slightly positive relationship has been determined between root dry weight and grain yield. Grain yield was also significantly positively associated with chlorophyll content at Z55 (r=0.555**) and, negatively correlated with canopy temperature at Z45 (r=-0.534**) growth stages. Days of heading was negatively correlated with chlorophyll content (SPAD) and positively correlated with biomass (NDVI) at Z55 and Z69 growth stages. This result showed that early genotypes had higher chlorophyll content. It was also determined that the latest genotypes had higher biomass (Table 6).

Table 6. Coefficients of correlation between grain yield and physiological parameters

Traits	GY	RFW	RDW	SFW	SDW	DH	SPAD Z55	NDVI Z55	NDVI Z69	CT Z55
RFW	0.056									
RDW	0.166	0.894**								
SFW	-0.212	0.677**	0.626**							
SDW	-0.035	0.585**	0.588**	0.916**						
DH	-0.173	0.060	0.133	0.159	0.044					
SPAD Z55	0.555**	-0.102	-0.095	-0.282	-0.038	-0.328				
NDVI Z55	-0.053	0.168	0.174	0.206	0.249	0.288	-0.035			
NDVI Z69	0.008	-0.195	-0.114	-0.136	-0.080	0.388	-0.053	0.678**		
CT Z55	-0.138	0.124	0.152	-0.044	-0.181	0.047	-0.255	-0.162	-0.142	
CT Z69	0.090	0.130	-0.032	-0.087	-0.098	-0.109	-0.034	-0.172	0.035	0.204

*, ** Significant at $P<0.05$ and $P<0.01$ respectively. GY: Grain yield (kg ha^{-1}), RFW: Root fresh weight (g), RDW: Root dry weight (g), SFW: Seedling fresh weight (g), SDW: Seedling dry weight (g), DH: Days of heading, SPAD: Chlorophyll content, NDVI: Biomass, CT: Canopy temperature (^oC), Z: Zadoks stage

4. CONCLUSIONS

A genotype having stabile grain yield across the environment condition is very important in wheat. The highest grain yield performed by genotypes Köprü and G4 had higher chlorophyll content and G16 had higher biomass. The lowest canopy temperature was determined in G17. The root of the plant plays an important role in yield potential. There were significant differences among genotypes for seedling fresh and dry weight and root fresh and dry weight. The highest root dry and fresh weight was found in G13, and seedling fresh weight in G13, and dry weight in G17 lines. Root fresh and dry weight positively affected grain yield and it was found a slightly positive correlation between roots fresh and dry weight with grain yield. Root fresh weight and root dry weight was also slightly positively correlated with biomass at Z55 growth stages. There was a slightly positive relation with seedling fresh weight and seedling dry weight with biomass (NDVI) at Z55 and Z69 growth stages. Although, there is no relationship between grain yield and root fresh weight, a slightly positive relationship has been determined between root dry weight and grain yield. Grain yield was also

significantly positively associated with chlorophyll content at the Z55 growth stage and, negatively correlated with canopy temperature at the Z55 growth stage. The result of the study showed that because of the easy to remove root during the seedling period (at Z25) seedling root weight could be used in bread wheat for selection. Also, physiological parameters such as chlorophyll content, canopy temperature, and biomass could be used in selection in bread wheat for yield potential under rainfed condition.

REFERENCES

Adamsen FJ, Pinter PJ, Barnes EM, LaMorte RL, Wall GW, Leavitt SW and Kimball BA 1999, Measuring Wheat Senescence with a Digital Camer, Crop Science, 39, 719.

Araus JL, Slafer GA, Reynolds MP & Royo C 2002, 'Plant breeding and water relations in C3 cereals: what should we breed for? Annals of Botany. 89: 925-940.

Babar MA, Reynolds MP, van Ginkel M, Klatt AR, Raun WR, Stone ML 2006, 'Spectral Reflectance to Estimate Genetic Variation for In-Season Biomass, Leaf Chlorophyll, and Canopy Temperature in Wheat, Crop Breeding and Genetics. Crop Sci 46:1046-1057.

Chaves MM, Pereira JS, Maroco J, Rodrigues ML, Ricardo CP, Osorio ML, Carvalho I, Faria T and Pinheiro C 2002, 'How plants cope with water stress in the field' Photosynthesis and growth. Annals Bot. 89: 907-916.

Dardanelli JL, Ritchie JT, Calmon M, Andriani JM, Collino DJ 2004, 'An empirical model for root water uptake' Field Crops Res. 87:59-71.

Eberhart SA & Russell WA 1966, 'Stability parameters for comparing varieties' Crop. Sci.6: 36-40

Finlay KW & Wilkinson GN 1963, 'The Analysis of Adaptation in a Plant Breeding Programme' Aust. J. Agric. Res., 14: 742-754.

Gomez KA & Gomez AA 1984, 'Statistical Procedures for Agricultural Research' 2nd Ed. John Willey and Sons, Inc. New York. 641.

Grando S and Ceccarelli S 1995, 'Seminal root morphology and coleoptile length in wild (*Hordeum vulgare* ssp. spontaneum) and cultivated (*Hordeum vulgare* ssp. vulgare) barley, Euphytica 86 (1995) 73–80.

Hoad SP, Russel G, Kettlewell PS and Belshaw M 2004, 'Root system management in winter wheat: Practices to increase water and nitrogen use, HGCA Project Report No. 351.

Jackson RD, Idso SB, Reginato RJ, Pinter PJ 1981, 'Canopy Temperature as a Crop Water Stress Indicator, Water Resources Research, Vol. 17, No. 4 Page: 1133-1138.

Kalaycı M 2005, 'Örneklerle Jump Kullanımı ve Tarımsal Araştırma için Varyans Analiz Modelleri, Anadolu TAE. Yayın No: 21. Eskişehir. (Example for Jump Use and Variance Analysis Model for Agricultural Research. Anotolia Agr. Res. Inst, Pub. No: 21 Eskişehir, Turkey).

Levitt J 1980, 'Responses of plants to environmental stresses, In: Physiological Ecology, (Kozlowski, T.T., Ed) New York: Academic Press, pp: 347-448.

Lilley JM, Kirkegaard JA 2011, 'Benefits of increased soil exploration by wheat roots, Field Crops Res. 122:118-130.

Loss SP and Siddique KHM 1999, 'Morphological and physiological traits associated with wheat yield increases in Mediterranean environments, Adv. Agron. 52 (1994) 229–276.

Ludlow MM, Muchow RC 1990, 'A critical evaluation of traits for improving crop yields in water-limited environments, Adv Agron. 43:107-153.

Manske GGB, Vlek PLG 2002, 'Root architecture - wheat as a model plant, In: Waisel Y, Eshel A, Kafkafi U (eds) Plant Roots: The Hidden Half', 3rd edition, Marcel Dekker, New York USA, pp 149-259.

Öztürk İ and Korkut ZK 2018a, 'Investigation of Drought Effect in Various Plant Development Stage on Root Weight in Bread Wheat (*Triticum aestivum* L.) and Relationship between Root Weight and Some Agronomic Traits, *Journal of Tekirdag Agricultural Faculty.* JOTAF. 15 (03) *P: 68-77.*

Öztürk İ and Korkut ZK 2018b, 'Drought Effect on Root Amount and its Relations with Some Physiological Parameters, Journal of Central Research Institute for Field Crops, 2018, 27 (1): 14–24

Pask AJD, Pietragalla J, Mullan DM and Reynolds MP. (Eds.) 2012, 'Physiological Breeding II: A Field Guide to Wheat Phenotyping, Mexico, D.F.: CIMMYT.

Passioura JB 1983, 'Roots and Drought Resistance. Agricultural Water Management, Vol. 7 (1-3) pp. 265-280.

Reynolds MP, Pask AJD and Mullan DM. (Eds.) 2012, 'Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation, Mexico, D.F.: CIMMYT.

Richards RA, Condon AG & Rebetzke GJ 2001, 'Traits to Improve Yield in Dry Environments' In: M.P. Reynolds, J.I. Ortiz-Monasterio, and A. McNab (eds.), 'Application of Physiology in Wheat Breeding, Mexico, D.F.: CIMMYT.

Richards RA, Condon AG, Rebetzke GJ 2001, 'Traits to improve yield in dry environments, In: Reynolds MP, Ortiz-Monasterio JI, McNab A (eds) Application of physiology in wheat breeding, Mexico, D.F., CIMMYT, pp 88-100

Van Noordwijk M 1983, 'Functional interpretation for root densities in the field for nutrient and water uptake, Root Ecology and its Practical Application, International Symposium Gumpenstein pp 207-226.

Yadav SP and Sharma SP 1982, 'A comparative study of seedling characters in wheat, barley, triticale and rye, Seed Res. 10 (1982) 91–97.

Zadoks J, Chang T, Konzak C 1974, 'A decimal code for the growth stages of cereals, Weed research 14: 415-421.