EFFECT OF BIOMASS AT DIFFERENT GROWTH STAGE ON GRAIN YIELD AND QUALITY IN BREAD WHEAT (*Triticum aestivum* L.) GENOTYPES

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Abstract
The aim of this research was to determine the effects of location, genotypes and the interaction of location x genotypes on biomass, canopy temperature, yield and some of the quality traits of the bread wheat genotypes under field conditions. Thus, it was established with 25 genotypes in randomized completely blocks design with 4 replications at 3 locations in Trakya Region, Turkey, in 2013-2014 growing season. Grain yield, biomass, canopy temperature, plant height, 1000-kernel weight, test weight, and relationship among these characters were investigated. For determining biomass of the genotypes, data was taken at three plant growth stages; tillering, shooting and heading. Combined analysis of variance across three locations revealed highly significant variation among wheat genotypes for grain yield, biomass of stem elongation, heading stage and canopy temperature. The mean yield of the genotypes was 723.0 kg da^{-1}, and the highest yields were obtained from Entry 22 with 826.3 kg da^{-1}. The highest biomass was scaled in Entry-9 during three-plant growth stages. Additionally, a positive correlation was observed between grain yield and biomass in tillering, shooting, and heading growth stages of the genotypes. These results indicated that higher biomass at early plant growth stage was more significant for yield potential. There was detected slightly negative relationship between canopy temperature and biomass, and grain yield. It could be that the canopy temperatures of genotypes were measured lower during the increasing of biomass in plant development. During tillering stage, higher biomass promoted to plant height and positively affected protein ratio, values of gluten and sedimentation. In shooting phase of genotypes, biomass positively affected and increased in 1000-kernel weight, protein ratio, gluten value and sedimentation value, as well. But increasing in biomass during heading stage, negatively affected and decreased in canopy temperature, 1000-kernel weight, test weight, protein ratio, gluten index and sedimentation value.

Keywords: Bread wheat, genotypes, yield, biomass, quality parameters.

Introduction

Almost all breeding programs in the world aim to improve varieties with stable yields. The yield stability is generally grouped as static or dynamic stability. The static stability is defined as the lack of response to environmental variations while the dynamic stability is defined as the average response (Pfeiffer and Braun, 1989). Improvement of grain quality is a major objective of wheat (*Triticum aestivum* L.) breeding programs. Beside for enhancement of biological and nutritive value of end-use products, the quality components of grain play an important role in the economic value of new cultivars determining (Mangova and Rachovska, 2004). Canopy temperature depression (CTD) measured with an infrared thermometer was significantly positively correlated with performance at the international sites when measured between 1200 and 1600 hours, after full canopy establishment. The correlation of CTD with yield was not affected by the irrigation status of the crop under well-watered conditions. The possible use of these traits in selection for yield under hot conditions is discussed (Reynolds et al., 1994). Biomass assessment is essential not only for studies monitoring crop growth, but also in cereal breeding programs as a complementary selection tool (Araus et al., 2009). The normalized difference vegetation index (NDVI) is widely used at ground level, and from low, high and satellite altitudes to measure vegetative greenness and canopy photosynthetic size (Reynolds et al., 2001). Trakya region of Turkey has a diversion climate conditions with distinct agro-ecological zone. Although the average annual rainfall is 560 mm in the region this precipitation ranges between 350 mm to 850 mm. During the growing season (October-June) the distribution of this rainfall is not regular. Due to this fluctuation of rainfall in some growing year drought problem occurs and decrease grain yield. The main objective of this research was to assess and effect of the biomass on yield and some quality parameters of some genotypes.

Material and methods

This experiment was conducted at three locations of Trakya region, Turkey for 2013-2014 growing seasons. Twenty five winter wheat genotypes, 5 of them were local check and 20 advanced lines, were examined under field condition. A randomized complete block design with four replications was used at each location. Each plot was sown into 6 rows, and plot sizes were 6 m^2 at harvesting. In the experiment 500 seeds m^2 was used at planting and sowings were performed by using a plot drill.

Table 1. The climatic value of the 2013-2014 growing year in Edirne and Tekirdağ location

Months	Edirne Location			Tekirdağ Location		
	Rainfall (mm)	Humidity (%)	Temperature (°C)	Rainfall (mm)	Humidity (%)	Temperature (°C)
October	30.7	77.5	12.8	96.4	76.2	14.3
November	73.9	86.7	11.0	36.6	79.0	12.9
December	2.3	82.2	2.7	2.4	74.1	6.2
January	74.9	87.4	5.5	44.0	85.0	8.0
February	3.8	86.0	7.6	6.0	83.2	8.7
March	124.5	81.4	10.1	65.2	81.6	9.9
April	36.8	81.6	13.6	41.2	83.3	13.4
May	61.7	76.6	18.6	65.2	80.3	17.5
June	68.8	73.8	22.9	60.0	76.2	21.8
Mean/Total	477.4	81.5	11.6	417.0	79.9	12.5

Data recorded for grain yield, biomass, canopy temperature (Jackson et al., 1981; Fisher, 2001; Reynolds et al., 2001; Guttierrez-Rodriguez et al., 2004; Babar et al., 2006; Morgounov et al., 2014), and plant height between these characters were investigated. For quality parameters, thousand kernel weight, test weight, protein ratio, gluten value, gluten index, hardness and sedimentation (Blakeney et al., 2009; Köksel et al., 2000; Marti et al., 2007) and relationship between these characters were investigated. Biomass (NDVI) of the genotypes was recorded at three times; tillering (GS25), stem elongation (GS35), and heading stage (GS55) of the plant growth. The canopy temperature was measured when the plants were in the heading period (GS57-61). Physiological parameters were taken in Edirne location. Also, regression graphs are used to predict adaptability and relationship of the characters of genotypes. The data were assessed by analysis of variance and the differences among the means were compared with LSD (Least Significant Differences) at a 5% significant level (Gomez and Gomez, 1984; Kalaycı, 2005). Correlation coefficients among all quality traits were evaluated based on the means of all genotypes in the individual environment.

Results and discussion

Combined analysis of variance across three locations revealed highly significant variation among wheat genotypes for grain yield, biomass at stem elongation and heading stage, and canopy temperature (Table 2). The results of study are presented in Table 2. Main effect of locations and genotypes interaction was also highly significant for investigated parameters. The mean grain yield of the genotypes was 723.0 kg da^{-1}, and the highest yields were obtained in Entry 22 and 24 lines with 826.3 kg da^{-1}, and 823.5 kg da^{-1}, respectively. The highest biomass was scaled in OK81306/STAR'S'4-9 and TCI011322-22 at three plant growth stage. Biomass in genotypes increased with plant growth development and the mean biomass in GS25, GS35 and GS55 was 0.50, 0.71 and 0.77, respectively. There was no significant difference among genotypes for canopy temperature due to experiment carried out normal field condition. The mean canopy temperature was 25.6 ^{o}C, minimum 24.55 ^{o}C and maximum 26.80 ^{o}C. Plant height for lodging resistant is one of the important characters for Trakya region. In this experiment there was significant difference among genotypes for plant height, ranked from 91.3 cm to 115.3 cm and mean was 102.5 cm.

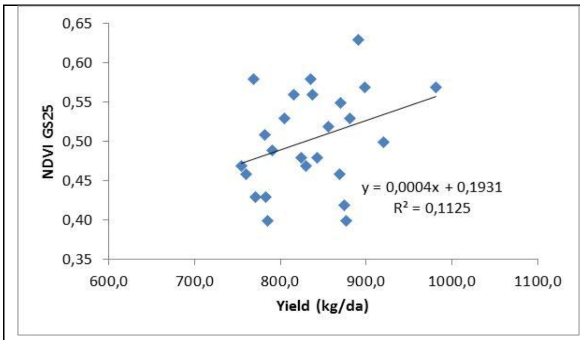
Table 2. The mean grain yield and physiological parameters of the genotypes

No	Genotypes	GY	NDVI (GS25)	NDVI (GS35)	NDVI (GS55)	CT (GS57-61)	PH
1	Aldane	601.2 j	0.46 b-e	0.78 ab	0.75 fgh	26.33 a-d	103.5 cde
2	TE5843-2	748.9 b-e	0.53 a-e	0.70 a-f	0.76 d-g	25.15 b-e	101.8 d-g
3	TCI-01-590	722.8 def	0.55 a-d	0.76 abc	0.77 c-f	26.25 a-d	105.0 cde
4	TE 5793-4	676.0 gh	0.43 cde	0.62 f	0.77 d-g	25.85 a-e	100.0 e-h
5	Selimiye	709.0 efg	0.52 a-e	0.77 ab	0.74 gh	25.28 b-e	103.0 c-f
6	TE 5793-6	681.4 fgh	0.40 e	0.65 def	0.78 b-e	25.75 a-e	102.0 d-g
7	CMSW1WM331S-7	786.9 ab	0.47 b-e	0.67 c-f	0.81 ab	25.33 b-e	113.3 a
8	OK81306/STAR-3-8	766.2 bcd	0.50 a-e	0.67 c-f	0.79 bcd	24.88 de	106.5 cd
9	OK81306/STAR-4-9	777.2 b	0.63 a	0.79 a	0.82 a	25.53 a-e	112.0 ab
10	Bereket	621.9 ıj	0.51 a-e	0.74 a-d	0.75 fgh	25.15 b-e	115.3 a
11	TE6038-11	728.8 cde	0.49 b-e	0.72 a-f	0.76 d-g	25.78 a-e	103.0 c-f
12	TE6217-12	729.1 cde	0.46 b-e	0.70 a-f	0.75 fgh	26.60 ab	97.0 ghı
13	TE6217-13	729.2 cde	0.42 de	0.63 ef	0.77 c-g	25.48 a-e	93.3 ıj
14	TE6217-14	718.0 d-g	0.48 b-e	0.70 a-f	0.78 b-e	25.55 a-e	97.8 f-ı
15	Pehlivan	647.5 hı	0.53 a-e	0.78 ab	0.75 fgh	25.50 a-e	114.3 a
16	BBVD-16	772.6 bc	0.56 abc	0.74 a-d	0.79 bc	26.10 a-d	96.0 hıj
17	BBVD-17	749.0 b-e	0.47 b-e	0.68 b-f	0.73 h	26.58 ab	95.3 hıj
18	BBVD-18	745.1 b-e	0.48 b-e	0.68 b-f	0.81 ab	26.25 a-d	101.8 d-g
19	BBVD-19	641.4 hıj	0.58 ab	0.72 a-f	0.78 bcd	25.95 a-e	94.0 ıj
20	Gelibolu	744.4 b-e	0.40 e	0.66 c-f	0.74 gh	26.80 a	103.8 cde
21	OCW1S304T-21	705.5 efg	0.58 ab	0.73 a-e	0.78 bcd	25.08 cde	102.5 c-f
22	TCI011322-22	826.3 a	0.57 abc	0.76 abc	0.78 b-e	26.43 abc	107.8 bc
23	BBVD-23	744.8 b-e	0.56 abc	0.74 a-d	0.80 ab	24.55 e	105.8 cd
24	CMSA4Y294S-24	823.5 a	0.57 abc	0.79 a	0.76 e-h	25.18 b-e	96.8 ghı
25	BBVD-25	714.5 efg	0.43 cde	0.65 def	0.79 bc	25.18 b-e	91.3 j
Mean		723.0	0.50	0.71	0.77	25.6	102.5
CV (%)		7.9	20.0	10.3	2.2	4.0	3.8
LSD (0.05)		46.1	0.14	0.10	0.03	1.46	5.5
F		**	ns	**	**	ns	**

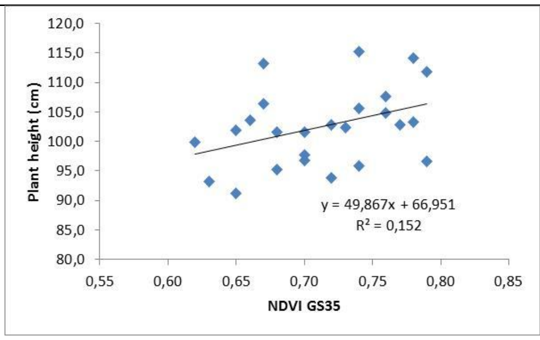
Note: Significance at **: P<0.01; *: P<0.05; GY: Grain yield (kg da^{-1}), NDVI: Biomass, CT: Canopy temperature, PH: Plant height (cm), GS: Growth Stage

Biomass assessment is essential not only for studies monitoring crop growth, but also in cereal breeding programs as a complementary selection tool (Araus et al., 2009). Tracking changes in biomass may also be a way to detect and quantify the effect of stresses on the crop, since stress may accelerate the senescence of leaves, affecting leaf expansion and plant growth (Royo et al., 2004; Villegas et al., 2001).

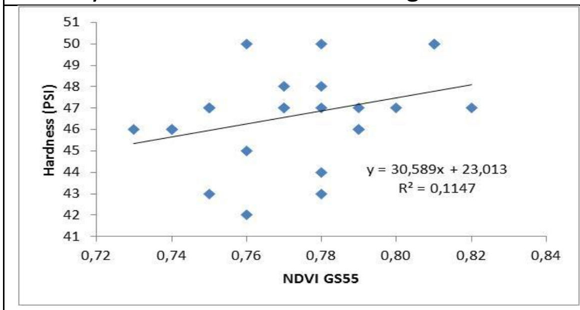
Physiological parameter such as biomass and canopy temperature was affected from environmental fluctuations and it was found various relations among investigated traits. In this research as it expected there was positively relation between biomass with grain yield at GS25 (R^2=0.112), plant height at GS35 (R^2=0.152), and grain hardness at GS55 (R^2=0.114). During grain filling period increasing in canopy temperature positively affected protein value in the genotypes (R^2=0.135). It was found slightly negative relation between canopy temperature and biomass at GS55 plant growth stage. These result showed that genotypes which have higher biomass decreased in canopy temperature (Figure 1).



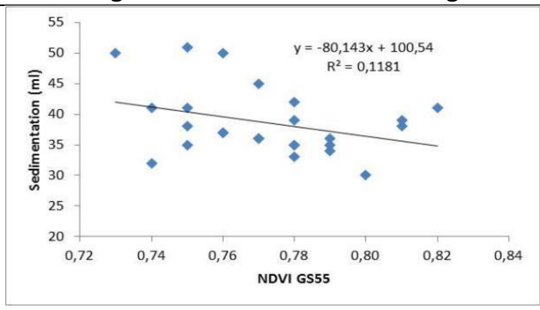
Grain yield and NDVI at GS25 stage



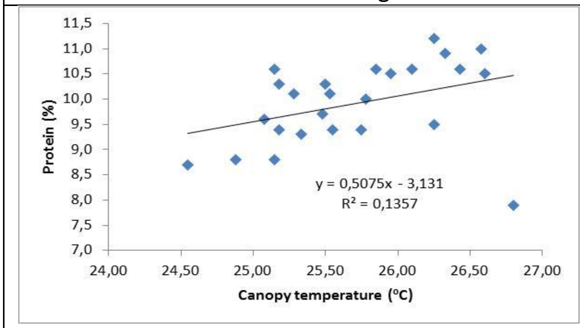
Plant height and biomass at GS35 stage



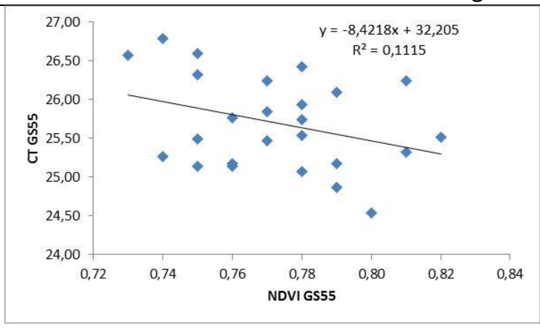
Hardness and biomas at GS55 stage



Sedimentation and biomass at GS55 stage



Canopy temperature and protein



Canopy temperature and biomass at GS55

Figure 1. Relationship between yield, some agronomic traits and physiological parameters

Correlation coefficients among yield and quality parameters varied according to location and environment condition. Generally, correlations between grain quality traits at each location and yield were low, although a few were significant (Table 3, 4, 5). A positive correlation was observed between grain yield and test weight at three locations. Grain yield was negatively correlated with protein ration at three locations, and at two locations (Edirne and Lüleburgaz) with gluten value. Grain yield also was negatively correlated with sedimentation at Edirne and Lüleburgaz location, whereas positive correlation was observed at Tekirdağ locations. A moderate positive significant correlation was found between test weight with gluten index in Edirne (r=0.731) and Lüleburgaz (r=0.637**) and slightly correlated in Tekirdağ location. There was significantly positive relation between protein ratio with gluten in Edirne (r=0.851**), and in Lüleburgaz (r=0. 814) location. Protein ratio was positively correlated with sedimentation in Edirne (r=0.620**), and Lüleburgaz (r=0.669**) location. Also, it was found positive relation between gluten index and sedimentation and there was significant correlation in Lüleburgaz (r=0.666**) and Tekirdağ (r=0.584**) location.

Table 3. Correlation coefficients among tested characters of cultivars in Lüleburgaz location

Traits	GY	TKW	TW	PRT	GLT	IND	HARD
TKW	0.188						
TW	0.430*	0.312					
PRT	-0.354	0.105	0.093				
GLT	-0.335	0.087	-0.079	0.814**			
IND	0.083	0.131	0.637**	0.183	-0.205		
HARD	0.291	0.394	0.480*	0.357	0.282	0.230	
SED	-0.199	-0.119	0.390	0.620**	0.403	0.666**	0.112

Table 4. Correlation coefficients among the tested characters of cultivars in Tekirdağ location

Traits	GY	TKW	TW	PRT	GLT	IND	HARD
TKW	-0.102						
TW	0.264	0.526**					
PRT	-0.003	0.095	0.208				
GLT	0.057	0.408*	0.320	0.369			
IND	-0.144	0.028	0.245	-0.041	-0.197		
HARD	0.085	0.233	0.050	0.138	0.208	0.159	
SED	0.244	0.226	0.372	0.117	0.478*	0.584**	0.278

Note: Significance at **: P<0.01; *: P<0.05; GY: Grain yield (kg da^{-1}), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Gluten (%), IND: Gluten index (%), HARD: Hardness (PSI), SED: Sedimentation (ml).

Protein quality and quantity have received more attention than other quality attributes, partly owing to the significant influence imparted by protein on end-use product quality of both common wheat and durum wheat. Environmental factors, such as nitrogen fertilization, water and temperature, influence protein content (Sissons et al., 2005). In contrast, protein quality is largely under genetic control (Lerner et al., 2006; Rogers et al., 2006). Because of the various environment conditions in Trakya region, protein quality and quantity and other quality characters in wheat vary year by year, location by location. Because of this it was determined varies correlation coefficient among investigated quality parameters by locations. Correlation coefficients among the tested characters varied according to location and environment condition. Generally, correlations between grain quality traits at each location and yield were low, although a few were significant (Table 5). A positive correlation was observed between grain yield and biomass in GS25 (r=0.335), GS35 (r=0.245), and GS55 (r=0.137) growth stages of the genotypes. These results indicated that higher biomass at early plant growth stage was significant for yield potential. There was slightly negative relation between canopy temperature with biomass (r=-0.335), and grain yield (r=-0.197). A moderate negative correlation was found between grain yield with protein ratio (r=-0.283), gluten value (r=-0.278) and sedimentation (r=-0.184). For determining biomass of the genotypes data was taken three plant growth stages, tillering, shooting and heading and there were various relations among characters. During tillering stage higher biomass promoted to plant height so, protein ratio, gluten and sedimentation value was affected positively. Biomass in genotypes during shooting phase of crops positively affected and increased plant height, TKW, protein ratio, gluten value and sedimentation value. Increasing in biomass during heading stage negatively affected and decreased canopy temperature, TKW, TW, protein ratio, gluten index and sedimentation value.

Table 5. Correlation coefficients among the tested characters of cultivars in Edirne location

Traits	GY	NDVI GS25	NDVI GS35	NDVI GS55	CT GS55	PH
NDVI GS25	0.335					
NDVI GS35	0.245	0.769**				
NDVI GS55	0.137	0.297	-0.085			
CT GS55	-0.197	-0.277	-0.074	-0.334		
PH	0.087	0.276	0.390	0.136	-0.210	
TKW	0.045	-0.342	0.109	-0.108	-0.040	0.283
TW	0.125	-0.088	0.086	-0.158	-0.016	-0.028
PRT	-0.283	0.204	0.232	-0.166	0.368	-0.283
GLT	-0.278	0.260	0.260	-0.083	0.123	-0.075
IND	0.180	-0.107	0.074	-0.133	-0.161	-0.025
HARD	0.147	-0.069	-0.137	0.339	-0.008	-0.226
SED	-0.184	0.178	0.307	-0.344	0.238	-0.024
Traits	TKW	TW	PRT	GLT	IND	HARD
TW	0.423*					
PRT	-0.322	-0.205				
GLT	-0.157	-0.335	0.851**			
IND	0.280	0.731**	-0.249	-0.464*		
HARD	0.166	0.122	-0.073	-0.003	0.216	
SED	-0.053	0.184	0.669**	0.578**	0.145	-0.026

Note: Significance at **: P<0.01; *: P<0.05; GY: Grain yield (kg da^{-1}), NDVI: Biomass, CT: Canopy temperature, PH: Plant height (cm), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Gluten (%), IND: Gluten index (%), HARD: Hardness (PSI), SED: Sedimentation (ml)

Conclusions

Combined analysis of variance across three locations revealed highly significant variation among wheat genotypes for grain yield, biomass of stem elongation, heading stage and canopy temperature. The highest yields were obtained from Entry 22 and 24 lines. The highest biomass was scaled in OK81306/STAR'S'4-9 and TCI011322-22 during three-plant growth stages. The biomass from GS25 up to GS35 and GS55 consistently increased of genotypes except four genotypes. A positive correlation was observed between grain yield and biomass at tillering (GS25), shooting (GS35), and heading (GS55) growth stages of genotypes. These results indicated that higher biomass at early plant growth stage was more significant effect for yield potential. There was detected slightly negative relationship between canopy temperature with biomass, and grain yield. It could be that the lower canopy temperatures of genotypes were measured with increasing in biomass in plant. Also, a moderate negative correlation was found between grain yield and protein ratio, gluten value and sedimentation. During tillering stage, higher biomass promoted to plant height and positively affected protein ratio, gluten and sedimentation. In shooting phase of genotypes, biomass positively affected and increased in 1000-kernel weight, protein ratio, gluten value and sedimentation value, as well. But increasing in biomass during heading stage, negatively affected and decreased in canopy temperature, 1000-kernel weight, test weight, protein ratio, gluten index and sedimentation value. Because of the various environment conditions in Trakya region, protein quality and quantity and other quality characters in wheat vary year by year, location by location. Because of this it was determined varies correlation coefficient among investigated quality parameters by locations.

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