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Stability of Quality Parameters of Bread Wheat (*Triticum aestivum* L.) Genotypes Under Drought Stress Condition

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ABSTRACT

Change in amount and distribution of precipitation during grain filling period is one of the major limiting stress factors of wheat quality and yield in Trakya region. Identification of the genetic stability and development of good quality cultivars are very important issues for wheat production in the region. In the present research, it was investigated that the effects of various levels of drought stress condition at different plant growth phase in quality parameters of bread wheat genotypes. This research was conducted in 2008-09 and 2009-2010 growing seasons. The experiment was established with 15 genotypes in randomised complete block design with 3 replications. Drought treatments were on the main parcel and genotypes on the sup-plots. In the research; grain yield, 1000-kernel weight, test weight, protein content, hardness, wet gluten, gluten index and sedimentation value and also correlation among these characters with stability parameters were investigated in wheat genotypes. According to results of the research; protein content, wet gluten content, hardness and sedimentation were negatively affected under irrigation condition during grain filling phase. Drought stress condition at GS51-94 had a positive effect on protein content, wet gluten and hardness. The highest test weight and 1000-kernel weight was determined under irrigation conditions. Non-treatment condition had a significant effect on sedimentation value. Based on stability parameters genotypes Pehlivan, Aldane and BBVD7 well adapted to overall environmental conditions for 1000-kernel weight. For test weight cultivars Gelibolu, Kate A-1, and Pehlivan were well adaptable to overall environmental conditions. Aldane had higher sedimentation under fertile environmental condition. Evaluation of quality parameters and drought application Aldane was the best performing cultivar and limitation of irrigation during grain filling period had a positive effect on quality parameters except 1000-kernel weight and test weight.

Keywords**:** Bread wheat, quality parameter, drought treatments, stability parameters

Introduction

Wheat is grown under a wide range of environmental conditions where climatic factors such as temperature and moisture combined with agronomic inputs vary with location and year. The manifestation of those effects in the developing kernel impacts the value of the crop by influencing yield, grain characteristics and flour quality. Within the kernel, complex programs of gene expression control physiological and biochemical processes, including water uptake and kernel expansion, accumulation of starch and protein, maturation and desiccation. A better understanding of the genetic program of grain development and the influence of specific environmental variables on that program is required to minimize the effects of environment on yield and quality (Altenbach *et al.* 2003). Climate change is gradually increasing the average world temperature, while also reducing water resources and causing agricultural lands to become drier. Parallel to these negative developments, the world population is rapidly rising while the area of agricultural/arable lands remain constant. Many scientists believe that the inability to produce enough food to feed the increasing world population will inevitably lead to food wars. In this context, it is imperative to increase yield per unit area by developing varieties that are more resistant to biotic and abiotic stresses (Yıldırım *et al*. 2017). Environmental factors play a main role in the expression of genotype characteristics (Peterson *et al.* 1998). In wheat, grain yield and baking quality are dependent on the environment, genetic factors and the interaction between them (Yan and Holland 2010; Coventry *et al.* 2011). Environmental conditions during anthesis and grain filling are important factors in the baking quality classification of wheat (Jiang *et al.* 2009). The weather conditions during the growing season, especially the rainfall quantity and temperature, have a substantial influence on the plant metabolic processes, and thus on wheat quality (Balla *et al.* 2011). A measure of the relative yield stability of the durum wheat genotypes under a wide range of environmental conditions is essential for determining efficiency a genotype evaluation program. Hence, a number of statistical procedures have been developed to enhance breeder's understanding of genotype-environment interaction (GEI), stability of genotypes and their relationships (Akçura *et al.* 2009). Limited water condition, drought, is one of the most important abiotic stress factors. Depending on the season, drought can limit crop production seriously. Plant responses to drought stress are complex mechanisms which include molecular changes and extend to the whole plant metabolism influencing the morphology and phenology of plants (Blum 1996; Chaves *et al.* 2003; Condon *et al.* 2004). Stress during the grain-filling stage may have an even greater effect on wheat, as it may cause reduced grain-filling (Wardlaw and Moncur 1995). Drought is the main factor limiting the productivity of crops in Mediterranean areas. The introduction of physiological traits into crops that improve their tolerance to drought is necessary if yields under these conditions are to be efficiently improved. Variability is important aiming to obtain drought-tolerant genotypes via the optimization of traits (Gonzales *et al.* 2010). Evaluation of genotypes across diverse environments and over several years is needed in order to identify spatially and temporally stable genotypes that could be recommended for release as new cultivars and/or for use in the breeding programs (Sharma *et al*. 2010).

In Trakya region winter and facultative type of bread wheat cultivars are grown. The amount of the precipitation during growing season (from October to June) is enough for wheat production, but the distribution of this precipitation is not regular especially in April, May and June. In this period, less amount and fluctuation of precipitation could cause lower grain yield and quality. Therefore, development of the stable genotypes for grain quality under various environmental conditions is very important issue in the region. This study was carried out to assess some quality parameters of some genotypes under various drought stress condition and, also to determine stability parameters of the bread wheat genotypes.

Materials and Methods

The research carried out at experimental field of Trakya Agricultural Research Institution in Edirne (Turkey), during 2008-2009 and 2009-2010 growing seasons. In this experiment, a total of 15 bread wheat genotypes viz., Kate A-1, Gelibolu, Pehlivan, Tekirdağ, Selimiye, Aldane, Bereket, Flamura-85 and Golia and 6 advanced lines (BBVD7, ÖVD26-07, ÖVD2/21-07, ÖVD2/27-07, EBVD24-07, BBVD21-07) were used. The experiment was set up in a randomized complete block design (RCBD) in split block design with 3 replicated. Each plot was 5 meter long with 6 rows, spaced 0.17 meters apart. A seed rate of 500 seeds per m^2 was used, and sowing was done by an experimental drill. The plots were fertilized with 40 kg P_2O_5 ha^{-1} at planting and 150 kg N ha^{-1} in three splits i.e. at planting, tillering and stem elongation phase. For weed control chemical was used. Drought applications and genotypes were main plot and sub-plot, respectively. The Zadoks Decimal Code (GS) was used to describe plant growth stages (Zadoks *et al*. 1974). The described plant development stages are; DS1: Drought stress applied from GS31 (stem starts to elongate) to GS51 (10% of spikes visible), DS2: Drought stress applied from GS51 (10% of spikes visible) to GS94 (over-ripe, straw brittle), DS3: Non-stress treatment (irrigation at three times; shooting, heading and grain filling phase), DS4: Non-treatment, and DS5: Drought stress applied from GS31 (stem starts to elongate) to GS94 (over-ripe, straw brittle).

In the research; thousand kernel weights, test weight (Blakeney *et al.* 2009; Köksel *et al.* 2000), protein content (Perten, 1990; % NIR AACC 39-10), sedimentation, hardness, wet gluten and gluten index (Atlı *et al.* 1993; Elgün *et al.* 2001; Köksel *et al.* 2000; Pena 2008) were investigated. The quality analysis of zeleny sedimentation test and wet gluten content were determined according to ICC standard methods No. 116/1 and 106/2, respectively (Anonymous, 1972; Anonymous, 1984). Several methods have been developed to analyse genotype x environment interaction (Lin *et al*. 1986). For stability of the genotypes the mean yield (x), determinations coefficient (R^2), deviation from regression (S^2d), intercept value (a), regression coefficient (b) were calculated (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Tai, 1971; Teich, 1983). In the study, regression graphs are used to predict adaptability of genotypes. The analysis of variance for each character was measured followed by LSD to test significance difference between means (Steel and Torrie 1980), and simple correlation coefficient and path analysis, which is the direct and indirect effects of each character was performed as per method of Dewey and Lu (1959). Regression analysis was done to determine relation between investigated characters. Correlations between all characteristics were calculated. Data variance analyses were performed by using J.M.P. 5.0.1. The significance of differences among means was compared by using Least Significant Difference (L.S.D. at a 5%) test (Gomez and Gomez, 1984; Kalaycı, 2005).

Some climate parameters for research field are provided in Table 1. The average temperature in 2008-09 growing years is 12.2°C, and 2009-10 is 11.3°C. The average temperatures during the first and second growing years of the study were lower than the long-term average (13.6°C). Annual average relative humidity of the 2008-09 growing year is 75.2% and of the 2009-10 growing year is 81.5%. Distribution of the precipitation within the year also significantly varied between the years. Especially, the amount of precipitation during the booting and heading growth stages of the first and second year (April and May) were relatively lower than the long-term average. In 2008-09, the total rainfall was 327.1 mm, whereas the total rainfall for the second years of the study was 536.5 mm. The long-term average monthly rainfall is 573.1 mm. During the first years of the study, the average rainfall was lower than the long-term and second year of the study average (Table 1).

Results and Discussion

The analysis variance for quality parameters were performed and given in Table 2 and 3. The results of variance analyses showed that there were significant differences ($p<0.01$) among genotypes, treatments and genotypes x treatments interaction (Table 2 and 3). The results of variance analyses showed that there were significant differences ($P<0.01$) among genotypes and treatments for investigated quality parameters under both stress and non-stress environments. Bereket had higher grain yield with 658.8 kg da^{-1} and, followed by BBVD7 and Kate A-1. The mean values of the genotypes varied between 29.7-43.5 g for 1000-kernel weight, 73.6-83.2 kg hl^{-1} for test weight, 11.1-13.3% for protein content, 28.5-37.0% for gluten value, 34.3-56.0% for sedimentation, 68.9-95.3% for gluten index, 47.0-58.6 for hardness (Table 4). Analysis of variance showed that there was higher genetic variability among the genotypes. According to results mean test weight of the genotypes was 79.7 kg. Limited water conditions decreased test weight and mean test weight was 81.2 kg under non-stress conditions, and 77.6 kg under fully-stress condition. Cultivar Selimiye had higher test weight with 83.19 kg followed by cv. Pehlivan with 81.63 kg. Cultivar Pehlivan had higher 1000-kernel weight with 43.56 g. Protein content varied from 11.3% to 12.5% among treatment. Based on genotypes BBVD21-07 had the highest protein content with 13.3% in and followed by cv. Aldane with 12.7%. Protein content of the genotypes decreased under fully-stress and non-stress conditions.

The mean gluten value was 31.8% in genotypes, and the highest gluten content was determined in BBVD21-07 with 37.0%, followed by ÖVD2/27-07 and Pehlivan. The highest protein content and wet gluten content was determined under drought stress conditions which drought stress were applied from heading to physiological maturity stage (GS51-94). The highest sedimentation value was obtained with 56.0 ml in cultivar Aldane. Highly significant differences for drought application indicated their influences on protein content at different environments. 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; Arya *et al.* 2014). In contrast, protein quality is largely under genetic control (Lerner *et al.* 2006; Rogers *et al.* 2006).

A genotype having stable grain quality across the environment condition is very important in wheat production. Genotype x environment interaction is a mainly issue for plant breeders in improving high-quality, stable genotypes across variable environments. Stability parameters based on test weight showed that all the genotypes were significantly different. Tekirdağ and Pehlivan were very stable cultivar for test weight due to their highest coefficient of determinations (R^2). There was high variation in regression coefficients (b) values and optimum b value was determined in cultivars Pehlivan and Tekirdağ. The highest intercept values (a) were determined in cultivars Golia, Aldane and Selimiye. The highest intercept value indicated that these cultivars were higher in grain quality both under fertile and less fertile environment condition. According to all stability parameters, it could be seen that cultivar Pehlivan was very stable for the test weight with higher determinations coefficient (R^2), positive intercept value (a) and suitable regression coefficient (b) with close to 1 (Table 5).

Regression coefficient for test weight and thousand kernel weights were determined and given in Table 5 and Figure 1. For test weight, it was determined that genotypes Pehlivan, Gelibolu, Kate A-1 and G11 (ÖVD26-07) were well adaptable to all environmental conditions. Cultivar Selimiye and Aldane had higher test weight under unfavourable environment conditions. Cultivars Tekirdağ, Bereket, G13 and Flamura-85 were medium adaptable to all environment conditions. For 1000-kernel weight, it was determined that cultivar Selimiye well adaptable to favorable environmental conditions. Cultivars Aldane, Pehlivan and G9 (BBVD7) had higher test weight under all environment condition. Tekirdağ, Gelibolu and G11 (ÖVD26-07) were medium adaptable into favorable environment conditions (Fig.1).

Stability parameters of the protein content and wet gluten of the genotypes showed that all stability parameters were significantly different. For protein content Gelibolu, Pehlivan, Tekirdağ, Bereket and, BBVD24-07 were very stable genotypes due to higher determinations coefficient (R^2). There was highly variation in regression coefficients (b) values varied from 0.48 to 1.60, and cultivars Pehlivan and Gelibolu had optimum b value. The highest intercept values (a) were determined in cultivars Golia, Selimiye, Aldane and Tekirdağ. The highest intercept value indicates that these cultivars had higher protein content under both fertile and less fertile environment conditions (Table 6).

For wet gluten content, cultivars Bereket, Gelibolu, and Pehlivan were very stable due to higher determinations coefficient (R^2). There was highly variation in regression coefficients (b) values varied from 0.27 to 1.81, and optimum b value was determined in G13 (ÖVD2/27-07) and Kate A-1. The highest intercept values (a) were determined in genotypes Aldane, BBVD7, G12 (ÖVD2/21-07) and Tekirdağ (Table 6).

Regression coefficient for protein content and gluten value were determined and given in Figure 2 and Table 6. It was determined that cultivar Flamura-85 had higher protein content under all environmental conditions. Cultivars Aldane, Tekirdağ, and Golia had higher protein content under unfertile environment conditions. For gluten content cultivar Pehlivan, Kate A-1, G13 (ÖVD2/27-07) and G9 (BBVD7) had higher gluten value. Aldanewas, the best performing variety according to its gluten value under unfertile environment conditions. Genotypes Flamura-85, Selimiye and G11 (ÖVD26-07) were medium adaptable in terms of their gluten value under all environment conditions. Stability parameters based on sedimentation and hardness of the genotypes showed that all stability parameters were significantly different (Table 7). For sedimentation genotypes EBVD24-07, ÖVD2/21-07 and Gelibolu was very stable for their highest determinations coefficient (R^2). Cultivars Pehlivan, Bereket and Golia had optimum b value. The highest intercept values (a) were determined in cultivars Tekirdağ, Selimiye, ÖVD2/27-07, and Kate A-1.Regression coefficients for sedimentation and grain hardness were determined and given in Figure 3 and Table 7. It was determined that Flamura-85 was well adapted to all environmental conditions. Cultivars Bereket, Gelibolu and Pehlivan were medium adaptable to all environment conditions. Selimiye and Tekirdağ cultivar had higher sedimentation under unfavourable environment conditions.

Correlation analysis was done in order to determine relationships among quality parameters based on stability parameters. Using Pearson's correlation analysis, a significant ($P<0.05$) and negatively correlation was found between mean test weightwith deviation from regression (S^2d) (R^2=-0.573*), regression coefficient (b) (R^2=-0.573*), and positively associated with intercept value (a) (R^2=0.865**). Based on protein content correlation was negative between determination coefficient (R^2) with deviation from regression (S^2d), and intercept value (a). Correlations coefficient of the stability parameters showed that mean of grain hardness was statistically significant ($P<0.05$) with deviation from regression (S^2d) (R^2=0.515). Based on TKW, gluten value and sedimentation determination coefficient (R^2) was negatively correlated with S^2d and intercept value (a). Furthermore, mean sedimentation value was statistically significant and positively correlated with deviation from regression (R^2=0.578*), and negatively non-significant correlated with determinations coefficient (Table 8).

Conclusion

Environment conditions had a significant effect in quality of winter wheat genotypes. Non-stress condition or additional irrigation during grain filling phase negatively affected and reduced grain protein content, wet gluten content, hardness and sedimentation value of the genotypes. Non-irrigation condition from heading up to maturity stage had had positively effect on protein and gluten content. As expected the highest test weight and thousand kernels weight was determined under fully non-stress conditions from shooting up to maturity. The highest sedimentation was determined under non-treatment condition. According to stability of genotypes, Pehlivan, Aldane and BBVD7 well adapted to overall environmental condition for 1000-kernel weight. For test weight, cultivars Gelibolu, Kate A-1, and Pehlivan were suitable to overall environmental conditions. Under overall environmental conditions cultivar Flamura-85 had higher protein content. According to sedimentation Aldane was very suitable to fertile environmental conditions and, for wet gluten value cv. Selimiye and Flamura-85 were medium adapted to overall environmental conditions. According to result of the research based on quality parameters and drought application Aldane was the best performing cultivar and limitation of the irrigation during grain filling period resulted in positive effect and increased quality parameters except thousand kernel weight and test weight.

Table 1. Precipitation, humidity and temperature in 2008-2009 and 2009-2010 growing season

Months	2008-2009 growing season				2009-2010 growing season			
	Rainfall (mm)	Humidity (%)	Max. temp. (°C)	Average temp. (°C)	Rainfall (mm)	Humidity (%)	Max. temp. (°C)	Average temp. (°C)
October	17.0	72.6	26.5	14.9	112.6	82.3	28.9	15.1
November	29.2	77.8	18.3	15.3	51.7	89.7	22.7	9.7
December	35.6	82.2	20.4	6.4	93.4	89.7	19.6	7.3
January	48.6	87.8	17.5	6.5	59.6	85.2	20.3	2.5
February	83.2	81.3	13.5	5.2	107.0	88.1	20.3	5.9
March	44.1	77.5	17.9	7.8	47.6	81.9	22.2	7.7
April	15.8	68.8	25.9	12.3	17.8	76.0	24.9	12.7
May	27.7	66.1	32.1	19.1	16.0	68.6	33.6	18.1
June	25.9	62.5	36.4	22.6	30.8	72.3	38.7	22.5
Total/Mean	327.1	75.2	23.2	12.2	536.5	81.5	25.7	11.3

Data were obtained from the Turkish State Meteorological Service

Table 2. Combined analysis of variance for 15 wheat genotypes across five environments for quality parameters

Source	DF	TKW		TW		PRT		HARD	
		MS	F	MS	F	MS	F	MS	F
Year (Y)	1	1781.65	615.06**	0.07	0.12	18.93	29.52**	1447.22	1156.31**
Replication (Year)	4	0.85	0.29	0.33	0.55	1.35	2.11	4.41	3.52
Genotype (G)	14	541.38	186.89**	170.64	284.18**	9.89	15.42**	266.24	212.72**
Year*Genotype	14	114.40	39.49**	10.42	17.36**	2.11	3.29**	8.29	6.62**
Error	56	2.89	1.77	0.60	1.92	0.64	1.52	1.25	0.83
Treatment (T)	4	584.31	356.38**	184.37	590.34**	21.22	50.29**	61.92	41.10**
Year*Treatment	4	172.70	105.33**	141.85	454.19**	13.80	32.70**	16.72	11.10**
Genotype*Treatment	56	6.04	3.68**	2.14	6.86**	0.52	1.23	2.37	1.58*
Y*G*T	56	5.91	3.61**	1.37	4.38**	0.48	1.13	2.21	1.47*

Significant at *: $p<0.05$ and **: $p<0.01$. TKW: Thousand kernel weight (g), TW: Test weight (kg), PRT: Protein content (%), HARD: Hardness

Table 3. Combined analysis of variance for 15 wheat genotypes across five environments for quality parameters

Source	DF	SED		GLT		IND	
		MS	F	MS	F	MS	F
Year (Y)	1	12335.0	1303.01**	449.8	72.56**	21498.1	1070.92**
Replication (Year)	4	8.14	0.86	18.71	3.02	83.13	4.14
Genotype (G)	14	1050.45	110.96**	327.96	52.91**	4486.37	223.48**
Year*Genotype	14	88.11	9.31**	46.61	7.52**	437.89	21.81**
Error	56	9.47	1.59	6.20	1.26	20.07	1.32
Treatment (T)	4	348.31	58.48**	205.0	41.80**	187.16	12.35**
Year*Treatment	4	372.41	62.53**	182.82	37.28**	159.59	10.53**
Genotype*Treatment	56	17.65	2.96**	7.76	1.58**	37.77	2.49**
Y*G*T	56	19.03	3.20**	9.17	1.87**	46.66	3.08**

Significant at *: p<0.05 and **: p<0.01; SED: Sedimentation (ml), GLT: Wet Gluten (%), IND: Gluten index (%)

Table 4. Mean of yield and quality parameters and standard deviation of fifteen genotypes at five various environments

No	Genotype	GY	TKW	TW	PRT	HARD	SED	GLT	IND
1	Kate A-1	631.5±132.0	34.5±3.11	81.2±1.35	11.4±0.53	55.3± 0.78	41.2±2.24	33.8±1.87	72.9±3.68
2	Gelibolu	613.0±111.8	37.7±3.14	80.8±1.37	11.1±0.54	47.0± 0.88	41.3±2.27	24.6±1.86	95.3±1.19
3	Pehlivan	587.7±113.1	43.5±2.51	81.6±1.48	11.7±0.50	53.5± 0.82	41.6±2.39	34.7±1.75	72.6±2.01
4	Tekirdağ	594.5±102.7	38.8±3.13	78.9±1.59	11.9±0.33	53.7± 0.61	45.3±1.70	32.8±1.42	83.3±3.38
5	Selimiye	608.9±116.4	41.5±2.92	83.2±1.32	11.6±0.34	55.1± 0.33	45.1±1.71	31.9±1.66	90.3±1.92
6	Aldane	551.1±105.5	42.1±2.86	81.3±1.27	12.8±0.41	55.2± 0.86	56.0±3.65	34.4±0.67	94.1±0.70
7	Flamura-85	518.9±103.8	37.3±2.45	80.6±1.32	12.1±0.54	53.3± 0.69	47.8±3.62	30.4±2.22	94.4±1.93
8	Golia	610.4±95.7	31.9±1.56	79.9±1.03	11.9±0.29	57.8± 0.92	35.0±2.01	28.7±1.64	94.2±2.16
9	BBVD7	651.0 ±152.2	42.7±2.80	78.9±1.32	12.3±0.69	51.1± 1.38	37.2±2.01	34.6±1.50	64.8±5.11
10	Bereket	658.3±121.5	37.9±2.04	80.6±1.40	11.4±0.80	52.8±1.24	44.7±2.90	28.7±2.83	94.5±2.19
11	ÖVD26-07	579.1±115.7	35.6±2.94	81.2±1.45	11.8±0.58	58.6± 1.50	36.6±1.84	31.6±2.15	88.2±2.13
12	ÖVD2/21-07	563.0±90.9	37.2±3.19	76.9±2.24	11.5±0.67	50.4±1.43	47.8±3.50	28.5±1.35	93.9±3.58
13	ÖVD2/27-07	617.8±96.4	34.6±1.91	79.9±1.36	11.4±0.48	55.7± 1.19	36.9±2.54	35.2±1.73	60.8±3.29
14	EBVD24-07	577.4±150.7	31.2±3.25	77.1±2.27	11.7±0.68	54.3± 1.16	38.7±3.09	30.2±2.13	83.6±3.55
15	BBVD21-07	383.0±89.4	29.7±2.30	73.6±2.34	13.3±0.68	57.0± 0.84	34.3±2.71	37.0±2.21	68.9±2.06
Mean		583.0	37.1	79.7	11.9	54.1	42.0	31.8	83.4
LSD (0.05)		21.94**	0.88 **	0.40**	0.41**	0.58**	1.59**	1.29**	2.32**

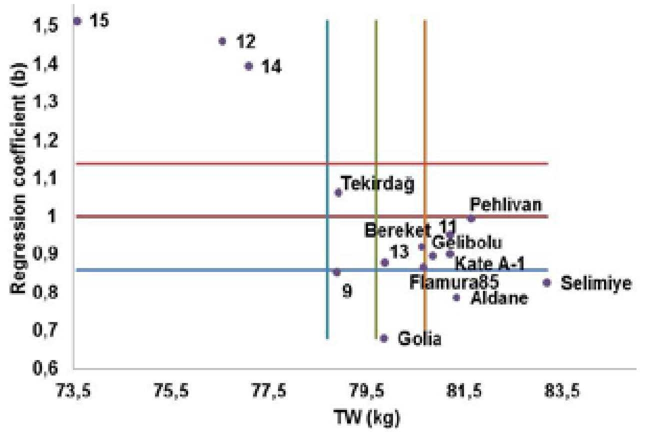
Note: *: p<0.05, **: p<0.01, GY: Grain yield (kg da-1), TKW: Thousand kernel weight (g), TW: Test weight (kg), PRT: Protein content (%), HARD: Hardness, SED: Sedimentation (ml), GLT: Wet Gluten (%), IND: Gluten index (%)

Table 5. Stability parameters for test weight and 1000-kernel weight of the genotypes

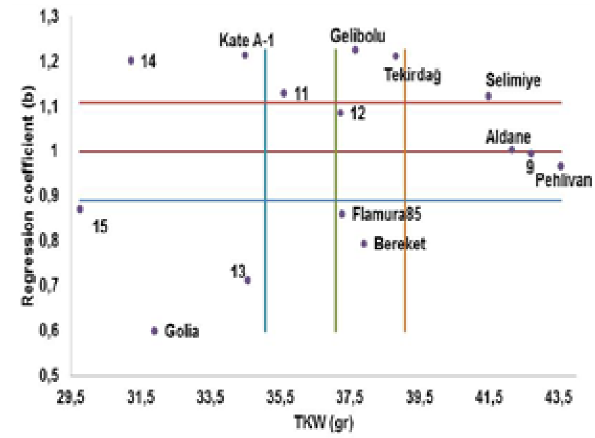
No	Genotype	Stability parameters for TW					Stability parameters for TKW				
		X	R^2	S^2d	a	b	X	R^2	S^2d	a	b
1	Kate A-1	81.20	0.97	0.016	9.32	0.90	34.49	0.99	0.46	-10.54	1.21
2	Gelibolu	80.85	0.93	0.038	9.48	0.90	37.67	0.99	0.54	-7.77	1.23
3	Pehlivan	81.63	0.98	0.012	2.36	0.99	43.54	0.96	1.09	7.69	0.97
4	Tekirdağ	78.91	0.98	0.017	-5.84	1.06	38.83	0.97	1.21	-6.14	1.21
5	Selimiye	83.19	0.86	0.068	17.18	0.83	41.47	0.96	1.52	-0.18	1.12
6	Aldane	81.34	0.83	0.078	18.56	0.79	42.15	0.80	6.66	4.93	1.00
7	Flamura-85	80.65	0.94	0.029	11.60	0.87	37.28	0.80	4.86	5.32	0.86
8	Golia	79.86	0.96	0.013	25.46	0.68	31.90	0.95	0.50	9.65	0.60
9	BBVD7	78.89	0.92	0.042	10.74	0.86	42.70	0.82	5.68	5.75	1.00
10	Bereket	80.63	0.94	0.036	7.28	0.92	37.91	0.98	0.29	8.40	0.80
11	ÖVD26-07	81.21	0.94	0.035	5.13	0.95	35.61	0.95	1.61	-6.30	1.13
12	ÖVD2/21-07	76.55	0.93	0.098	-39.95	1.46	37.24	0.75	10.25	-3.04	1.09
13	ÖVD2/27-07	79.87	0.90	0.051	9.85	0.88	34.56	0.90	1.47	8.14	0.71
14	EBVD24-07	77.08	0.82	0.260	-34.05	1.39	31.21	0.89	4.78	-13.39	1.20
15	BBVD21-07	73.56	0.92	0.130	-47.12	1.51	29.75	0.93	1.55	-2.52	0.87

Note: X: mean, R^2: determinations coefficient, S^2d: deviation from regression, a: intercept value, b: regression coefficient

Figure 1. According to the regression coefficient and adaptability of varieties for the test weight and 1000-kernel weight



Regression coefficient for test weight



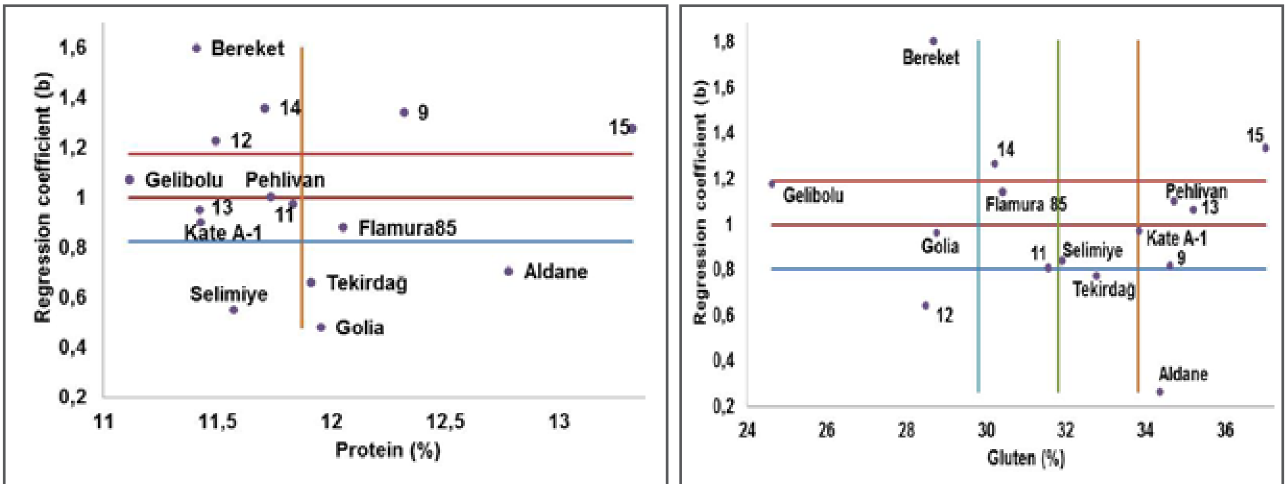
Regression coefficient for 1000-kernel weight

Table 6. Stability parameters for protein content and wet gluten of the genotypes

No	Genotype	Stability parameters for protein content					Stability parameters for wet gluten				
		X	R^2	S^2d	a	b	X	R^2	S^2d	a	b
1	Kate A-1	11.43	0.68	2.612	0.73	0.90	33.83	0.61	0.394	2.93	0.97
2	Gelibolu	11.11	0.93	0.627	-1.62	1.07	24.61	0.91	0.087	-12.99	1.18
3	Pehlivan	11.73	0.92	0.609	-0.18	1.00	34.70	0.90	0.088	-0.47	1.11
4	Tekirdağ	11.91	0.92	0.249	4.06	0.66	32.76	0.68	0.187	8.00	0.78
5	Selimiye	11.57	0.62	1.266	5.04	0.55	31.91	0.58	0.328	5.18	0.84
6	Aldane	12.78	0.68	1.601	4.40	0.71	34.36	0.36	0.084	25.87	0.27
7	Flamura-85	12.05	0.62	3.158	1.58	0.88	30.40	0.60	0.568	-5.94	1.14
8	Golia	11.95	0.64	0.871	6.25	0.48	28.74	0.78	0.167	-1.94	0.96
9	BBVD7	12.32	0.87	1.752	-3.62	1.34	34.60	0.68	0.206	8.57	0.82
10	Bereket	11.41	0.92	1.431	-7.59	1.60	28.67	0.92	0.174	-28.84	1.81
11	ÖVD26-07	11.83	0.65	3.499	0.23	0.98	31.56	0.32	0.902	5.78	0.81
12	ÖVD2/21-07	11.49	0.78	2.908	-3.12	1.23	28.47	0.52	0.253	8.02	0.64
13	ÖVD2/27-07	11.42	0.90	0.646	0.14	0.95	35.20	0.85	0.125	1.36	1.06
14	EBVD24-07	11.71	0.92	1.052	-4.44	1.36	30.21	0.80	0.254	-10.05	1.27
15	BBVD21-07	13.32	0.81	2.583	-1.84	1.28	37.01	0.83	0.242	-5.48	1.34

Note: X: mean, R^2: determinations coefficient, S^2d: deviation from regression, a: intercept value, b: regression coefficient

Figure 2. According to the regression coefficient and adaptability of varieties for the protein content and sedimentation



Regression coefficient for protein content

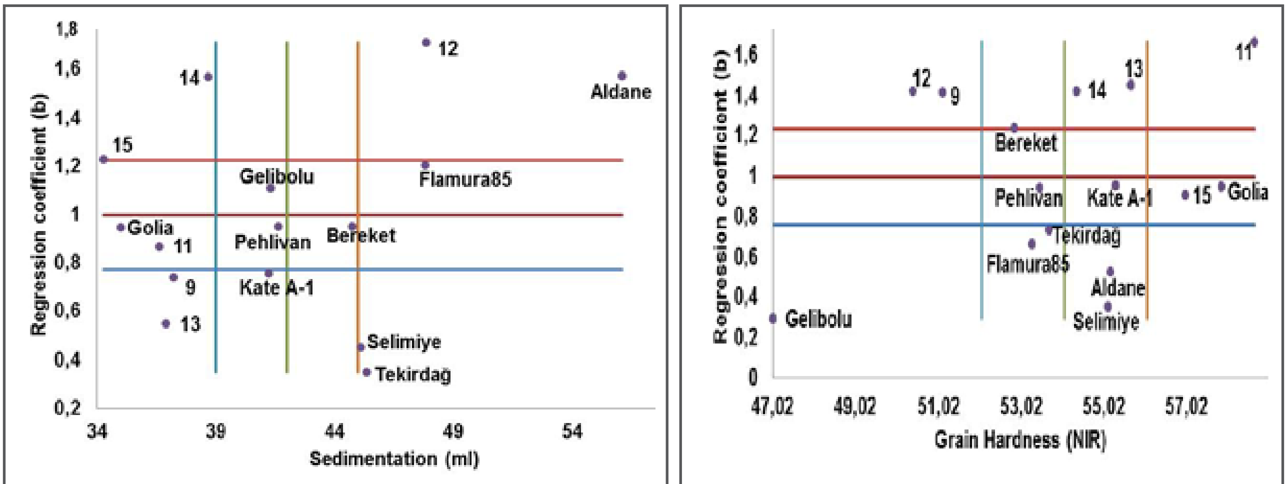
Regression coefficient for gluten value

Table 7. Stability parameters for sedimentation and hardness of the genotypes

No	Genotype	Stability parameters for sedimentation					Stability parameters for hardness				
		X	R^2	S^2d	a	b	X	R^2	S^2d	a	b
1	Kate A-1	41.23	0.44	0.806	9.32	0.76	55.3	0.93	0.07	3.48	0.96
2	Gelibolu	41.30	0.92	0.121	-5.33	1.11	47.0	0.07	0.01	30.92	0.30
3	Pehlivan	41.63	0.61	0.635	1.59	0.95	53.5	0.83	0.06	2.28	0.95
4	Tekirdağ	45.33	0.16	0.692	30.61	0.35	53.7	0.91	0.07	13.62	0.74
5	Selimiye	45.10	0.27	0.613	26.03	0.45	55.1	0.69	0.05	35.81	0.36
6	Aldane	56.03	0.72	1.070	-10.21	1.58	55.2	0.24	0.02	26.45	0.53
7	Flamura-85	47.77	0.43	2.152	-2.92	1.21	53.3	0.58	0.04	17.24	0.67
8	Golia	35.03	0.85	0.169	-4.82	0.95	57.8	0.67	0.05	6.54	0.95
9	BBVD7	37.23	0.53	0.547	6.12	0.74	51.1	0.66	0.05	-25.74	1.42
10	Bereket	44.73	0.42	1.402	4.65	0.95	52.8	0.62	0.04	-14.34	1.24
11	ÖVD26-07	36.63	0.86	0.135	0.09	0.87	58.6	0.77	0.05	-31.51	1.67
12	ÖVD2/21-07	47.80	0.93	0.255	-24.26	1.72	50.4	0.62	0.04	-26.76	1.43
13	ÖVD2/27-07	36.90	0.74	0.115	13.79	0.55	55.7	0.93	0.07	-23.00	1.46
14	EBVD24-07	38.67	0.99	0.014	-27.32	1.57	54.3	0.94	0.07	-22.81	1.43
15	BBVD21-07	34.27	0.79	0.439	-17.35	1.23	57.0	0.73	0.05	7.82	0.91

Note: X: mean, R^2: determinations coefficient, S^2d: deviation from regression, a: intercept value, b: regression coefficient

Figure 3. According to the regression coefficient and adaptability of varieties for the amount of sedimentation and hardness



Regression coefficient for sedimentation

Regression coefficient for grain hardness

Table 8. Correlation coefficients among stability parameters based on quality parameters

	Test weight					Thousand-kernel weight				
	X	R^2	S^2d	CV	a	X	R^2	S^2d	CV	a
R^2	0.077					-0.180				
S^2d	-0.573*	-0.735**				0.201	-0.944**			
CV	-0.573*	-0.735**	1.000**			1.000**	-0.180	0.201		
a	0.865**	0.130	-0.689**	-0.689**		0.355	-0.202	-0.022	0.355	
b	-0.834**	-0.134	0.690**	0.690**	-0.998**	0.209	0.107	0.140	0.209	-0.840**
	Protein content					**Wet gluten value**				
R^2	-0.207					-0.133				
S^2d	0.262	-0.582*				-0.020	-0.597*			
CV	0.262	-0.582*	1.000**			-0.020	-0.597*	1.000**		
a	0.174	-0.611*	-0.162	-0.162		0.466	-0.730**	0.052	0.052	
b	-0.026	0.589*	0.204	0.204	-0.989*	-0.217	0.766**	-0.063	-0.063	-0.965**
	Hardness					**Sedimentation value**				
R^2	0.515*					-0.320				
S^2d	0.515*	1.000**				0.578*	-0.606*			
CV	-0.506	-0.692**	-0.692**			0.578*	-0.606*	1.000**		
a	-0.122	-0.491	-0.491	-0.233		0.036	-0.818**	0.183	0.183	
b	0.248	0.546**	0.546*	0.162	-0.992**	0.309	0.668**	0.025	0.025	-0.939**

Note: *: $p<0.05$, **: $p<0.01$, X: mean, R^2: determinations coefficient, S^2d: deviation from regression, a: intercept value, b: regression coefficient, CV: variation of coefficient

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