Original Research Article

Climatic Effects on Quality Parameters and Their Relationships of Bread Wheat Genotypes (*Triticum aestivum* L.*)* Grown Under Semi-Arid Region

.

ABSTRACT

Aims: Wheat *(Triticum aestivum* L.*)* is used primarily for human consumption especially in developing countries. Bread and bakery products have an important role in human nutrition, and generally, wheat is considered to be a good source of energy and nutrients for the human body. This study was conducted to determine climatic effects to quality parameters of bread wheat genotypes grown in the semi-arid region.

Study design: The experiment was carried out in a randomized block design with three replications. Thirty-three bread wheat genotypes (*Triticum aestivum* L.*)* were used in the study. Plot sizes were 6 m by 1.2 m (7.2 m²) and each plot consisted of six rows with a row spacing of 20 cm.

Place and Duration of Study: The research was carried out during the 2008 and 2009 growing seasons at Sanliurfa, Turkey.

Methodology: For analyses 20 main spikes that contained fully developed kernels were chosen randomly from each plot and taken to the laboratory for analyses. The nitrogen content of kernels was determined using the Kjeldahl method. Test weight and Sodium Dodecyl Sulphate (SDS)-sedimentation values were determined using standard procedures. Wet and dry gluten values were determined using a glutomatic system after separating gluten from the soluble starch and protein fractions.

Results: Genotypes were significant (P < .01) for all characteristics. Thousand kernel weight ranged from 25.8 to 42.3 g, test weight 73.7 to 81.7 kg hl^{-1}, protein content 9.7 to 14.8%, wet gluten 28.5 to 42.2%, dry gluten 9.4 to 14.1% and SDS-sedimentation value 19 to 39 ml. Bezostaya-I, Kutluk-94, Lirasa, Altay-85, Kirgiz-95, Cham-4, Harmankaya-99, Marmara-86, Ikizce, Pehlivan, Momtchill, Fatima-2, Dagdas-94 and Aytin-98 genotypes had the best quality among tested genotypes. A positive significant correlation was found between thousand kernel weight and SDS-sedimentation value. Protein content was positively correlated with wet gluten, dry gluten and SDS- sedimentation value, respectively. Relationships were significant between wet gluten and both dry gluten and SDS-sedimentation. There was a positive significant correlation between dry gluten and SDS-sedimentation.

Conclusion: Protein content, wet and dry gluten and SDS-sedimentation values were affected by climatic factors in the semi-arid region. Protein content, wet and dry gluten values were high but SDS sedimentation values were low in semi-arid region due to high temperature and low precipitation.

Keywords: Climatic effect, bread wheat, protein, wet and dry gluten, SDS, correlation

1. INTRODUCTION

Wheat is one of the most important crops in the world. It is grown both in arid and semi-arid regions of the world as a rain-fed conditions. Turkey is one of the largest producers of wheat in the world with about 7.7 million ha sown area and 21.5 million tons of annual production. Sowing area of wheat in the southeast region of Turkey is about 759 717 ha and production is about 2 456 204 tons [1].

Wheat products are considered to be a good source of energy and nutrients for the human body. The major use of wheat is bulgur, pasta and noodles, and various types of breads. Bread and bakery products have an important role in human nutrition. Bakery products, supplemented with various nutrients, have been gaining popularity worldwide.

The wheat processing industry requires grain lots which are consistent for moisture, test weight and protein content. Wheat quality is a concept in continuous evolution in response to market demands and consumer preferences for specific attributes of different end-products [2]. The technological quality of wheat for milling and baking use varies widely. Growing conditions, climate and variety characteristics are the most important factors affecting quality and affects changes in protein and starch quality. About 13.5% protein content in Canada and 11-13% in USA are acceptable standards for wheat, respectively [3, 4]. A thousand kernel weight of 35-40 g is required in USA [3]. Gangadharappa et al. [5] stated that the required quality parameters of wheat are a test weight of 79.6 kg hl^{-1}, gluten values in the range of 7.93-9.60%, SDS-sedimentation value of 46 ml and protein concentration of 9.5%. About 74 kg hlt^{-1} test weight is required in Australia [4]. Pasha et al. [6] reported 19.67-36 mL SDS-sedimentation volume value, 13.82-43.13% wet gluten content and 4.46 -14.55% dry gluten values.

Wheat production under abiotic stress conditions has become important in recent years. Grain composition and the quality of the wheat kernel are affected by both variety and environment [7, 8, 9, 10]. The environment (climate, soil, agronomic practices, etc.) exerts a strong influence on the expression of the technological quality of different cultivars [8, 11].

Rharrabti et al. [12] reported that thousand kernel weight and test weight are greatly affected by climatic parameters. Grain protein content, perhaps the most important quality feature for wheat, is known to be influenced by climatic factors such as rainfall and temperature, cultivar and available moisture during grain filling [12, 13, 14, 15]. The protein content in wheat kernels is influenced by climatic conditions [14, 16, 17, 18, 19, 20, 21]. After anthesis, heat or drought may increase grain protein content [22, 23]. Faergestad et al. [24] emphasis climatic conditions affect gluten composition of wheat kernel.

The availability of soil water is a major factor limiting wheat production in most regions of the world. Not only is the amount of precipitation usually small, but there is often the problem of poor and unpredictable distribution. Especially under semiarid and arid environments water deficits often limit grain yields and quality. Effect of high temperatures and deficit water on grain protein composition during grain filling period was reported by Oktem [25].

Genotype is also one of the most important quality factors. Wheat quality has implications for human health and nutrition. The present investigation was undertaken with thirty-three wheat genotypes to determine some quality parameters of bread wheat genotypes grown in semi-arid region.

The objectives of this study were: (i) to determine some quality parameters of bread wheat genotypes grown in semi-arid region; (ii) to investigate the influence of climatic parameters on the expression of different grain quality characteristics; (iii) to study the relationships between quality traits; (iv) to evaluate the effect of environmental conditions on these relationships.

2. MATERIAL AND METHODS

This study was conducted during 2008 and 2009 in the Harran Plain, Sanliurfa, South-east Anatolia region of Turkey (altitude: 465 m; 37^{0}08$^'$ N and 38^{0}46$^'$ E). Climate varies from arid to semi-arid depending on the year. Total precipitation was 314 and 448 mm for 2008 and 2009 growing seasons, respectively. Monthly average temperature and total precipitation values were given in the Table 1. The soil texture of the experimental field was clay. Field capacity, permanent wilting point and bulk density of the soil was 33.8% (dry basis), 22.6% and 1.41 Mg m^{-3}, respectively.

Table 1. Average temperature and total precipitation values of experiment years.

Months	Average Temperature (^{0}C)		Minimum Temperature (^{0}C)		Maximum Temperature (^{0}C)		Total precipitation (mm)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
October	20.5	21.9	9.6	12.5	35.3	34.8	22.5	76.6
November	14.1	12.2	5.8	4.7	28.5	24.0	35.3	35.5
December	7.0	10.0	3.0	2.0	22.1	18.7	37.7	121.2
January	5.7	8.3	-4.7	-3.2	15.7	18.8	29.8	95.7
February	8.0	9.1	0.1	-1.9	17.3	19.7	54.5	23.5
March	10.0	13.8	1.5	1.1	23.0	25.2	55.3	42.7
April	15.8	17.4	5.9	6.6	27.5	29.2	48.8	26.2
May	22.7	24.0	10.0	11.0	37.0	36.8	4.7	7.1
June	29.6	29.4	17.8	17.5	40.0	42.2	9.2	0.5
July	32.0	33.9	20.3	20.0	41.5	45.2	3.2	-
August	30.6	33.6	20.9	23.0	41.2	43.6	-	-
September	25.0	28.5	11.3	18.5	39.4	40.0	6.9	0.2

Thirty-three bread wheat genotypes (*Triticum aestivum* L.) were used in the study. The experiment was carried out in a randomized complete block design with three replications. Plot sizes were 6 m by 1.2 m (7.2 m^2) and each plot consisted of six rows with a row spacing of 20 cm. The seeds were sown at 30-40 mm depth with a density of 500 plants m^2. At sowing, 60 kg ha^{-1} of pure P and N was applied to each plot; this was followed by 60 kg ha^{-1} of N when the plants reached 25-30 cm in height. As a first fertilizer Compose (20, 20, 0 NPK) and secondary Ammonium Nitrate (26% N) fertilizers were used at experiment.

For analysis of the kernel, 20 spikes that contained fully developed kernels were chosen randomly from each plot and taken to the laboratory for analysis. The nitrogen content of kernels was determined using the Kjeldahl method [26] and the result was multiplied by the factor 5.7 [27] to calculate the protein content of kernels, this was expressed on dry weight basis. Test weight of wheat samples were determined using standard procedures [28]. Sodium Dodecyl Sulphate (SDS)-sedimentation value [29] was determined for the wheat samples. Wet and dry gluten values were determined using a glutomatic system after separating gluten from the soluble starch and protein fractions [30].

An analysis of variance (ANOVA) was performed on the two years combined for the physico-chemical characteristics to evaluate statistical differences between genotypes. Differences among means were assessed by the Duncan's multiple range test (P = .05). A correlation analysis was performed to determine relationship among tested quality characteristics.

3. RESULTS AND DISCUSSION

Genotypes were statistically significant ($P < .01$) for thousand kernel weight, test weight, protein content, wet gluten, dry gluten and SDS-sedimentation.

3.1. Thousand Kernel Weight and Test Weight

The Pehlivan genotype gave the highest thousand kernel weight value whereas the lowest value was obtained from Sultan-95 genotypes (Fig. 1.). One thousand kernel weight ranged from 25.8 to 42.3 g, and thousand kernel weight of some genotypes such as Momtchill, Bezostaya-I, Kutluk-94, Yüregir-89, Kinaci-97 and Marmara-86 were higher than others (Table 2). Maddonni et al. [31] stated that genotypic difference might affect kernel biomass accumulation.

Genotypes were different from each other for test weight. Test weight values of bread wheat genotypes were between 73.7 (Kutluk-94) and 81.7 (Pehlivan) kg hl^{-1}. Average test weight of 79.6 kg hl^{-1} was reported by Gangadharappa et al. [5]. Test weight was the highest at Bezostaya-1, Gonen-98, Ikizce, Lirasa, Cham-4, Orso and Marmara-86 genotypes. Rharrabti et al. [12] reported that thousand kernel weight and test weight are greatly affected by climatic parameters, particularly high temperature during the final phase of grain filling. Water deficiency during grain growth, results lower test weights due to reduced accumulation rate.

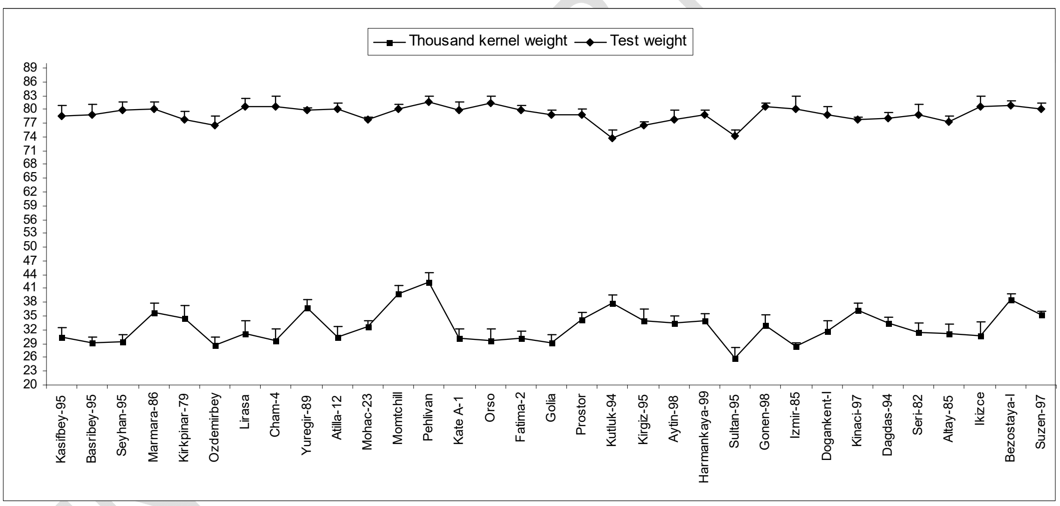

Fig. 1. Thousand weight and test weight values of some bread wheat genotypes grown in South-eastern Anatolia region of Turkey. Vertical bars indicate standard errors of the mean.

3.2. Protein Content

Protein content was the lowest for the Orso genotype (9.7%) while the highest value found was for Bezostaya-I (14.8%). The quality of wheat grain is dependent on the characteristics of starch and protein present. Variety composition is also one of the most important factors and it causes protein quality changes. Different levels of wheat kernel protein content values were reported 9.7-14.3% [32], 7.1-11.6% [33], 9.5% [5] and 14.9-21.54% [34]. Protein content of Kutluk-94, Dagdas-94, Altay-85, Harmankaya-99, Kirgiz-95, Lirasa and Aytin-98 genotypes were higher than others (Fig. 2.), thus genotype had an effect on grain protein concentration. Genetic background is the most important factor for wheat protein quality and grain protein concentration [35]. The protein concentration is determined by the genetic background but is also influenced to a large extent by environmental factors such as rainfall and temperature [16, 18, 19].

The environment (climate, soil, agronomic practices, etc.) exerts a strong influence on the expression of the quality of different cultivars [8, 11]. Wheat kernel quality depends on precipitation amount in the rain fed conditions. Under rain-fed conditions the developing grains are frequently exposed to mild to severe stress at different stages of grain development. High temperatures and deficit water during grain filling period had a greater positive effect on grain protein composition [25]. The research area for this study, South-eastern Anatolia, is semi-arid region and characterized by warm winters, hot and dry summers with an inadequate and irregular rainfall distribution pattern.

An effective drought and hot climate in grain filling period, results high protein content in wheat grains under rainfed conditions (Table 1). Influences of the environment on protein content have been shown by other authors [14, 17, 20, 21]**.** Climatic factors such as temperature and amount of precipitation during the wheat growing terms have an important role for quality of kernel. Prior to anthesis, yield and grain protein content are influenced by effects of genetics, environment and other aspects of crop management [36]. But after anthesis, kernel growth is directly impacted by air temperature and water.

Protein ratio was high at the most of wheat genotypes in this study. It is seen climatic data from Table 1. that air temperature was high and precipitation was very low in the May month. Generally May month covers both milky and starch filling stages at wheat plant in the Harran Plain which is located in the southeast Anatolia region. In the semi-arid regions such as research area, air temperature increases suddenly and precipitation is very low in May month (Table 1) at the early starch filling period of kernel. High temperature and low water affects wheat plants negatively in this term. The duration of starch accumulation period ends in a short time due to high temperature and low water. Maturation begins at the most of the plants. Thus, plants mature more quickly at high temperature. Generally, the protein amount is stable in the milky stage, but the protein ratio can change according to the amount of starch filling in the kernel. If there is a decrease in the amount of starch in the kernel, the protein content percentage increases. Frequently there is a negative relationship between grain yield and protein content [37]. Post-anthesis heat or drought may increase grain protein content but reduce yield because of their effects on starch production [22, 23, 37].

In the present study, the protein content was high due to low starch content in the kernel. Rao et al. [14] emphasis heat stress during the grain-filling stage influenced the protein content of wheat kernel.

Generally, a rise in temperature resulted in higher protein contents. Climatic factors significantly influence protein levels in wheat. Daniel and Triboi [38] stated that protein percent in wheat increased with the increase of air temperature. Topal et al. [39] reported that the protein content of the kernel increased with water stress. Mallikarjunaswamy et al. [40] reported that decreased irrigation water negatively affects the quality of kernel.

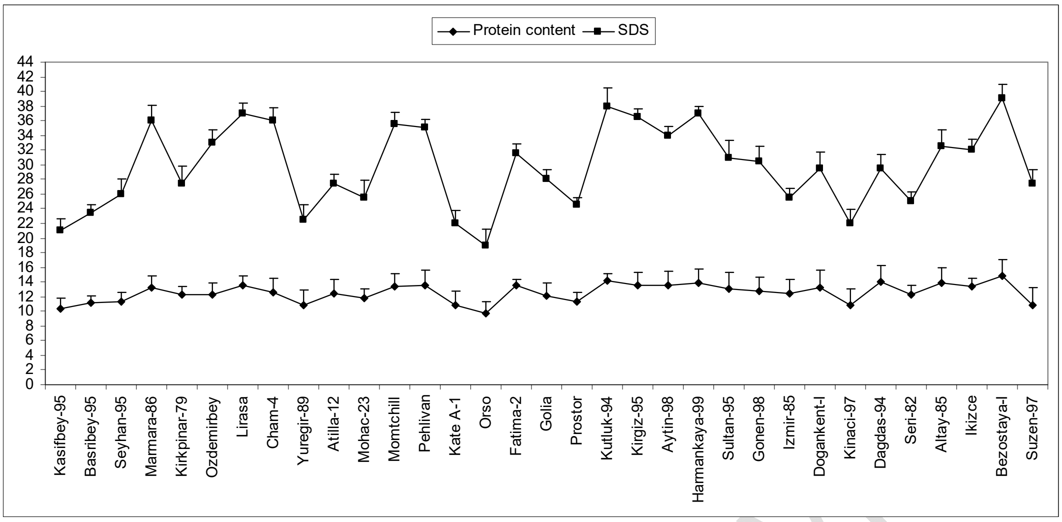

Fig. 2. Protein content and SDS-sedimentation values of some bread wheat genotypes grown in South-eastern Anatolia region of Turkey. Vertical bars indicate standard errors of the mean.

3.3. SDS-Sedimentation Value

SDS-sedimentation values of bread wheat genotypes ranged between 19.0 ml (Orso) and 39.0 ml (Bezostaya-I) (Table 2). The highest SDS-sedimentation values were found in Kutluk-94, Lirasa, Kirgiz-95, Harmankaya-99, Cham-4, Marmara-86 and Momtchill genotypes (Fig. 2.). Sedimentation value reflects the quality of protein [28]. Pasha et al. [6] reported 19.67-36 mL SDS-sedimentation volume values. Gangadharappa et al. [5] measured a 46 ml SDS-sedimentation value in wheat. Tonk et al. [34] reported higher SDS-sedimentation values of 46-95 ml in wheat. The quality of the wheat kernel is affected by both variety and environment [10]. Balkan and Genctan [45] stated that SDS values should be between 30 and 43 ml. SDS values were lower than expected in the study. All of varieties gave lower SDS value than 40 ml. Most of SDS values were below 30 ml. SDS values can be reduced in dry and hot environments [46, 20]. SDS values increases with increasing temperature during grain filling up to about 30°C and then decreases as temperatures rise above 30 °C [20, 47]. Temperature during grain-filling period was higher than 30 °C in the present study (Table 1). Thus, it appears that increasing protein content due to high temperature and low water input during the grain filling period could lead to a decrease in SDS value under the conditions of our study. Water input during grain filling also had a negative influence on SDS volume [12].

3.4. Wet and Dry Gluten

Gluten is the major component of flour protein that determines processing quality. Wet gluten reflects the gluten quality and quantity. The highest wet gluten content was found in Bezostaya-I (42.2%), whereas Orso genotype gave the lowest value (28.5%) (Table 2). Kutluk-94, Lirasa, Altay-85, Kirgiz-95, Cham-4, Harmankaya-99, Marmara-86 and Ikizce genotypes gave higher wet gluten value than others. Pasha et al. [6] reported 13.82-43.13% wet gluten content values.

Dry gluten values varied from 9.4% (Orso) to 14.1% (Bezostaya-I). It was shown that the content of dry gluten of Kutluk-94, Altay-85, Lirasa, Kirgiz-95, Harmankaya-99 and Dagdas-94 genotypes were slightly higher than other genotypes (Fig. 3.). The present findings are in collaboration with the previous studies conducted by Curic et al. [41] who reported the range of dry gluten from 8.44 to 11.77% in flours of different wheat varieties, and Lin et al. [42] found the range of dry gluten from 7.0 to 16.7%.

Table 2. Average thousand kernel weight, test weight, protein content, wet gluten, dry gluten and SDS-sedimentation values of some bread wheat genotypes grown in South-eastern Anatolia region of Turkey.

Genotypes	Thousand kernel weight** (g)	Test weight** (kg hl^{-1})	Protein content** (%)	Wet Gluten** (%)	Dry Gluten** (%)	SDS** (ml)
1. Kasifbey-95	30.5 m-p	78.5 efg	10.3 mn	30.1 n†	10.0 mn	21.0 r
2. Basribey-95	29.1 qrs	78.9 def	11.1 klm	32.4 m	10.8 j-m	23.5 p
3. Seyhan-95	29.4 q-s	79.7 cde	11.3 jkl	34.1 kl	11.0 ı-m	26.0 n
4. Marmara-86	35.8 ef	80.2 bcd	13.2 b-g	38.9 cde	12.9 b-e	36.0 cde
5. Kirkpinar-79	34.6 gh	77.7 fgh	12.2 hıj	35.3 ıj	11.7 f-j	27.5 m
6. Ozdemirbey	28.6 rs	76.6 h	12.3 ghı	36.1 hı	11.9 e-ı	33.0 g
7. Lirasa	31.2 lmn	80.5 abc	13.6 bcd	40.0 bc	13.2 abc	37.0 c
8. Cham-4	29.6 q-r	80.5 abc	12.6 d-ı	39.6 cd	12.1 d-h	36.0 cde
9. Yuregir-89	36.8 de	79.7 cde	10.9 klm	30.8 n	10.4 klm	22.5 q
10. Atilla-12	30.4 m-p	80.1 bcd	12.5 e-ı	35.2 ıjk	11.9 e-ı	27.5 m
11. Mohac-23	32.8 jk	77.7 fgh	11.8 ıjk	33.4 lm	11.2 h-l	25.5 no
12. Momtchill	39.9 b	80.1 bcd	13.4 b-f	38.3 ef	12.7 cde	35.5 de
13. Pehlivan	42.3 a	81.7 a	13.5 b-e	38.2 ef	12.9 b-e	35.0 e
14. Kate A-1	30.2 n-q	79.7 cde	10.8 lm	30.6 n	10.3 lmn	22.0 q
15. Orso	29.7 o-r	81.3 ab	9.7 n	28.5 o	9.4 n	19.0 s
16. Fatima-2	30.2 n-q	79.7 cde	13.5 b-e	38.6 def	12.9 b-e	31.5 ıj
17. Golia	29.1 qrs	78.9 def	12.1 hıj	34.1 kl	11.3 g-l	28.0 m
18. Prostor	34.2 ghı	78.9 def	11.3 jkl	32.5 m	10.9 l-m	24.5 o
19. Kutluk-94	37.7 cd	73.7 ı	14.2 ab	41.0 b	13.8 ab	38.0 b
20. Kirgiz-95	34.1 ghı	76.5 h	13.6 bcd	39.8 c	13.2 abc	36.5 cd
21. Aytin-98	33.4 hıj	77.7 fgh	13.5 b-e	38.4 ef	12.9 b-e	34.0 f
22. Harmankaya-99	34.0 g-j	78.9 def	13.8 bc	39.1 cde	13.1 bcd	37.0 c
23. Sultan-95	25.8 t	74.1 ı	13.1 c-h	36.9 gh	12.3 c-g	31.0 jk
24. Gonen-98	33.1 ıj	80.7 abc	12.7 d-ı	36.0 hı	11.6 f-j	30.5 k
25. Izmir-85	28.3 s	80.1 bcd	12.4 f-ı	34.5 jkl	11.6 f-j	25.5 no
26. Dogankent-I	31.8 kl	78.9 def	13.3 b-f	37.5 fg	12.4 c-f	29.5 l
27. Kinaci-97	36.3 ef	77.7 fgh	10.9 klm	30.6 n	10.1 mn	22.0 q
28. Dagdas-94	33.6 hıj	78.1 fg	14.0 abc	38.2 ef	13.0 bcd	29.5 l
29. Seri-82	31.5 ım	78.9 def	12.2 g-j	33.8 l	11.4 f-k	25.0 no
30. Altay-85	31.1 lmn	77.3 gh	13.9 abc	39.9 bc	13.2 abc	32.5 gh
31. Ikizce	30.7 l-o	80.5 abc	13.4 b-f	38.8 cde	12.9 b-e	32.0 hı
32. Bezostaya-I	38.7 c	80.9 abc	14.8 a	42.2 a	14.1 a	39.0 a
33. Suzen-97	35.2 fg	80.1 bcd	10.9 klm	35.8 hı	10.5 klm	27.5 m
Average	37.7	78.9	12.5	36.0	11.9	29.7

† : There are no statistical differences among the genotypes in the same column having the same letter at 0.05 level according to Duncan test.
** : Denotes significant difference among genotypes *P* < .01.

Gangadharappa et al. [5] stated that dry gluten values were in the range of 7.93-9.60%. Indrani et al. [43] reported 10.3% dry gluten value, and Pasha et al. [6] reported 4.46 - 14.55% dry gluten values. Gluten amount in wheat grain may affected by genetic and climatic factors.

The contents of protein and dry gluten reflect the quality of wheat varieties [44]. Gluten amount in the kernel is firmly related with protein amount in the kernel. Protein ratio in the kernel effects positively wet and dry gluten amount. Gluten amount in the kernel effects dough and bread quality. In the present study, gluten values were found high correspondingly to protein content. Hence, effect of high temperature and low water in grain filling stages in semi-arid region result high protein content and gluten values. Faergestad et al. [24] emphasis climatic conditions affect kernel quality, protein and gluten composition of wheat kernel.

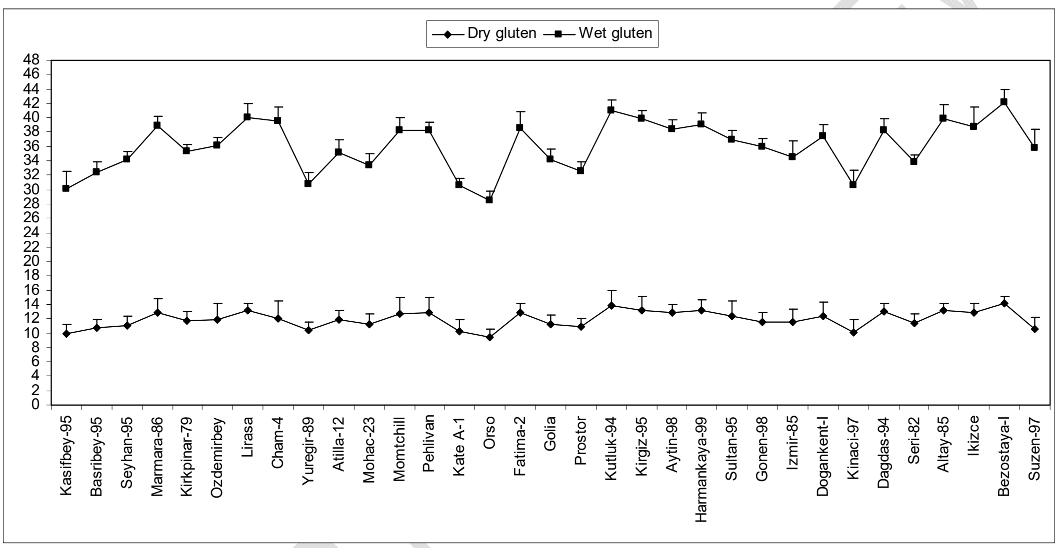

Fig. 3. Dry gluten and wet gluten values of some bread wheat genotypes grown in South-eastern Anatolia region of Turkey. Vertical bars indicate standard errors of the mean.

3.5. Correlation Coefficients

Relationships between quality traits have been investigated in some studies on bread wheat [7, 24, 48]. Correlation coefficients for some quality parameters are given in Table 3. According to correlation analysis; a positive significant correlation was found between thousand kernel weight and SDS-sedimentation value (0.347*). Protein content was positive correlated with wet gluten (0.941**), dry gluten (0.986**) and SDS-sedimentation value (0.888**) at the *P* = .01 level, respectively. Some researchers reported a correlation between protein and wet gluten [9, 21, 32, 49, 50]. A positive correlation between protein and dry gluten value is emphasized by Anjum and Walker [51]. An inverse relationship between protein content and SDS volume was reported by Rharrabti et al. [12].

Positive correlations between wet gluten and both dry gluten (0.960**) and SDS-sedimentation value (0.956**) were great and significant at level of 1%. The significant positive correlation between SDS-sedimentation value wet gluten content was reported [6, 9]. There was a positive significant correlation between dry gluten and SDS-sedimentation value (0.920**) at the 1% level. Pasha et al. [6] emphasized a positive significant correlation of SDS-sedimentation value with dry gluten values.

Table 3. Correlation coefficients among 1000 kernel weight, test weight, protein content, wet gluten, dry gluten and SDS-sedimentation values.

Traits	1000 kernel weight	Test weight	Protein content	Wet gluten	Dry gluten	SDS-sedimentation value
1000 kernel weight	1	0.158	0.289	0.278	0.298	0.347*
Test weight	-	1	-0.173	-0.119	-0.178	-0.110
Protein content	-	-	1	0.941**	0.986**	0.888**
Wet gluten	-	-	-	1	0.960**	0.956**
Dry gluten	-	-	-	-	1	0.920**

*: $P < .05$, ** : $P < .01$.

4. CONCLUSION

The data obtained from our study indicate that quality parameter values of bread wheat genotypes were different from each other. Bezostaya-I, Kutluk-94, Lirasa, Altay-85, Kirgiz-95, Cham-4, Harmankaya-99, Marmara-86, Ikizce, Pehlivan, Momtchill, Fatima-2, Dagdas-94 and Aytin-98 genotypes were the best in quality among the tested other genotypes in semi-arid region. Differences in quality of bread wheat could be associated with differences in adaptation ability of genotypes, genotypic structure and reacted differently to soil and climate conditions. Climatic conditions during grain filling appear to be crucially important in determining grain quality in semi-arid environments. Protein content, wet and dry gluten and SDS-sedimentation values were affected by climatic factors in the semi-arid region. Protein content, wet and dry gluten values were high but SDS sedimentation values were low due to high temperature and low precipitation in semi-arid region. Although the hot and dry conditions of semi-arid region cause a large fluctuation in yield, they often provide the opportunity for a good expression of quality parameters such as high protein and gluten values.

A positive significant correlation was found between thousand kernel weight and SDS-sedimentation value. Protein content was positively correlated with wet gluten, dry gluten and SDS-sedimentation, respectively. Relationship between wet gluten and both dry gluten and SDS-sedimentation value were great and significant. There was a positive significant correlation between dry gluten and SDS-sedimentation value.

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