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Evaluation of Yield and Some Agro-Morphological Characters of Triticale Genotypes in Trakya Region

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ABSTRACT

Triticale under both normal and drought stress conditions were superior and also combines high plant productivity and grain yield. This research was carried out to determine the yield and agronomic performance of some triticale genotypes in Trakya region. This research was established with 16 genotypes in completely randomized blocks experimental design with 4 replications in Edirne in 2014-2015 and 2015-2016 growing seasons. In this research project grain yield, plant height, days to heading, lodging resistance, winter kill, 1000-kernel weight, test weight, protein ratio and hardness and relationships among characters were investigated. According to the results it significant differences were found among genotypes in terms of grain yield and other investigated characters. Mean yield of the genotypes was 630.7 kg/da. Entry 11 had higher gran yield with 737.8 kg/da and followed by entry 15 and entry 16. Correlation coefficients among the investigated characters showed that there were various relations among investigated parameters. Grain yield was positively correlated with 1000-kernel weight, test weight, and hardness and negatively correlated with protein ratio. Biomass at Z35 positively affected grain yield. Protein ratio was positively correlated with days to heading and plant height and negatively correlated with 1000-kernel weight and test weight. Canopy temperature was measured at Z55 and Z75 plant growth stages and there was negative relation with days to heading, plant height and protein ratio and positive relation with test weight at Z55. Biomass at Z35 growth stage had positive effect on grain yield, plant height, and protein ratio. Chlorophyll content had significantly effect on test weight. Biomass at Z25 and Z35 growth stage had positive effect on protein ratio and hardness.

Keywords**:** triticale, genotypes, yield, quality, agronomic characters

Introduction

The global warming is a major challenge for crop production. Every year temperature is rising. Also within year fluctuations in temperature is more in recent years. Under such circumstances, only resistance genotype is a solution for crop production (Suresh et al. 2018). Triticale (x *Triticosecale* Wittmack) is one of the most successful man-made cereals and was synthetized to obtain a cereal that combines the unique grain quality of its wheat (*Triticum* ssp.) parent with tolerance to abiotic and biotic stresses of the rye (*Secale* spp.) parent. It was found to have superior tolerance to low nutrient availability, drought, frost, soil acidity, aluminium and other element toxicities and salinity. Triticale has gained importance as an alternative crop to solve the nutritional problems of the rapidly increasing world population. Triticale gains the yield potential of durum wheat and adaptation of rye to cold, drought and marginal soil conditions in itself. It is also known that triticale is resistant to many diseases and pests (Çarıkçı et al. 2017). Also, triticale combines high plant productivity and grain yield (Royo *et al.*, 1999). The forage production and silage yield as well as the quality of hexaploid triticales, both as a monocrop and in small grain mixtures, have been reported to be favorable in comparison with other small grains (Erekul and Kohn, 2006; Juskiw et al. 2000; Sun et al. 1996; Rao et al. 2000). Triticale has genes for abiotic stress tolerance as most of the genotypes have shown very low heat susceptibility index (HIS) values for all the traits. Triticale has proved to be a good gene pool of abiotic stress tolerant genes (Suresh et al. 2018).

Triticale which possesses the yield potential of durum wheat and adaptation of rye to cold, drought and marginal soil conditions, has gained importance as an alternative crop to solve the nutritional problems of the rapidly increasing world population. **.** It is also known that triticale is resistant to many diseases and pests (Varghese et al. 1996). Triticale is, in general, more tolerant to environmental stresses than are wheat and barley (Jessop, 1996). The increased acceptance and production of triticale will depend on obtaining information on the extent of genetic diversity available and on the response of triticale genotypes to a wide range of environmental conditions. It is widely accepted that information regarding germplasm diversity and genetic relatedness among elite breeding material is a fundamental element in plant breeding (Siddiqui, 1994). The performance of the triticale cultivars under both normal and drought stress conditions was superior to that of wheat cultivars. The drought tolerance superiority of triticale cultivars under water-restricted conditions could be associated with their lower flag leaf angle, lower leaf area and lower number of stomata (Lonbani and Arzani, 2011). The objectives of the present study were to investigate the performance of the triticale genotype in Trakya region and to compare them with those under normal field conditions using morpho-physiological and agronomical traits.

Materials and Methods

The experiment was carried out to determine the yield and agronomic performance of some triticale genotypes in Trakya region, Turkey. This research was established with 16 genotypes in completely randomized blocks experimental design with 4 replications in Edirne in 2014-2015 and 2015-2016 growing seasons. Each plot had 6 meter long, 6 rows, spaced 0.17 meters apart. A seed rate of 500 seeds m^2 was used. In the research grain yield, plant height, days to heading, lodging resistance, winter kill, 1000-kernel weights, test weight, protein ratio and hardness and relationships between these characters were investigated. Grain yield, days to heading, plant height, 1000-kernel weights and test weight, (Blakeney et al. 2009), protein ratio, grain hardness (Köksel et al. 2000; Perten H. 1990; Anonymous, 2002; Anonymous, 1990; Blackman and Payne, 1987) were investigated.

To determination of the regression equations (R^2) were calculated (Finlay and Wilkinson, 1963; Eberhart and Russell, 1969). Also, regression graphs are used to predict adaptability of genotypes. Data were analysed statistically for analysis of variance method as described by Gomez and Gomez (1984). The significance of differences among means was compared by using Least Significant Difference (L.S.D. at a 5%) test (Kalaycı, 2005). Stability analysis of 5 wheat cultivars for all traits was also done using the model proposed by Eberhart and Russel (1966). The effect of the year and genotypes effect based on parameters and correlations between the quality parameters were determined by Pearson's correlation analysis.

Results

Combined analysis of variance across two growing seasons revealed various variation among years and Triticale cultivars for yield, days to heading, plant height and quality characters (Table 2 and 3). According to the results significant differences were found among genotypes in terms of grain yield. During the season of 2014-2015 the mean grain yield was in the range of 488.1- 672.8 kg/da, and mean grain yield was 589.4 kg/da. During the season of 2015-2016 the grain yield per hectare of triticale genotypes ranged from 5441 to 8483 kg/ha, and mean yield was 672.0 kg/da. Averaged across years and genotypes the overall Mean yield of the genotypes was 630.7 kg/da (Table 2). The year had a significant effect on both quantity and the quality of yield in the different triticale genotypes. In 2015-2016 mean yield was higher than first year. Based on mean value of both years Entry 11 had higher gran yield with 737.8 kg/da and followed by entry 15 and entry 16.

Based on the mean days to heading, genotypes showed statistically significant ($p<0.01$) differences. The late heading was in Focus while G9 and TVD18-2013 were the early genotypes. Plant height is very important character due to lodging resistance. Plant height ranged between 100.0 cm and 135.0 cm in genotypes. Short plant height was scaled in G16 with 100 cm, and followed by G13 and TVD18-2013. The mean plant height was 118.4 cm. For lodging resistance 1-9 scale was used where 1 means very resistance to lodging and 9 very susceptible. Based on lodging resistance score G16, Focus, G8, G11 and G15 were tolerant to lodging.

Test weight is the weight of a specific volume of grain and is an indication of the bulk density of the grain. It reflects the extent of grain filling and the potential for flour yield (Blakeney et al. 2009). Based on mean value of the genotypes, the highest mean values of test weight were determined in G13 (74.7 kg), G14 (74.0 kg) and cultivar Karma 2000 (73.9 kg) while the lowest values were in genotypes Focus, G8, and G9. The highest mean values of 1000-kernel weight were observed in G15 (43.4 g), G12 (43.3 g) and G11 (42.4 g) while the lowest values were obtained in Focus and MIKHAM-2002 cultivars.

Results revealed significant differences ($p<0.01$) in protein content among growing years and triticale genotypes. Protein content of the genotypes varied between 10.2% and 12.7%, mean protein content was 11.8%. Hardness in triticale genotypes varied from 40.5 to 55.5 and mean was 44.8 (Table 3).

The effect of the year and genotypes effect based on parameters and correlations between the investigated parameters were determined by Pearson's correlation analysis. Correlation coefficients among the tested characters in 2014-2015 growing season are given Table 4. Different relations were found among investigated parameters. Grain yield was positively correlated with 1000-kernel weight (r=0.506), and test weight (r=0.154) but negatively correlated with protein ratio (r=-0.433). Biomass at Z35 positively affected grain yield. There was negative relation between winter kill with days to heading (r=-0.842**) and plant height (r=-0.603*). Genotypes damaged by winter kill had short plant height and reduced days to heading. Also, winter kill caused an increase in canopy temperature and chlorophyll content in genotypes. Cold damage caused sparse plant stand on plots and increased 1000-kernel weight in genotypes. Protein ratio was positively correlated with days to heading and plant height but negatively correlated with 1000-kernel weight and test weight. Cold damage reduced biomass therefore negative relation was found between cold damage and NDVI (Z35) (r=-0.788**).

Days to heading was negatively correlated with lodging resistance (r=-0.585*), test weight (r=-0.324), canopy temperature at Z55 (r=-0.716**), and chlorophyll content (r=-0.519*). Days to heading was positively correlated with plant height (r=0.587*), protein ratio (r=0.334), and NDVI at Z35 (r=0.782**). There was negative association between plant height with hardness, and CT at Z55 and Z75. Plant height was positively related with NDVI at Z35 (r=-0.716**). Hardness in grain had negative correlation with plant height (r=-0.458) and lodging (r=-0.246). Canopy temperature was measured at Z55 and Z75 plant growth stages and there were negative relation with days to heading, plant height and protein ratio and positive relation with lodging and test weight at Z55. Biomass at Z35 growth stage had positive effect on grain yield (r=0.239), plant height (r=0.620*), and protein ratio (r=0.457). The higher biomass at Z35 growth stage caused various levels of reductions in 1000-kernel weight and test weight. Chlorophyll content had significant positive effect on test weight (r=0.686). Tall genotypes had higher test weight and protein ratio and lower 1000-kernel weight, canopy temperature.

Correlation coefficients among the tested characters in 2015-2016 growing season are given Table 5. Different relations were found among investigated parameters. Grain yield was positively correlated with 1000-kernel weight (r=0.832**), test weight (r=0.632**), and hardness (r=0.382). There was negative relation between plant height with grain yield and winter kill. It means that winter type genotypes had higher grain yield than facultative types. 1000-kernel weight was negatively correlated with days to heading (r=-0.469) and plant height (r=-0.829**). There was negative relation between test weight and days to heading (r=-0.736**) and plant height (r=-0.489). Hardness in grain was negatively correlated with plant height (r=-0.572*) and lodging (r=-0.334), while there was positive correlation with TKW (r=0.333), and protein ratio (r=0.532*). Biomass (NDVI) was scaled at Z25 and Z35 plant growth stages. The higher biomass during Z25 and Z35 growth stage had negative effect and caused various decline on grain yield (r=-0.311; r=-0.615*) because of the cold damage. Higher biomass at Z25 and Z30 growth stage led to various level of reductions in 1000-kernel weight and test weight. Also, there was positive correlation between biomass at Z25 and Z35 growth stage and protein ratio and hardness. Facultative type genotypes had higher flag leaf area and due to cold damage negative relation between grain yield and flag leaf area was found . Tall genotypes had higher biomass and significant positive relation was found between flag leaf area and plant height (r=0.823**). Genotypes which have higher flag leaf have been lower TKW and test weight.

In 2014-205 cropping season in triticale genotypes some parameters were investigated and some relation showed (Figure 1). Lower temperature caused cold damage in genotypes, reduced plant height and increased CT at Z55. So positive relation was found between cold damage and CT (Z55) (R^2=0.457) and negative relation with plant height (R^2=-0.363). Chlorophyll content (SPAD Z55) had a positive effect on test weight (R^2=0.470). Canopy temperature at

Z75 plant growth phase led to reduced test weight in genotypes (R^2=0.397) (Figure 1).

In 2015-2016 cropping season in triticale genotypes some parameters were investigated and some relation showed (Figure 2). Grain yield was positively associated with test weight (R^2=0.691) and negatively associated with plant height (R^2=-0.679). Flag leaf area had positive correlation with biomass (NDVI Z35) (R^2=0.547) and negative correlation interaction with 1000-kernel weight (R^2=-0.602) (Figure 2). Lower temperature caused cold damage in genotypes and reduced plant biomass. Due to reduced biomass, negative association was found between winter kill and NDVI (Z35) (R^2=-0.565) and flag leaf area in triticale genotypes (R^2=-0.616).

Conclusion

According to the results significant differences were found among genotypes in terms of grain yield and other parameters. In 2015-2016 mean yield was higher than 2014-2015 cycles. Correlation coefficients among the tested characters showed that there were various relations among investigated parameters. Grain yield was positively correlated with 1000-kernel weight, and negatively correlated with protein ratio. Biomass at Z35 positively affected grain yield. Protein ratio was positively correlated with days of heading and plant height but negatively correlated with 1000-kernel weight and test weight. Days to heading was negatively correlated with lodging, test weight, canopy temperature at Z55, and chlorophyll content. Canopy temperature was measured at Z55 and Z75 plant growth stages and there was negative relation with days to heading, plant height and protein ratio and positive relation with lodging and test weight at Z55 plant phase. Biomass at Z35 growth stage had positive effect on grain yield, plant height, and protein ratio. The higher biomass at Z35 growth stage caused various levels of reductions in 1000-kernel weight and test weight. Chlorophyll content had significantly affect on test weight. Correlation coefficients among the tested characters in 2015-2016 growing season showed various relations among investigated parameters. Grain yield was positively correlated with 1000-kernel weight, test weight, and hardness. 1000-kernel weight was negatively correlated with days to heading and plant height. There was negative relation between test weight and days to heading and plant height. Biomass at Z25 and Z35 growth stage had positive effect on protein ratio and hardness.

Table 1. Rainfall mean and maximum temperature in 2014-2015 and 2015-2016.

Months	**Rainfall (mm)**		**Max. temperature (°C)**		**Mean temperature (°C)**	
	2014-2015	**2015-2016**	**2014-2015**	**2015-2016**	**2014-2015**	**2015-2016**
October	121.8	52.6	26.8	26.2	12.8	15.6
November	43.2	26.2	23.4	25.1	11.0	13.5
December	111.3	0.3	12.1	14.9	2.7	5.5
January	42.2	114.8	17.3	18.4	5.5	2.8
February	68.6	91.4	20.2	22.2	7.6	9.2
March	67.8	54.8	23.7	23.3	10.1	10.2
April	44.4	116.1	25.5	31.8	13.6	15.5
May	45.2	81.4	32.1	32.2	18.6	17.4
June	31.0	10.2	33.6	38.4	22.9	23.9
Total	575.5	547.8				
Average			23.8	25.8	11.6	12.6

Table 2. Mean grain yield of the genotypes based on two cropping seasons.

Entry	**Genotypes**	**Years**		**Mean yield (kg/da)**
		2014-2015	2015-2016	
1	Karma 2000	581.0 c-f	613.9 ef	597.4 e-h
2	Presto	570.3 def	617.8 ef	594.0 fgh
3	Tatlıcak 97	648.6 ab	638.3 de	643.4 b-e
4	Focus	602.5 bcd	547.6 f	575.1 hı
5	MİKHAM 2002	569.6 def	598.3 ef	584.0 ghı
6	TVD18-2013	600.9 bcd	660.3 de	630.6 c-g
7	CTWS95WM00095S-7FM-030FM-3FM-0FM-0FM	542.9 ef	711.3 bcd	627.1 d-g
8	CTWW95WM00004S-2WM-030WM-2WM-0WM-0WM	528.8 fg	544.1 f	536.4 ı
9	CTSS00B00197S-0M-4Y-010M-3Y-4M-0Y	586.9 cde	666.0 cde	626.5 d-g
10	CTSS01B00020S-3M-9Y-3Y-2M-0Y	488.1 g	701.6 bcd	594.8 fgh
11	CTSS01B00022S-5M-8Y-2Y-4M-0Y	627.3 abc	848.3 a	737.8 a
12	CTSS00Y00230S-0Y-0M-10Y-6M-3Y-4M-0Y	672.8 a	679.4 cde	676.1 bc
13	CTSS04Y00163S-102Y-06M-06Y-2M-3Y-0M	555.5 def	711.3 bcd	633.4 c-f
14	CTSS04Y00163S-102Y-06M-06Y-5M-1Y-0M	630.6 abc	704.7 bcd	667.6 bcd
15	CTSS03Y00089T-050TOPY-19M-4Y-06Y-1M-1Y-0M	625.2 abc	744.3 bc	684.8 b
16	CTSS03Y00089T-050TOPY-19M-4Y-06Y-1M-2Y-0M	599.9 bcd	765.6 b	682.7 b
Mean		589.4	672.0	630.7
L.S.D (0.05)		53.1**	81.4**	47.7**
C.V (%)		6.3	8.5	7.6

Table 3. Mean value of the investigated parameters of the genotypes.

Entry	Genotypes	WK	DH	PH	LOD	TKW	TW	PRT	HARD
1	Karma 2000	1.5 cde	106.0 d	126.5 ab	5.5 cd	37.8 a-d	73.9 ab	12.2 ab	43.0 cde
2	Presto	2.0 b-e	105.5 de	131.5 ab	5.0 de	35.8 bcd	72.8 abc	12.4 ab	43.0 cde
3	Tatlıcak 97	1.0 de	116.0 ab	135.0 a	5.5 cd	34.5 d	71.7 abc	12.2 ab	42.5 def
4	Focus	0.5 e	120.5 a	129.5 ab	4.0 ef	33.8 d	61.9 d	11.3 b-e	41.5 ef
5	MİKHAM-2002	2.0 b-e	103.5 def	135.0 a	7.5 ab	33.5 d	72.6 abc	12.7 a	43.5 cde
6	TVD18-2013	4.0 a	101.0 ef	107.5 de	7.5 ab	39.2 a-d	71.7 abc	11.8 abc	45.0 bc
7	G7	2.5 a-d	103.0 def	115.5 cd	6.5 bc	36.3 bcd	72.7 abc	12.4 ab	46.5 b
8	G8	0.5 e	111.5 bc	128.0 ab	4.0 ef	34.6 cd	68.6 c	12.7 a	44.5 bcd
9	G9	3.0 abc	100.0 f	113.5 cd	7.0 b	41.2 ab	69.5 bc	12.6 a	44.5 bcd
10	G10	4.0 a	105.5 de	115.5 cd	5.5 cd	37.7 a-d	73.9 ab	11.6 a-d	42.5 def
11	G11	3.5 ab	107.0 cd	109.5 de	4.5 de	42.4 ab	73.3 abc	11.6 a-d	42.0 ef
12	G12	3.0 abc	105.0 de	121.5 bc	5.0 de	43.3 a	71.7 abc	10.2 e	40.5 f
13	G13	3.5 ab	103.0 def	106.0 de	8.5 a	39.2 a-d	74.7 a	10.5 de	43.5 cde
14	G14	2.5 a-d	105.5 de	110.0 de	7.0 b	37.9 a-d	74.0 ab	10.8 cde	44.5 bcd
15	G15	3.0 abc	105.5 de	109.5 de	4.5 de	43.4 a	71.4 abc	12.1 ab	54.5 a
16	G16	3.0 abc	106.0 d	100.0 e	3.0 f	41.1 abc	71.1 abc	12.2 ab	55.5 a
Mean		2.5	106.5	118.4	5.6	38.2	71.6	11.8	44.8
C.V (%)		29.2	2.1	4.0	8.6	8.1	3.1	5.1	2.3
L.S.D (0.05)		1.53**	4.79**	10.11**	1.04**	6.62ns	4.72**	1.29**	2.25**
F year		**	**	ns	**	**	**	**	**

Note: Significant at **: P<0.01; *: P<0.05; GY: Grain yield (kg da-1), DH: Days to heading, PH: Plant height (cm), LOD: Lodging resistance (1-9), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), HARD: Hardness (PSI)

Table 4. Correlation coefficients among yield, quality and physiological characters in 2014-2015 growing years.

Traits	GY	WK	DH	PH	LOD	TKW	TW	PRT	HARD	Z55 CT	Z75 CT	Z55SPAD
WK	0.035											
DH	0.008	-0.842**										
PH	0.093	-0.603*	0.587*									
LOD	-0.152	0.417	-0.585*	-0.229								
TKW	0.506	0.364	-0.192	-0.253	-0.397							
TW	0.154	0.135	-0.324	0.203	0.301	0.093						
PRT	-0.433	-0.483	0.334	0.387	-0.262	-0.444	-0.307					
HARD	0.047	0.041	-0.144	-0.458	-0.246	0.333	-0.107	0.182				
Z55 CT	-0.007	0.676**	-0.716**	-0.407	0.414	0.018	0.440	-0.325	-0.053			
Z75 CT	0.051	0.216	-0.107	-0.340	-0.148	0.110	-0.631**	0.249	0.332	0.014		
Z55SPAD	-0.164	0.491	-0.519*	0.054	0.228	0.261	0.686**	-0.117	-0.175	0.464	-0.420	
Z35 NDVI	0.239	-0.788**	0.782**	0.620*	-0.420	-0.163	-0.289	0.457	-0.035	-0.616*	0.228	-0.581*

Note: Significant at **: P<0.01; *: P<0.05; GY: Grain yield (kg/da), WK: Winter kill (0-9), DH: Days to heading, PH: Plant height (cm), LOD: Lodging resistance (1-9), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), HARD: Hardness (PSI), CT: Canopy temperature (°C), SPAD: Chlorophyll content, NDVI: Normalized difference vegetative index

Table 5. Correlation coefficients among yield, quality and physiological characters in 2015-2016 growing years

Traits	GY	WK	DH	PH	LOD	TKW	TW	PRT	HARD	Z25 NDVI	Z35 NDVI
WK	0.749**										
DH	-0.313	-0.549*									
PH	-0.824**	-0.786**	0.323								
LOD	-0.149	0.204	-0.500*	0.123							
TKW	0.832**	0.773**	-0.469	-0.829**	-0.043						
TW	0.632**	0.741**	-0.736**	-0.489	0.391	0.508*					
PRT	0.021	-0.010	-0.426	0.020	0.039	-0.010	0.245				
HARD	0.382	0.281	-0.255	-0.572*	-0.334	0.333	0.124	0.523*			
Z25 NDVI	-0.311	-0.609*	0.460*	0.286	-0.156	-0.498*	-0.498*	0.349	0.200		
Z35 NDVI	-0.615*	-0.752**	0.511*	0.477	-0.268	-0.668**	-0.685**	0.329	0.172	0.829**	
FLA	-0.832**	-0.785**	0.300	0.823**	-0.076	-0.776**	-0.627**	0.332	-0.129	0.556*	0.740**

Note: Significant at **: P<0.01; *: P<0.05; GY: Grain yield (kg/da), WK: Winter kill (0-9), DH: Days to heading, PH: Plant height (cm), LOD: Lodging resistance (1-9), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), HARD: Hardness (PSI), NDVI: Normalized difference vegetative index, FLA: Flag leaf area (cm^2)

Figure 1. Some pairwise relationship among investigated parameters in 2014-2015 cycles.

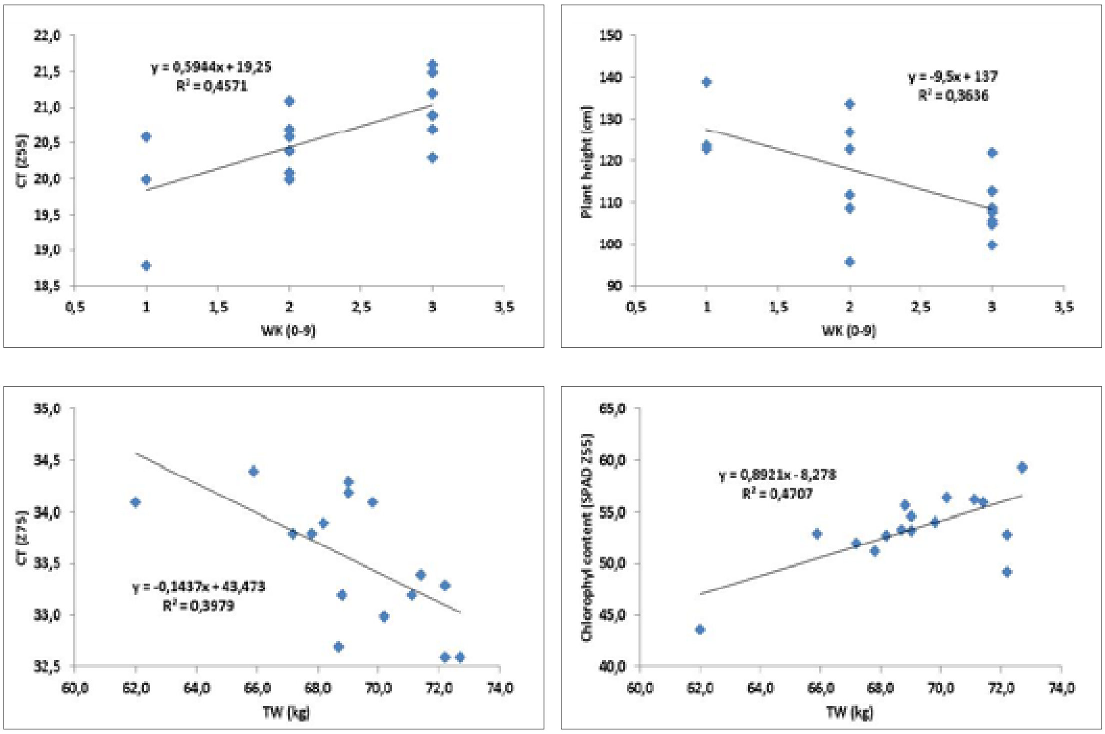
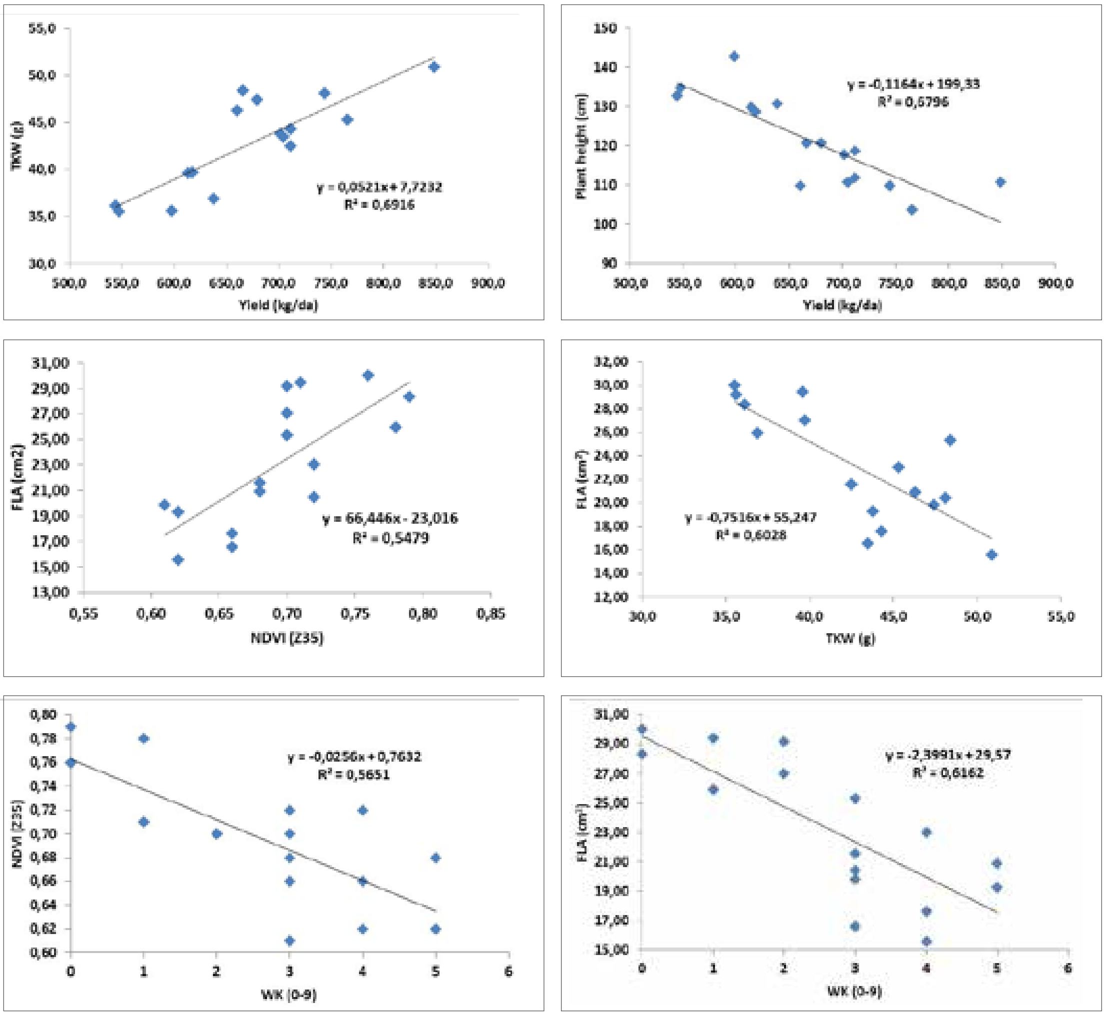


Figure 2. Some pairwise relationship among investigated parameters in 2015-2016 cycles.



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