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Physiological Parameters of Bread Wheat (*Triticum aestivum* L.) Genotypes and Association with Yield and Quality under Rainfed Conditions

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ABSTRACT

Bread wheat is grown under a wide range of environmental conditions where climatic factors combined with agronomic inputs impart diverse effects on plant growth. This research was carried out in an experimental area of the Institute in Edirne, Trakya region (Turkey) to compare the yield, quality and some physiological parameters of wheat genotypes. The research was carried out with 11 genotypes in RCBD with 4 replications during 2012-2013 and 2013-2014 growing seasons. Data on grain yield, days to heading, plant height, 1000-kernels weight, test weight, biomass, canopy temperature and chlorophyll content were examined. According to the results, significant differences among genotypes in terms of yield, plant height, biomass, chlorophyll content and 1000-kernel weight were found. Genotypes G16-2012 and Tekirdağ had higher grain yield. Tekirdağ had the highest biomass and Bereket and Selimiye had higher chlorophyll content. The lowest canopy temperature was measured in genotypes G19-2012, Bereket, Selimiye and Aldane. The highest 1000-kernels weight and test weight were determined in cultivar Pehlivan and Selimiye. A positive correlation was determined between grain yield with biomass and chlorophyll content. There was a negative correlation between canopy temperatures with grain yield. Biomass in genotypes negatively correlated with days of heading, plant height, 1000-kernel weight and test weight. A negative relationship was also determined between chlorophyll content and canopy temperature. Due to, the positive relation between grain yield and chlorophyll content and biomass and a negative relation with canopy temperature, physiological parameters could be used in selection in bread wheat for yield potential under rainfed condition.

***Keywords*: **Bread wheat, genotypes, yield, quality traits, physiological parameters.

Introduction

Wheat is one of the most important cereal crops in the world. As it is the major crop commodity for food security, there is a need to increase wheat production by developing new high yielding and climate-resilient varieties to meet the projected demand of increasing population and with changing climate (Khatodia et al. 2019). Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world due to its adaptation to diverse environments from -35 ºC in the vegetative stage to 40 ºC during grain filling period (Shewry, 2009). 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). Breeding for stress tolerance/resistance requires an assessment of the differential sensibility of relevant genotypes (Kant et al. 2014). It is only when the response of a genotype to given stress is known that more detailed analyses of the underlying physiological and/or genetic mechanisms of adaptation to stress can be undertaken. However, responses to abiotic stresses are more frequently quantitative than qualitative and, therefore, this task is not trivial. Stress characterization is often addressed as a particular case of genotype by environment interaction (GE). G×E is one of the statistical areas more extensively reviewed in plant breeding (Cooper and Hammer 1996; Annicchiarico 2002; Voltas et al. 2002; Romagosa et al.

2009). Plants can experience abiotic stresses resulting from the shortage of an essential resource or from the excess of a toxic substance or from climatic extremes. Occurrence, severity, timing and duration of stresses vary from location to location and in the same location from year to year. Furthermore, abiotic stress seldom occurs alone, the plants often face growing conditions characterized by a combination of different physical stresses (Cattivelli et al. 2002). Grain yield is a product of an organized interplay of its several components, which are highly susceptible to environmental fluctuations. However, yield can be estimated based on the performance of yield components. Enhancement in yield in most situations is more effectively fulfilled based on the performance of yield components, which are closely associated with grain yield (Ashfaq et al. 2003; Kant et al. 2011).

The use of infrared imaging to quantify the differences in the 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). 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). 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. 2001), 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 Normalized Difference Vegetation Index (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; Marti et al. 2007). Genotypes with the horizontal orientation of leaves at the stem elongation stage had higher NDVI values compared to erect types and it was also determined that wheat yield would be more accurately predicted if NDVI was measured at both the early heading and the filling stage (Feng and Yang 2011). Moisture deficit differentially and significantly affected cultivar test weight and yield. The overall moisture-deficit-induced reduction in yield was primarily due to a reduction in kernel weight; effects of moisture deficit on a yield of specific cultivars were largely due to effects on kernels per spike. Cultivar x moisture treatment interactions was highly significant for test weight and yield (Guttieri et al. 2001). The main objective of this study was to investigate yield, physiological parameters and some agronomic characters of the genotypes under rainfed conditions.

Materials and Methods

The experiment was conducted in Edirne, Trakya region (Turkey) during the 2012-2013 and 2013-2014 growing seasons. This research was carried out with eleven genotypes. A randomized complete block design (RCBD) with four replications was used at each location. Each plot had 6 meter long, 6 rows, spaced 0.17 meter apart. Using a plot drill performed sowing and a seed rate of 500 seeds m^2 were used. Sowings were performed by using a plot drill in October and nitrogen was applied three times. Data on grain yield, plant height, days to heading, thousand kernels weights and test weight (Köksel et al. 2000) were investigated. In the research; physiological characters such as canopy temperature (CT), chlorophyll content (SPAD) and biomass (NDVI) were measured at the heading stage of the plant development.

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 et al. 2006). 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°C to the horizontal. Readings were made between 13.00 and 15.00 h 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 (Gutierrez-Rodriguez et al. 2004; Pask et al. 2012). Chlorophyll content (SPAD) and canopy temperature (^{o}C) were taken at GS55 growth stages. The Zadoks Decimal Code (Z) was used to describe plant growth stages of cereals (Zadoks et al. 1974).

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Statistical analysis

To evaluate significant differences between genotypes, the analysis of variance 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 in 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 (1966). Regression graphs were used to predict the adaptability of genotypes and the correlations between the quality parameters were determined by Pearson's correlation analysis.

Results and Discussion

There were significant differences among genotypes and between years because of the fluctuation of the rainfall across two growing cycles (Table 1). The results of the study showed that yield and other parameters investigated in wheat genotypes varied depending on genotypes and environmental conditions (Table 2). According to the results, the average yield of the experiment was 6799 kg ha^{-1}, but the highest yield was obtained with 7471 kg ha^{-1} in Selimiye and 7077 kg ha^{-1} in Bereket cultivars. The lowest yielding cultivar was Kate A-1. Biomass and canopy temperature was measured at the heading stage and there were significant differences among genotypes. An earlier study showed that there was a positive correlation between yield and biomass (Reynolds et al. 1994; Gutierrez-Rodriguez et al. 2004; Marti et al. 2007). In the study, there was a positive association between biomass and grain yield. It was measured that the mean biomass was 0.74, the highest biomass in Tekirdağ cultivars with 0.79 and the lowest biomass was determined in Kate A-1 cultivar.

The chlorophyll content of the genotypes was measured at the heading stage by using a SPAD meter. There was a high variation in chlorophyll content of the genotypes and the lowest was found 44.50 in cultivar Saban and the highest was 50.35 in cultivar Bereket and 50.00 in Selimiye. Chlorophyll content positively affected grain yield in the genotypes. Canopy temperature is generally related to yield under drought stress condition in wheat (Reynolds et al. 1994; Trethowan and Reynolds, 2007; Reynolds et al. 2001). The mean canopy temperature was 19.39 °C. Minimum and maximum canopy temperature ranged between 18.06 °C and 20.13 °C among genotypes and the lowest canopy temperature was measured in genotypes G19-2012, Bereket, Selimiye and Aldane (Table 3).

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 (Chaves et al. 2002). Due to the fluctuation of rainfall mid-early genotypes generally are favorable in bread wheat in the Trakya region. Medium maturity is the preferred feature in the region. Days of heading ranged from 105.0 to 116.1 among genotypes and the mean value was 109.9 days. Cultivars Tekirdağ and Saban were early (days to heading) genotypes (Table 3). Plant breeders have tried to select and release intermediate varieties (Richards et al. 2001; Calderini et al. 1999). Plant height and stem structure is a quite important trait in a wheat breeding program for lodging resistance. Table 3 shows that the mean plant height was 101.3 cm, the lowest and highest plant height ranged between 78 cm and 112 cm under rainfed conditions. The shortest plant height was scaled in cultivars Tekirdağ and followed by Saban and G11-2012 genotypes (Table 3).

The overall moisture-deficit-induced reduction in yield was primarily due to the reduction in kernel weight; the effects of moisture deficit on the yield of specific cultivars were largely due to the effects on kernels per spike. Cultivars x moisture treatment interactions were highly significant for test weight and yield. The effect of moisture deficit on kernel weight also was reflected in reduced test weight (Guttieri et al. 2001). Thousand kernel weight and test weight in wheat varied by genotypes and genotypes x year interactions (Table 2, 3 and 4). In the study, 1000-kernels weights (TKW) were very variable among genotypes and ranged between 37.9 g (G19-2012) and 47.3 g (Aldane). Aldane and Pehlivan had the highest TKW and the mean TKW were 42.8 g. The test weight of the genotypes ranged between 75.9 kg and 80.0 kg, while the mean test weight was 78.08 kg. The highest test weight was obtained from Selimiye, which is followed, by Pehlivan and Aldane cultivar (Table 3).

Correlation analysis

Correlation coefficients were determined by Pearson's correlation analysis. In the study, some relations between investigated characters were examined and correlation coefficients among the tested characters of cultivars were given in Table 4. Higher biomass positively affected grain yield and a moderate positive correlation were observed between grain yield and biomass (r= 0.333). It was found a moderate positive correlation between grain yield and thousand kernels weight (r= 0.205). There was a negative correlation between plant height and grain yield so genotypes which have shorter plant height gave more yields (Table 4). According to results, there was a negative correlation between biomass with chlorophyll content (r= -0.241), days of heading (r= -0.512), plant height (r= -0.738**), 1000-kernels weight (r= -0.357) and test weight (r= -0.682*). These resulted indicated that higher biomass significantly caused to decrease in the test weight and 1000-kernel weight of the genotypes. Low canopy temperature was scaled genotypes that have late heading and higher plant height. So, a negative correlation was determined between canopy temperature and days to heading (r= -0.554) and plant height (r= -0.171) (Table 4). These results showed that to see the expected relationship between grain yield with physiological and agronomical traits, physiological researches should be carried out under both various drought stress and rainfed environment conditions.

Grain yield is affected by environmental fluctuations and there are various components, such as some physiological traits, morphological and agronomic traits related to grain yield. In this study, some of the characters given above were examined and assessed for the relationship amongst them and were presented in Figure 1. There was a negative relationship between biomass and test weight (R^2=0.464), plant height (R^2=0.544). Grain yields positively associated with biomass (R^2=0.110) and grain yield was also negatively associated with plant height (R^2=0.311). This result showed that short genotypes had higher yield potential. Similar findings were also reported by (Kant et al. 2011). A negative relation was found between canopy temperature and chlorophyll content (R^2=0.816). There was also a positive relationship between chlorophyll content and grain yield (R^2=0.263) (Figure 1). These results indicated that an increase in biomass and chlorophyll content of the genotypes led to an increase in grain yield. Also, lower canopy temperature was scaled in late heading and tall genotypes.

Conclusions

Bread wheat production in the Trakya region is important because of the high yielding capacity in wheat thanks to favorable environmental conditions. However, the fluctuations in rainfall in April and May causes yield losses and low-quality products in wheat. Therefore, physiological and agronomical studies on wheat under various environmental conditions are needed. In this experiment, there were significant differences among genotypes. Higher biomass and chlorophyll content positively affected grain yield and also higher thousand kernels weight increased grain yield. Genotypes, which have shorter plant height, had higher yields. The higher biomass negatively affected and decreased chlorophyll content, thousand kernels weight and test weight. Higher canopy temperature negatively affected grain yield and chlorophyll content in genotypes. The lower canopy temperature was scaled genotypes which has tall plant and late heading. All these results showed that to get the expected relationship among grain yield and physiological characters, researches should be carried out under various drought stress conditions. Also, physiological parameters such as biomass, canopy temperature and chlorophyll content could be used for yield components under rainfed conditions. The higher canopy temperature significantly reduced grain yield and chlorophyll content of genotypes.

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Table 1. The rainfall and temperatures for two growing cycles in Edirne location.

Months	Rainfall (mm)		Temperature (°C) 2012-2013			Temperature (°C) 2013-2014		
	2012-2013	2013-2014	Min	Max	Mean	Min	Max	Mean
October	46.1	30.7	5.7	34.0	18.9	-1.6	26.8	12.8
November	12.4	73.9	-0.9	24.0	12.2	-2.4	23.4	11.0
December	165.8	2.3	-6.2	17.6	3.6	-5.6	12.1	2.7
January	134.6	74.9	-7.7	18.2	4.2	-4.2	17.3	5.5
February	104.5	3.8	-0.7	18.8	6.8	-4.4	20.2	7.6
March	62.9	124.5	-1.7	23.6	9.8	-1.4	23.7	10.1
April	51.0	36.8	4.0	32.0	14.5	-0.1	25.5	13.6
May	11.0	61.7	4.9	32.9	20.8	4.0	32.1	18.6
June	26.6	68.8	11.4	36.2	23.3	10.3	33.6	22.9
Total/Mean	614.9	477.4	-7.7	36.2	12.7	-5.6	33.6	11.6

Table 2. Combined analysis of variance for bread wheat genotypes across two years for investigated parameters.

Parameters	Year (Y)		Genotypes (G)		Y × G	
	MS	F Value	MS	F Value	MS	F Value
GY	802550.0	102.66**	15737.5	4.87**	21167.8	6.56**
TW	98.28	114.14**	14.34	19.91**	1.68	2.34*
TKW	391.36	216.89**	70.49	106.41**	18.76	28.31**
SPAD	177.56	66.00**	36.43	18.93**	5.83	3.83**
NDVI	0.031	32.77**	0.0056	26.83**	0.0006	2.92**
CT	5.11	4.06ns	4.58	5.86**	0.98	1.26ns
PH	1581.01	61.49**	492.71	28.85**	24.78	1.45**
DH	4860.41	2448.76**	88.05	38.12**	65.05	28.17**

*, ** Indicate significances, ns: non-significant at P<0.05 and P<0.01, respectively

MS: Mean square, GY: grain yield (kg ha^{-1}), TW: Test weight (kg), TKW: Thousand kernels weight (g), SPAD: Chlorophyll content, NDVI: Biomass, CT: Canopy temperature (°C), PH: Plant height (cm), DH: Days of heading (day)

Table 3. Mean performance of genotypes based on yield, physiological and quality parameters across two environments conditions.

No	Genotypes	GY	NDVI	SPAD	CT	DH	PH	TKW	TW
1	Kate A-1	5658c	0.70g	46.26 c	20.03 a	113.0b	116.4a	40.6d	78.4c
2	Pehlivan	6558b	0.72f	44.54 d	20.05 a	110.9cd	109.0b	46.8a	79.4ab
3	Gelibolu	6688b	0.74de	45.74 cd	20.04 a	108.1e	99.3d	42.2c	78.9bc
4	Tekirdağ	6875b	0.79a	45.16 cd	19.66 ab	105.0g	89.6f	40.3d	77.3d
5	Aldane	6967ab	0.73f	48.55 b	18.96 bc	110.8cd	103.9c	47.3a	79.4ab
6	Selimiye	7471a	0.72f	50.00 a	18.83 bcd	109.8d	98.8d	45.1b	80.0a
7	Bereket	7077ab	0.73f	50.35 a	18.23 cd	116.1a	107.9bc	42.3c	78.1cd
8	Saban	6792b	0.75cd	44.50 d	20.13 a	106.0fg	94.4e	44.5b	77.5d
9	G11-2012	6877b	0.73ef	46.05 c	19.88 a	106.6ef	94.4e	40.2d	78.1cd
10	G16-2012	6855b	0.76bc	46.45 c	19.43 ab	112.0bc	96.3de	44.5b	76.0e
11	G19-2012	6951ab	0.77b	48.98 ab	18.06 d	111.5bc	104.6c	37.9e	75.9e
Mean		6797	0.74	46.96	19.39	109.97	101.3	42.88	78.08
LSD (0.05)		56.8	0.01	1.38	0.88	1.52	4.13	0.81	0.84

Significance at * P<0.01, ** P<0.05, ns: not significant

GY: grain yield (kg ha^{-1}), NDVI: Biomass, SPAD: Chlorophyll content, CT: Canopy temperature (°C), DH: Days of heading (day), PH: Plant height (cm), TKW: Thousand kernels weight (g), TW: Test weight (kg)

Table 4. Coefficient of correlation among the tested parameters of the genotypes.

Traits	GY	NDVI	SPAD	CT	DH	PH	TKW
NDVI	0.333						
SPAD	0.513	-0.241					
CT	-0.559	-0.082	-0.904**				
DH	-0.137	-0.512	0.612*	-0.554			
PH	-0.558	-0.738**	0.273	-0.171	0.781**		
TKW	0.205	-0.357	-0.048	0.180	0.089	0.052	
TW	0.041	-0.682*	0.107	0.210	0.002	0.269	0.560

Significance at * P<0.01, ** P<0.05, ns: not significant

GY: grain yield, NDVI: Biomass, SPAD: Chlorophyll content, CT: Canopy temperature (°C), DH: Days of heading (day), PH: Plant height, TKW: 1000-kernels weight (g), TW: Test weight (kg)

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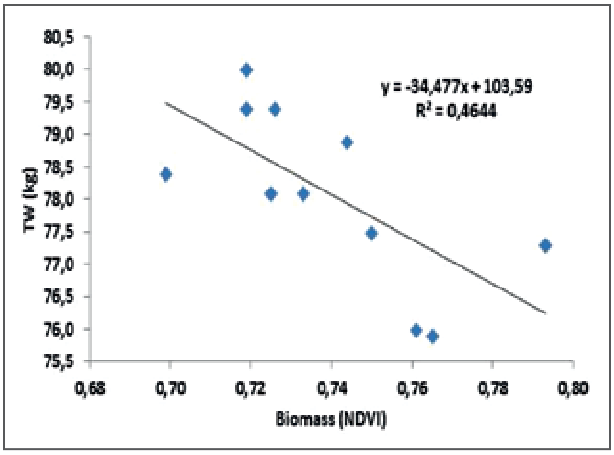
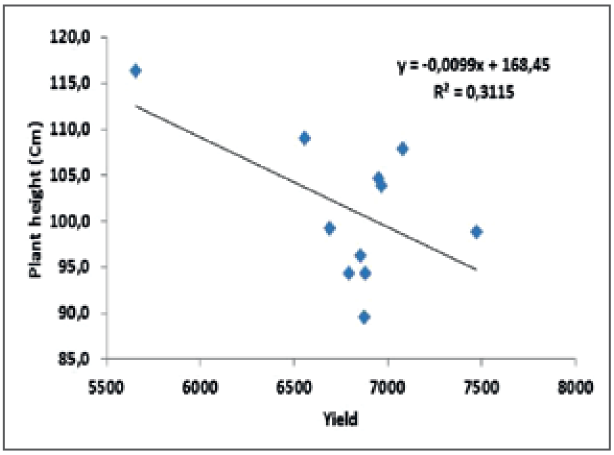
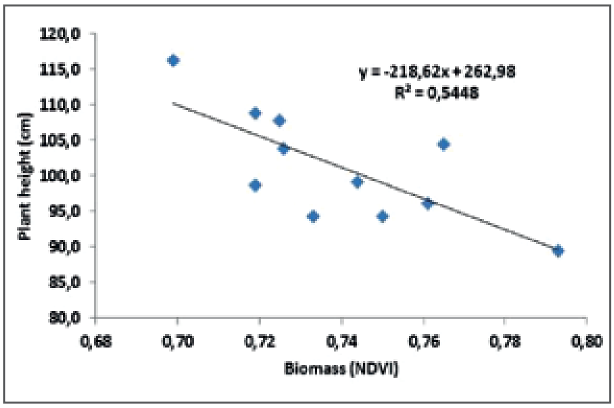
Figure 1. Relationship with yield, quality and other physiological parameters.



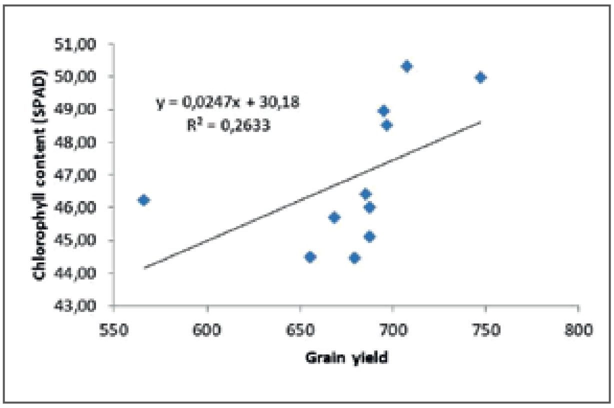
Test weight and biomass (NDVI)



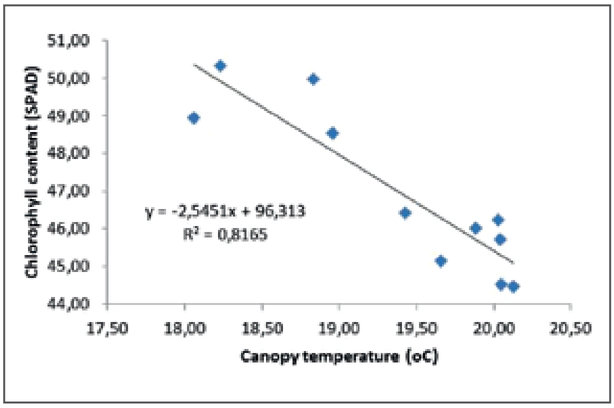
Plant height and yield



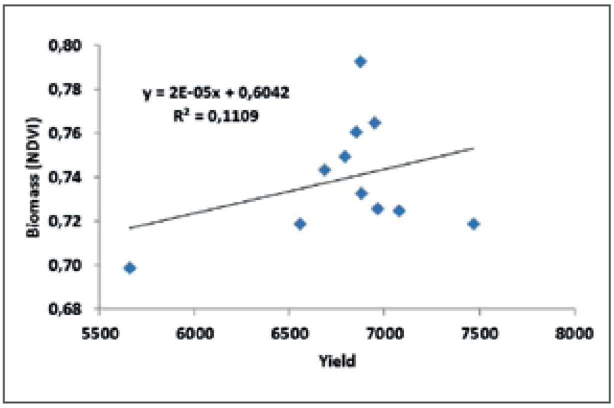
Plant height and biomass (NDVI)



Grain yield and chlorophyll content



Chlorophyll content and canopy temperature



Biomass (NVDI) and grain yield

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