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Genetics and Breeding

Association between physiological parameters and yield in *Triticum aestivum* L. genotypes under rainfed conditions

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Abstract. *The purpose of the study was to assess the relationships between physiological parameters and grain yield of different bread wheat genotypes. In the present research a total of 25 bread wheat genotypes were tested during the 2016-2017 seasons under rainfed conditions. The experiment was conducted in a randomized complete blocks design with four replications. Grain yield, days of heading, plant height, biomass (NDVI) from GS25 up to GS85 growth stage, chlorophyll content (SPAD) during the heading stage, canopy temperature (CT) at GS60 and GS75 growth stages, and glaucousness were investigated. The results of variance analyses showed that there were significant differences (p<0.01) among genotypes for yield. The mean grain yield was 7948 kg ha*$^{-1}$ *and yield ranged from 7033 kg ha*$^{-1}$ *to 8759 kg ha*$^{-1}$*, the highest grain yield performed by TE6744-16 line. According to the results, significant differences among cultivars in terms of plant height, days of heading, biomass, chlorophyll content, canopy temperature, glaucousness were found. TE6627-6 line had the highest chlorophyll content and also, chlorophyll content positively affected grain yield. Canopy temperature is generally related to yield under drought stress condition in bread wheat. In the study early maturing (days of heading) genotypes had lower canopy temperature. An increase in biomass after the heading phase has positively affected grain yield. In the study, no correlation was found between grain yield and biomass at GS25 and GS45 growth phase. There was a negative correlation between glaucousness with biomass at GS60, GS75 and GS85 growth phase. These results showed that physiological parameters such as biomass (at GS75 and GS85), canopy temperature (at GS60 and GS75), and chlorophyll content (at GS60), and glaucousness could be used for selection parameters under rainfed conditions for yield in bread wheat.*

Keywords: biomass, plant height, days of heading, canopy temperature, chlorophyll content, glaucousity, correlations

Introduction

A better understanding of relatively simple crop-physiological attributes that determine yield in a wide range of conditions may be instrumental for assisting future breeding. Physiological traits may be selected either directly or through the use of molecular-biology tools. Physiological and breeding literature frequently distinguishes between yield under potential, stress-free conditions and under the pressure of stress, mostly abiotic. Genotypes with physiological attributes conferring higher yield potential usually also perform better under stress conditions, at least when excluding extremely severe environments. As breeders normally need to release improved cultivars to be grown in different sites throughout several seasons and subjected to a wide range of management decisions, identifying physiological traits that may confer simultaneously high yield potential and constitutive tolerance to stress would be critical. These traits must allow the plants to capture more resources or to use them more efficiently (Slafer and Araus, 2007). The Normalized Difference Vegetation Index (NDVI) has also been shown to have a positive relationship with grain yield and biomass under well-irrigated conditions and a stronger association with yield under drought conditions (Gutierrez-Rodriguez et al., 2004), although association with yield varies according to when the NDVI is measured (Marti et al., 2007). Genotypes with horizontal orientation of leaves at the stem elongation stage had higher NDVI values compared to erect types, and it was also shown that wheat yield was more accurately predicted if NDVI was measured at both the early heading and the filling stage (Feng and Yang, 2011). Hazratkulova et al. (2012) showed that maintaining stable NDVI from booting and heading stage to milk maturity serves as a criterion of heat tolerance due to stay-green character. The use of infrared imaging to quantify the differences in the Canopy temperature (CT) of wheat genotypes under drought was first reported by Blum and co-workers in 1982 and has also been shown to be an excellent predictor of yield in hot, irrigated environments (Reynolds et al., 1994; Blum, 2000). The trait was shown to explain approximately 60% of yield variation in random inbred lines (RILs) under drought stress and is applied as a selection tool by breeders working in heat and drought stressed environments (Trethowan and Reynolds, 2007).

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Canopy temperature effected by biological and environmental factors like water status of soil, wind, evapotranspiration, cloudiness, conduction systems, plant metabolism, air temperature, relative humidity, and continuous radiation (Reynolds et al., 2001a, b), has preferably been measured at high air temperature and low relative humidity because of high vapour pressure deficit conditions (Amani et al., 1996). Phenotypic correlations of CT with grain yield were occasionally positive (Reynolds et al., 1994). The NDVI has frequently been used to evaluate the status of the crop and associate it with growth traits and grain yield (Morgunov et al., 2014). NDVI has also been shown to have a positive relationship with grain yield and biomass under well-irrigated conditions and a stronger association with yield under drought conditions (Reynolds et al., 1994; Gutierrez-Rodriguez et al., 2004).

Therefore, the main objective of the present investigation was to find out suitable morpho-physiological traits that could be invariably used for the yield improvement of winter wheat grown under rainfed condition. This study aimed to evaluate the use of NDVI parameters at different plant growth phases of bread wheat genotypes and as supplementary selection tools for winter wheat.

Material and methods

In the study, a total of 25 bread wheat genotypes were tested during 2016-2017 seasons under rainfed condition at four locations in Edirne region. The experiment was conducted in randomized complete blocks design with four replications. Biomass (NDVI) was taken at GS25, GS30, GS38, GS45, GS60, GS75 and GS85 growth stage (Pask et al., 2012). The genotypes chlorophyll content (SPAD) at heading stage (GS60), canopy temperature (CT, °C) at GS60 and GS75 growth stages, glaucousness (1-9 scale), grain yield (kg ha^{-1}), days of heading, plant height (cm) were investigated. Using a plot drill performed sowing and 500 seeds per square meter were used. The Zadoks Decimal Code (GS) was used to describe plant growth stages of cereals (Zadoks et al., 1974).

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 heading stage. 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 50 cm 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)

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 by the method described by Gomez and Gomez (1984). The significance of differences among means was compared by using 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 adaptability of genotypes and the correlations between the quality parameters were determined by Pearson's correlation analysis.

Meteorological data for growing season from September 2016 to June 2017 are given in Table 1. Monthly precipitations, relative air humidity, minimum, maximum, and mean temperature were recorded from the weather station of the Institute experimental site. Average daily mean temperatures during plant growth stages (from September to June) were 10.2°C, absolute maximum temperature was 40°C, and absolute minimum temperature -17.0°C. Total rainfall was 417.2 mm and amount of the rainfall in November and December was very little compared with the long year. Also mean air relative humidity was 71.2% (Table 1).

Table 1. Climate conditions in the experimental area in 2016-2017 growing season at Edirne location

Months	Rainfall (mm) Long year	Rainfall (mm)	Relative Humidity (%)	Air Temperature (°C)		
				min	max	mean
September 2016	34.0	9.2	57.5	5.0	33.8	20.8
October 2016	52.9	44.4	69.5	1.3	28.8	14.3
November 2016	72.4	3.2	72.9	-9.9	15.4	0.7
December 2016	61.7	3.2	72.9	-9.9	15.4	0.7
January 2017	48.1	67.8	83.7	-17.0	8.4	-1.9
February 2017	46.9	43.4	80.0	-8.4	20.6	5.3
March 2017	52.2	51.0	73.0	-1.9	25.5	10.2
April 2017	51.0	65.6	63.1	-1.6	28.6	12.5
May 2017	56.0	85.0	65.4	4.4	30.0	17.9
June 2017	41.5	44.4	74.4	12.9	40.0	21.2
Total/Mean	516.7	417.2	71.2	-2.5	24.6	10.2

Results and discussion

The data for yield, physiological and morphological parameters are given in Table 2. The results showed that there were significant differences ($p<0.01$) among genotypes based on grain yield. Mean grain yield across four locations ranged from the highest 8927 kg ha^{-1} to the smallest 7033 kg ha^{-1}. The mean grain yield was 7949 kg ha^{-1}. The highest grain yield was performed by TE6411-2 lines and followed by TE6744-16, TE6226-25, TE5857-11 and TE6748-17 genotypes. The results of the study showed that yield in wheat varied depending on genotypes, environment and its interaction. The lowest yielding genotype was Aldane. There was significant variation ($p<0.01$) in chlorophyll content of the genotypes. The lowest chlorophyll content was 51.65 (SPAD) in TE6662-21 and the highest was 60.65 (SPAD) in TE6627-6 genotypes. Chlorophyll content also positively affected grain yield in the genotypes.

Table 2. Mean grain yield, physiological and morphological characters of the genotypes

No	Genotypes	GY	CT (GS60)	CT (GS75)	SPAD (GS60)	DH	PH	GLO
1	Aldane	7033 ^{i}	21.90 ^{e}	32.88 ^{def}	52.65 ^{jk}	118.5 ^{h}	91.5 $^{a-d}$	8.0 ^{abc}
2	TE6411-2	8927 ^{a}	23.30 $^{a-e}$	33.20 $^{c-f}$	55.48 $^{c-i}$	123.3 ^{bc}	91.0 ^{bcd}	3.0 ^{h}
3	OCW1S304T-3	7504 $^{e-i}$	22.83 $^{a-e}$	32.48 ^{ef}	55.15 $^{e-i}$	114.5 ^{i}	88.8 $^{d-g}$	1.0 ^{i}
4	TCI011656-4	8225 ^{bc}	23.08 $^{a-e}$	33.58 $^{a-f}$	53.50 $^{h-k}$	122.8 ^{cd}	85.3 $^{f-i}$	3.0 ^{h}
5	Selimiye	7895 $^{c-f}$	23.70 $^{a-d}$	34.00 $^{a-d}$	54.40 $^{f-j}$	120.5 ^{efg}	89.5 $^{c-f}$	7.5 ^{bcd}
6	TE6627-6	8075 ^{bcd}	23.38 $^{a-e}$	33.85 $^{a-e}$	60.65 ^{a}	125.3 ^{a}	74.0 ^{k}	5.5 ^{ef}
7	TE6474-7	7423 $^{f-i}$	23.45 $^{a-e}$	33.35 $^{b-f}$	57.75 ^{bcd}	120.8 ^{efg}	85.5 $^{e-i}$	6.5 ^{de}
8	TE6474-8	7834 $^{c-h}$	23.13 $^{a-e}$	33.05 $^{c-f}$	55.45 $^{d-i}$	120.8 ^{efg}	87.3 $^{d-h}$	5.5 ^{ef}
9	TE6474-9	7345 ^{i}	22.70 $^{b-e}$	33.65 $^{a-f}$	57.85 ^{bc}	121.0 ^{def}	85.0 $^{f-i}$	5.0 ^{f}
10	Pehlivan	7748 $^{c-h}$	22.15 ^{de}	32.18 ^{f}	53.53 $^{h-k}$	122.3 ^{cde}	94.5 ^{ab}	8.5 ^{ab}
11	TE5857-11	8569 ^{ab}	23.20 $^{a-e}$	33.48 $^{a-f}$	55.30 $^{e-i}$	115.5 ^{i}	85.5 $^{e-i}$	3.0 ^{h}
12	TE6321-12	7897 $^{c-f}$	23.08 $^{a-e}$	34.03 $^{a-d}$	55.35 $^{e-i}$	123.5 ^{abc}	90.0 $^{b-e}$	8.5 ^{ab}
13	TE5554-13	7695 $^{d-h}$	23.93 ^{abc}	34.73 ^{ab}	54.83 $^{f-j}$	121.0 ^{def}	71.0 ^{k}	3.5 ^{gh}
14	TE6412-14	7455 $^{e-i}$	23.68 $^{a-d}$	34.93 ^{a}	55.25 $^{e-i}$	123.3 ^{bc}	63.5 ^{l}	1.0 ^{i}
15	Gelibolu	7948 $^{c-f}$	22.25 ^{de}	32.38 ^{ef}	55.60 $^{c-h}$	119.0 ^{gh}	87.5 $^{d-h}$	5.5 ^{ef}
16	TE6744-16	8759 ^{a}	23.30 $^{a-e}$	33.85 $^{a-e}$	58.65 ^{ab}	122.0 ^{cde}	93.5 ^{abc}	9.0 ^{a}
17	TE6748-17	8555 ^{ab}	22.53 ^{cde}	33.48 $^{a-f}$	56.15 $^{c-g}$	123.5 ^{abc}	84.0 ^{hij}	7.0 ^{cd}
18	TE6636-18	7981 ^{cde}	23.85 ^{abc}	34.48 ^{abc}	54.85 $^{f-j}$	123.0 ^{bc}	80.0 ^{j}	4.5 ^{fg}
19	TE6636-19	7887 $^{c-g}$	23.60 $^{a-d}$	33.45 $^{a-f}$	55.53 $^{c-h}$	122.3 ^{cde}	83.3 ^{hij}	4.5 ^{fg}
20	Saban	8228 ^{bc}	24.23 ^{ab}	34.28 $^{a-d}$	56.25 $^{c-f}$	119.5 ^{fgh}	84.8 ^{ghi}	5.5 ^{ef}
21	TE6662-21	7725 $^{c-h}$	23.43 $^{a-e}$	33.43 $^{a-f}$	51.65 ^{k}	125.3 ^{a}	96.0 ^{a}	2.5 ^{h}
22	TE6714-22	8078 ^{bcd}	23.65 $^{a-d}$	34.45 ^{abc}	55.63 $^{c-h}$	124.8 ^{ab}	82.5 ^{ij}	3.5 ^{gh}
23	TE6714-23	7359 ^{ghi}	24.03 ^{abc}	33.08 $^{c-f}$	53.83 $^{g-k}$	122.0 ^{cde}	85.3 $^{f-i}$	3.5 ^{gh}
24	TE6038-24	7967 ^{cde}	23.25 $^{a-e}$	33.40 $^{b-f}$	53.10 ^{ijk}	118.5 ^{h}	84.8 ^{ghi}	7.0 ^{cd}
25	TE6226-25	8585 ^{ab}	24.35 ^{a}	33.80 $^{a-e}$	57.50 $^{b-e}$	122.3 ^{cde}	82.5 ^{ij}	7.5 ^{bcd}
Mean		7948	23.27	33.57	55.43	121.4	85.1	5.18
LSD (0.05)		50.86**	1.55^{ns}	1.49*	2.38**	1.96**	4.52**	1.05**
CV (%)		4.7	4.84	3.17	3.1	1.14	3.77	14.2

Note: *$p<0.05$; **$p<0.01$; ns- non-significant; GY- Yield (kg ha^{-1}); CT- Canopy temperature (°C); SPAD- Chlorophyll content; DH- Days of heading; PH- Plant height (cm); GLO- Glaucousness (1-9); GS- Growth stages

Canopy temperature is generally related to yield under drought stress condition in bread wheat. The mean canopy temperature was 23.27°C at GS60 and 33.57°C at GS75. Minimum and maximum canopy temperatures varied between 21.90°C and 24.35°C at GS60 and between 32.18°C and 34.93°C at GS75 among the tested genotypes. Cultivars Aldane and Pehlivan had the lowest canopy temperature at GS60 and GS75, respectively.

Early maturity is an important plant breeding objective because of its contribution to better survival of plant. Days to maturity is direct measure of earliness of a genotype which allows a farmer to sow the next crop on its optimum sowing time and it also minimizes input cost of crop production (Muhammed et al., 2015). The adaptation strategies of the plants to drought stress include drought escape, drought avoidance and drought tolerance. Among these strategies, escaping drought involves the completion of the life cycle before the onset of the drought period. Therefore, early maturity has been known as a major drought escaping mechanism, particularly in terminal drought stresses (Chaves et al., 2002). Due to fluctuation of rainfall mid-early genotypes generally are favorable in bread wheat in the region. Data of days of heading was taken from each plot of genotypes and ranged from 114.5 days to 125.3 days among genotypes and mean value was 121.4 days (Table 2).

Plant height is an important factor for wheat and its contribution towards yield is indirect. More plant height causes yield losses, as tall stature plants become more susceptible to lodging problem hence moderate to short plant height is good for crops as it contributes towards making the mechanical operation and handling of crop easy, also reduced the chances of losses due to lodging (Muhammed et al., 2015). With regard to genotypic effects, although the G21 genotype exhibited the highest plant height of 96.0 cm under field condition, it was significantly different from mean plant height. On the other hand, genotype 14 (G14), which showed the lowest plant height of 63.5 cm, was followed by entry 13 (G13) with plant height of 71.0 cm. Plant breeders have tried to select and release intermediate varieties (Calderini et al., 1999; Richards et al., 2001).

Glaucousness first appears on the leaf sheath at the time of stem elongation. It rapidly reaches maximum expression, particularly on the flag leaf sheath and the abaxial surface of the flag leaf lamina as well as on the emerging head. In this study, glaucousness values in genotypes were very variable and ranged between 1.0 (TE6412-14, OCW1S304T-3) and 9.0 (TE6744-16). The genotypes TE6744-16, TE6321-12 and Aldane had higher glaucousness and also, there was a slightly positive relation between yield and glaucousness.

Biomass was measured at seven different growth stages from GS25 up to GS85 stage and there were various differences among wheat genotypes (Table 3). Effect of the biomass progressively increased and there were significant differences among genotypes at GS60, GS75 and GS85 growth stages. There was no significant difference among genotypes at GS25 and GS45 growth stages. Cultivar Selimiye had higher biomass at GS25 growth stages. TE6321-12 had higher biomass at GS30, GS38 and GS45 growth stages. Genotypes TE6412-14 had higher biomass at GS60 and TE6627-6 at GS85 growth stages.

Table 3. Mean biomass (NDVI) of the genotypes from GS25 to GS85 growth stages

No	Genotypes	NDVI (GS25)	NDVI (GS30)	NDVI (GS38)	NDVI (GS45)	NDVI (GS60)	NDVI (GS75)	NDVI (GS85)
1	Aldane	0.50 $^{a-d}$	0.63 $^{a-i}$	0.78 $^{a-d}$	0.82 ^{a}	0.74 $^{h-k}$	0.64 $^{e-h}$	0.38 ^{hij}
2	TE6411-2	0.55 $^{a-d}$	0.64 $^{a-h}$	0.72 $^{a-g}$	0.81 $^{a-d}$	0.78 ^{bcd}	0.70 ^{ab}	0.57 ^{bc}
3	OCW1S304T-3	0.53 $^{a-d}$	0.62 $^{a-i}$	0.76 $^{a-f}$	0.80 $^{a-d}$	0.77 $^{c-f}$	0.63 ^{fgh}	0.36 ^{ij}
4	TCI011656-4	0.53 $^{a-d}$	0.58 $^{c-i}$	0.73 $^{a-g}$	0.82 ^{a}	0.79 ^{ab}	0.69 ^{abc}	0.51 ^{cde}
5	Selimiye	0.62 ^{a}	0.72 ^{ab}	0.80 ^{ab}	0.81 ^{abc}	0.73 $^{i-l}$	0.63 ^{fgh}	0.37 ^{hij}
6	TE6627-6	0.47 ^{cd}	0.54 $^{f-i}$	0.66 ^{g}	0.78 ^{cd}	0.78 $^{b-e}$	0.71 ^{ab}	0.66 ^{a}
7	TE6474-7	0.62 ^{a}	0.66 $^{a-f}$	0.77 $^{a-e}$	0.81 $^{a-d}$	0.72 ^{l}	0.59 ^{i}	0.34 ^{ij}
8	TE6474-8	0.56 ^{abc}	0.67 $^{a-e}$	0.78 $^{a-e}$	0.81 $^{a-d}$	0.73 $^{i-l}$	0.63 ^{fgh}	0.40 ^{ghi}
9	TE6474-9	0.55 ^{abc}	0.68 $^{a-d}$	0.77 $^{a-e}$	0.80 $^{a-d}$	0.72 ^{kl}	0.62 ^{ghi}	0.39 $^{g-j}$
10	Pehlivan	0.48 ^{bcd}	0.61 $^{a-i}$	0.75 $^{a-f}$	0.82 ^{ab}	0.74 $^{h-k}$	0.66 $^{c-f}$	0.50 ^{cde}
11	TE5857-11	0.51 $^{a-d}$	0.59 $^{b-i}$	0.73 $^{a-g}$	0.81 $^{a-d}$	0.77 $^{c-f}$	0.66 $^{c-f}$	0.41 $^{f-i}$
12	TE6321-12	0.58 ^{abc}	0.72 ^{a}	0.81 ^{a}	0.82 ^{a}	0.74 ^{hi}	0.64 $^{e-h}$	0.48^{def}
13	TE5554-13	0.54 $^{a-d}$	0.64 $^{a-h}$	0.75 $^{a-f}$	0.81 $^{a-d}$	0.77 $^{c-f}$	0.66 ^{cde}	0.45 $^{e-h}$
14	TE6412-14	0.58 ^{abc}	0.64 $^{a-i}$	0.71 $^{b-g}$	0.82 ^{ab}	0.81 ^{a}	0.71 ^{a}	0.49 ^{de}
15	Gelibolu	0.50 $^{a-d}$	0.51 ^{hi}	0.69 ^{efg}	0.81 $^{a-d}$	0.74 ^{hij}	0.64 $^{d-g}$	0.40 $^{f-i}$
16	TE6744-16	0.60 ^{ab}	0.66 $^{a-g}$	0.79 ^{abc}	0.81 $^{a-d}$	0.72 ^{jkl}	0.65 ^{def}	0.46 ^{efg}
17	TE6748-17	0.48 ^{bcd}	0.51 ^{i}	0.67 ^{fg}	0.80 $^{a-d}$	0.74 ^{ghi}	0.66 $^{c-f}$	0.55 ^{bcd}
18	TE6636-18	0.42 ^{d}	0.55 $^{e-i}$	0.70 $^{c-g}$	0.81 ^{abc}	0.76 ^{efg}	0.65 $^{d-g}$	0.47 ^{ef}
19	TE6636-19	0.57 ^{abc}	0.62 $^{a-i}$	0.78 $^{a-e}$	0.82 ^{a}	0.76 ^{def}	0.66 $^{c-f}$	0.48 ^{def}
20	Saban	0.58 ^{abc}	0.71 ^{abc}	0.81 ^{ab}	0.82 ^{a}	0.75 ^{fgh}	0.65 $^{d-g}$	0.38 ^{hij}
21	TE6662-21	0.48 ^{bcd}	0.53 ^{ghi}	0.69 $^{d-g}$	0.78 ^{d}	0.78 ^{bc}	0.71 ^{ab}	0.61 ^{ab}
22	TE6714-22	0.48 ^{bcd}	0.56 $^{d-i}$	0.71 $^{b-g}$	0.81 $^{a-d}$	0.79 ^{ab}	0.71 ^{ab}	0.60 ^{ab}
23	TE6714-23	0.51 $^{a-d}$	0.67 $^{a-f}$	0.79 ^{abc}	0.82 ^{ab}	0.77 $^{c-f}$	0.68 ^{bcd}	0.48 ^{de}
24	TE6038-24	0.49 $^{a-d}$	0.55 $^{e-i}$	0.74 $^{a-g}$	0.78 ^{bcd}	0.74 $^{h-k}$	0.61 ^{hi}	0.32 ^{j}
25	TE6226-25	0.53 $^{a-d}$	0.61 $^{a-i}$	0.78 $^{a-e}$	0.82 ^{ab}	0.75 ^{fgh}	0.64 $^{d-g}$	0.45 $^{e-h}$
Mean		0.53	0.62	0.75	0.81	0.75	0.66	0.46
LSD (0.05)		0.13^{ns}	0.13*	0.093*	0.037^{ns}	0.19**	0.033**	0.75**
CV (%)		17.8	15.2	8.96	3.22	1.79	3.64	11.6

Note: *p<0.05, **p<0.01; ns- non-significant; Biomass (NDVI)- Normalized Difference Vegetation Index; GS- growth stages

The coefficients of correlation between grain yield and biomass (NDVI), and between grain yield and physiological parameters are presented in Tables 4 and 5. Increasing the biomass positively affected grain yield (positive correlations were found) especially after heading phase (r=0.229 at GS75 and r=0.322 at GS85) (Table 4). Genotypes, which have higher chlorophyll content, had higher grain yield, so there was moderate positive correlation between grain yield and chlorophyll content (r=0.316) (Table 5). In the study, no correlation was found between grain yield and biomass at GS25, GS45 and GS60 growth stages.

Table 4. Coefficients of correlation between biomass (NDVI) and physiological parameters and grain yield

Parameters	NDVI (GS25)	NDVI (GS30)	NDVI (GS38)	NDVI (GS45)	NDVI (GS60)	NDVI (GS75)	NDVI (GS85)
CT (GS60)	0.229	0.256	0.196	0.089	0.314	0.189	0.099
CT (GS75)	0.171	0.176	-0.029	0.061	0.327	0.282	0.207
SPAD (GS60)	0.254	0.102	-0.042	-0.094	-0.213	-0.090	0.118
DH	-0.148	-0.164	-0.337	-0.067	0.275	0.596**	0.802**
PH	0.031	0.095	0.306	-0.029	-0.488*	-0.269	-0.132
GLO	0.146	0.194	0.373	0.106	-0.788**	-0.507**	-0.226
GY	-0.018	-0.211	-0.204	-0.031	0.064	0.229	0.322

Note: *P<0.01; **P<0.05; NDVI- Biomass; GS- Growth stage; CT- Canopy temperature; SPAD- Chlorophyll content; DH- Days of heading; PH- Plant height; GLO- Glaucousness (1-9); GY- Grain yield

Table 5. Coefficients of correlation among physiological parameters and grain yield

Parameters	CT (GS60)	CT (GS75)	SPAD (GS60)	DH	PH	GLO
CT (GS75)	0.672**					
SPAD (GS60)	0.187	0.229				
DH	0.252	0.397*	0.151			
PH	-0.427*	-0.654**	-0.304	-0.171		
GLO	-0.260	-0.163	0.201	0.066	0.400*	
GY	0.224	0.140	0.316	0.172	0.122	0.126

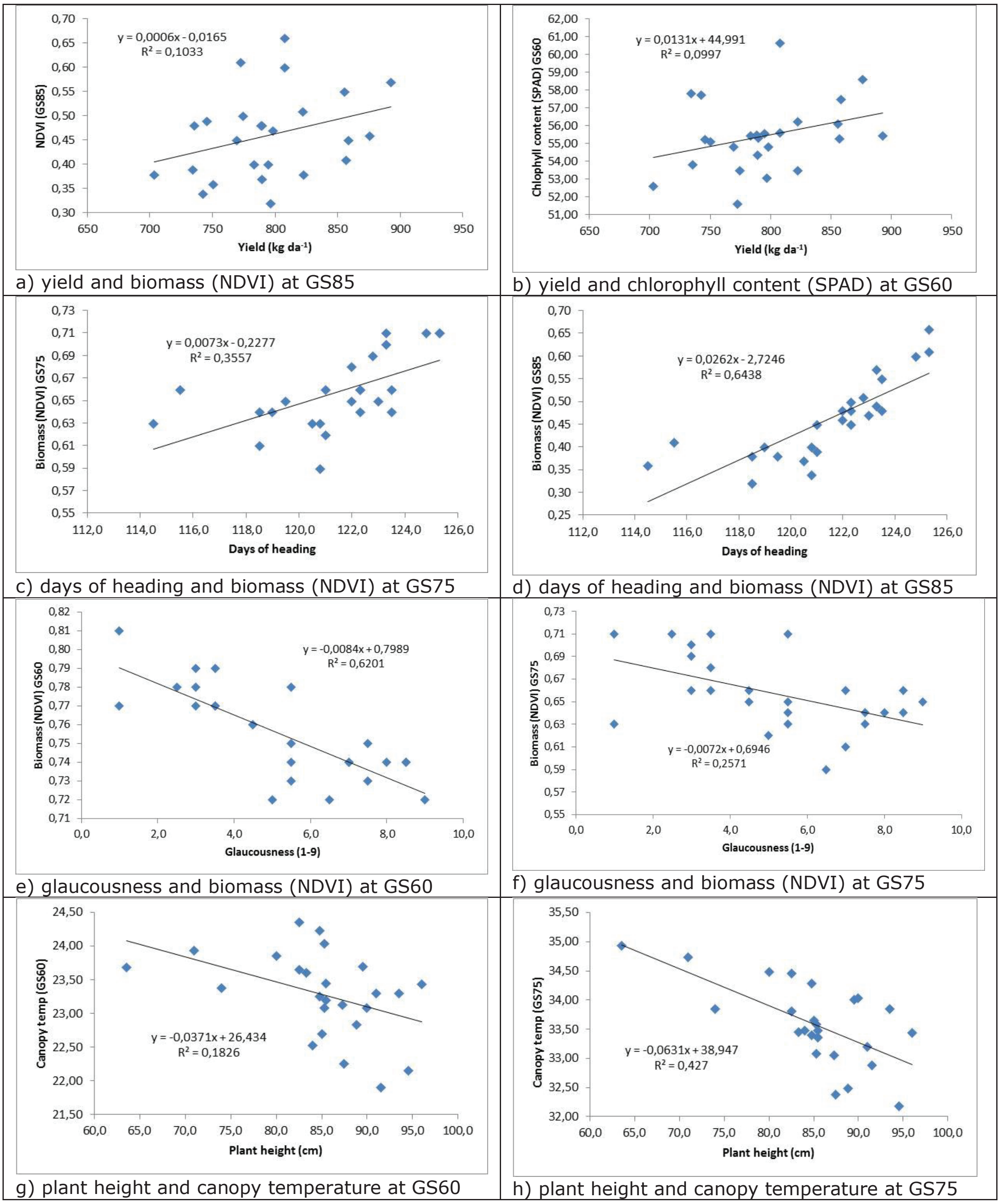
Note: *P<0.01; **P<0.05; CT- Canopy temperature; SPAD- Chlorophyll content; DH- Days of heading; PH- Plant height; GLO- Glaucousness; GY- Grain yield; GS- Growth stage

Correlation coefficients among biomass (NDVI) and other physiological parameters were determined by Pearson's correlation analysis (Table 4). There was a slightly positive correlation between biomass (from GS25 up to GS85 growth stages) and canopy temperature at GS60. While there was a positive relationship between days of heading and biomass from GS25 until GS45 growth stages, positive relationship was detected in the later period at GS60 (r=0.275), GS75 (r=0.596**) and GS85 (r=0.802**). While there was a slightly positive relationship between plant height and biomass from GS25 until GS45 growth stages, negative relationship was determined in the later period at GS60 (r=-0.488**), GS75 (r=-0.269) and GS85 (r=-0.132). While there was a slightly positive relationship between glaucousness and biomass from GS25 until GS45 growth stages, negative relationship was determined in the later period at GS60 (r=-0.788**), GS75 (r=-0.507**) and GS85 (r=-0.226).

Other correlations among physiological parameters and grain yield are given in Table 5. Positive relationship was found with canopy temperature and days of heading r=0.252 (at GS60), r=0.397* (at GS75), respectively. According to results, there was a significant negative correlation between plant height and canopy temperature at GS60 (r=-0.427*) and GS75 (r=-0.657**), also plant height was negatively correlated with chlorophyll content (SPAD) (r=-0.304). A positive correlation was determined with plant height and glaucousity (r=0.400*). Also, grain yield was positively correlated with chlorophyll content (r=0.316).

Grain yield is affected by environmental fluctuations, such as some physiological traits, morphological and agronomic traits related with grain yield. In this study correlations (R) between tested parameters and yield components were estimated through regression analysis during 2016-2017 growing seasons (Figure 1).

Figures 1a and 1b illustrate the slightly positive relationship between grain yield and biomass (NDVI) at GS85 plant stages (R^2=0.103), and chlorophyll content (SPAD) at GS60 plant stages (R^2=0.099). Earlier study showed that there was positive correlation between yield and biomass (Reynolds et al., 1994; Gutierrez-Rodriguez et al., 2004; Marti et al., 2007). There was also a positive correlation between biomass (NDVI) and days of heading at GS75 (R^2=0.355) and at GS85 (R^2=0.643) growth stages (Figures 1c and 1d). These results indicated that late maturity genotypes had higher biomass. Strong negative correlation was found between glaucousness and biomass (NDVI) at GS60 plant stages and medium correlation was found between glaucousness and biomass (NDVI) at GS75 plant stages, R^2=0.620 and R^2=0.257, respectively (Figures 1e and 1f). A negative relation was found between biomass and plant height at GS60 (R^2=0.182) and significant negative relation at GS75 (R^2=0.427) growth stages (Figures 1g and 1h). These results showed that tall genotypes had lower canopy temperature.



a) yield and biomass (NDVI) at GS85
b) yield and chlorophyll content (SPAD) at GS60
c) days of heading and biomass (NDVI) at GS75
d) days of heading and biomass (NDVI) at GS85
e) glaucousness and biomass (NDVI) at GS60
f) glaucousness and biomass (NDVI) at GS75
g) plant height and canopy temperature at GS60
h) plant height and canopy temperature at GS75

Figure 1a,b,c,d,e,f,g,h. Correlations (R) between tested parameters and yield components based on regression analysis: a) yield and biomass (NDVI) at GS85; b) yield and chlorophyll content (SPAD) at GS60; c) days of heading and biomass (NDVI) at GS75; d) days of heading and biomass (NDVI) at GS85; e) glaucousness and biomass (NDVI) at GS60; f) glaucousness and biomass (NDVI) at GS75; g) plant height and canopy temperature at GS60; h) plant height and canopy temperature at GS75

Conclusion

Bread wheat production in Trakia region basically depends on rainfall, which can be very variable. According to the present study, there were significant differences among genotypes based on grain yield, plant height, days of heading, glaucousness, chlorophyll content, biomass at GS60, GS75 and GS85, canopy temperature at GS75 growth stage. Chlorophyll content had a positive effect on grain yield. Increase in biomass during grain filling period (at GS75 and GS85 growth stages) had positive effect on grain yield under rainfall condition. In the present study early maturing (days of heading) genotypes had lower canopy temperature. Negative correlations between glaucousness with biomass at GS60, GS75 and GS85 growth phase were found. Also, tall genotypes had lower canopy temperature. The results obtained give reason the physiological parameters such as biomass (at GS75 and GS85 growth stages), chlorophyll content (at GS60) and glaucousness to be used as selection parameters for improving the bread wheat yield cultivated under rainfed conditions.

References

Adamsen FJ, Pinter PJ, Barnes EM, LaMorte RL, Wall GW, Leavitt SW and Kimball BA, 1999. Measuring wheat senescence with a digital camera. Crop Science, 39, 719.

Amani I, Fischer RA and Reynolds MP, 1996. Canopy temperature depression association with yield of irrigated spring wheat cultivars in hot climate. Journal of Agronomy and Crop Science, 176, 119-129.

Babar MA, Reynolds MP, van Ginkel M, Klatt AR, Raun WR and 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 Science, 46, 1046-1057.

Blum A, 2000. Mitigation of drought stress by crop management. Plant Stress.com,
http://www.plantstress.com/articles/drought_m/ (18.02.2010).

Calderini DF, Reynolds MP and Slafer GA, 1999. Genetic gains in wheat yield and main physiological changes associated with them during the 20th century (Chapter 16). In: Wheat: Ecology and Physiology of Yield Determination (eds. E.H. Satorre and G.A. Slafer), 1st Edition, Food Production Press, New York-London-Oxford, pp. 351-378. ISBN 9781560228752 - CAT# HW13008 .

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 of Botany, 89, 907-916.

Eberhart SA and Russell WA, 1969. Yield stability for a 10-line diallel of single-cross and double-cross maize hybrids. Crop Science, 9, 357-361.

Feng MC and Yang WD, 2011. Changes in NDVI and yield of winter wheat cultivars with different plant types. Chinese Journal of Eco-Agriculture, 19, 87-92.

Finlay KW and Wilkinson GN, 1963. The analysis of adaptation in a plant breeding programme. Australian Journal of Agricultural Research, 14, 742-754.

Feng MC and Yang WD, 2011. Changes in NDVI and yield of winter wheat cultivars with different plant types. Chinese Journal of Eco-Agriculture, 19, 87-92.

Gutierrez-Rodriguez M, Reynolds MP, Escalante-Estrada JA and Rodriguez-Gonzalez MT, 2004. Association between canopy reflectance indices and yield and physiological traits in bread wheat under drought and well-irrigated conditions. Australian Journal of Agricultural Research 55, 1139-1147.

Gomez KA and Gomez AA, 1984. Statistical procedures for agricultural research, 2nd Edition. John Willey and Sons Inc., New York, p. 641.

Hazratkulova S, Sharma R, Alikulov S, Islomov S, Yuldashev T, Ziyaev Z, Khalikulov Z, Ziyadullaev Z and Turok J, 2012. Analysis of genotypic variation for normalized difference vegetation index and its relationship with grain yield in winter wheat under terminal heat stress. Plant Breeding, 131, 716-721.

Jackson RD, Idso SB, Reginato RJ and Pinter PJ, 1981. Canopy temperature as a crop water stress indicator. Water Resources Research, 17, 1133-1138.

Kalaycı M, 2005. Örneklerle Jump Kullanımı ve Tarımsal Araştırma için Varyans Analiz Modelleri. Anadolu Tarımsal Araştırma Enst, Yayınları, Yayın No. 21, Eskişehir (Tr).

Marti J, Bort J, Slafer GA and Araus JL, 2007. Can wheat yield be assessed by early measurements of Normalized Difference Vegetation Index? Annals of Applied Botany, 150, 253-257.

Morgounov A, Gummadov N, Belen S, Kaya Y, Keser M and Mursalova J, 2014. Association of digital photo parameters and NDVI with winter wheat grain yield in variable environments. Turkish Journal of Agriculture and Forestry, 38, 624-632.

Muhammad AR, Hafiz MA, Zahid A and Qurban A, 2015. Evaluation of wheat (*Triticum aestivum* L.) genotypes for morphological traits under rainfed conditions. Academia Arena, 7, 19-26.

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

Reynolds MP, Balota M, Delgado M, Amani I and Fischer R, 1994. Physiological and morphological traits associated with spring wheat yield under hot, irrigated conditions. Functional Aust. J. Plant Biology 21, 717-730.

Reynolds MP, Nagarajan S, Razzaque MA and Ageeb OAA, 2001a. Heat tolerance. Application of physiology in wheat breeding, Chapter 10, pp.124-135. International Maize and Wheat Improvement Center, CIMMYT, Mexico.

Reynolds MP, Ortiz-Monasterio JI and McNab A, 2001b. Application of Physiology in Wheat Breeding. Mexico, D.F.: CIMMYT.

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

Richards RA, Condo AG and Rbetzke GJ, 2001. Trait to improve yield in dry environments. In: Application physiology in wheat breading (eds. M.P. Reynold, J.I. Oritz-Monasterio and A. McNab), Mexico, D.F, CIMMYT, pp. 88-100.

Slafer GA and Araus JL, 2007. Physiological Traits for Improving Wheat Yield under a Wide Range Of Conditions. In: Scale and Complexity in Plant Systems Research: Gene-Plant-Crop Relations (eds. J.H.J. Spiertz, P.C. Struik and H.H. van Laar), pp.147-156.

Trethowan RM and Reynolds MP, 2007. Drought resistance: Genetic approaches for improving productivity under stress. In: Wheat production in stressed environments (eds. H.T.Buck, J.E. Nisi, and N. Salomon). Series: Developments in Plant Breeding, Vol. 12.

Zadoks J, Chang T and Konzak C, 1974. A decimal code for the growth stages of cereals. Weed research 14, 415-421.