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Effect of Semi-arid Environmental Conditions to Quality of Durum Wheat Genotypes (*Triticum turgidum* L. *var. durum)*

Ayse Gulgun Oktem[1] and Abdullah Oktem[1*]

[1]Department of Field Crops, Faculty of Agriculture, University of Harran, 63200 Sanliurfa, Turkey.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was conducted to determine some quality parameters of durum wheat genotypes in semi-arid environmental conditions.
Study Design: The field trial was carried out in a Randomize Complete Block Design with three replications. Thirty-one wheat genotypes were grown in a field trial and kernel samples analyzed for dry matter content, thousand kernel weight, test weight, vitreousness, protein content, wet gluten, dry gluten and SDS-sedimentation value.
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 different significantly ($P \leq 0.01$) for all parameters. Dry matter content ranged from 92.4 to 93.1%; thousand kernel weight from 27.5 to 45.5 g, test weight from 79.3 to

**Corresponding author: Email: aoktem@harran.edu.tr, aoktem33@yahoo.com;*

85.0 kg hl^{-1}, vitreousness from 92.7 to 99.5%, protein content from 12.1 to 17.9%, wet gluten from 28.2 to 53.1%, dry gluten from 10.1 to 16.9% and SDS-sedimentation value from 13 to 23 ml. Kunduru-1149, Selcuklu-97, Cosmodor, Zenith, C.1252, Aningavoll, Altintoprak-98, Dicle-74, Kiziltan-91, Sham-I and Havrani genotypes had good quality among other tested genotypes.

Conclusion: 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. 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.

Keywords: Durum wheat; vitreousness; protein content; wet and dry gluten; SDS.

1. INTRODUCTION

Durum wheat is spring wheat mainly grown for human consumption. Although durum wheat is grown in various regions of the world, the great bulk of durum area and production is concentrated in the North America and in the Mediterranean Basin. Five Mediterranean countries (Turkey, Morocco, Algeria, Tunisia and Syria) had over one third of the world's annual durum wheat area and production. Turkey is a leading durum wheat consumer in the Middle East and is also one of the largest producers of durum wheat in the world with about 1.2 million ha sowing area and 3.9 million tonnes of annual production [1]. The sowing area of durum wheat in the southeast region of Turkey is about 429 590 ha with production of about 1.5 million tonnes. Around 37% of total durum wheat production of Turkey is obtained from the southeast region. Most of the wheat buyers in the Turkey prefer qualified durum wheat product to buying. Good qualified wheat product is always sold with high price in Turkey. Also Turkish food and Agriculture ministry supports farmer for growing good quality wheat.

Wheat products are considered to be a good source of energy and nutrients for the human body. The major use of durum wheat is bulgur, pasta and noodles, and various types of breads and bakery products. Durum wheat must fulfill certain quality requirements of protein content, sedimentation value, test weight, etc. About 13.5% protein content in Canada and 11-13% in USA are acceptable standards for durum wheat [2, 3]. A 35-40 g of thousand kernel weight and 86-91% kernel vitreousness is required in USA [2]. Gangadharappa et al. [4] 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 [3]. Pasha et al. [5] reported 19.67-36 mL SDS-sedimentation volume value, 13.82-43.13% wet gluten content and 4.46 -14.55% dry gluten values.

Grain quality of the wheat kernel is affected by both variety and environment (climate, soil, agronomic practices, etc.). Rharrabti et al. [6] reported that thousand kernel weight and test weight are greatly affected by climatic parameters. Grain protein content is influenced by available moisture, temperature and cultivar during grain filling. Faergestad et al. [7] emphasized that climatic conditions affect gluten composition of wheat kernel.

The availability of soil water is a major factor limiting wheat production in most regions in the world. Especially under semi-arid 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 well reported by Oktem [8].

The objectives of this study were: (i) to determine some quality parameters of durum wheat genotypes grown in semi-arid climatic conditions; (ii) to investigate the influence of climatic factors on the expression of different grain quality characteristics.

2. MATERIALS AND METHODS

This study was conducted during the 2008 and 2009 growing seasons in the Harran Plain, Sanliurfa, Turkey (altitude: 465 m; $37^{0}08^{'}$ N and $38^{0}46^{'}$ E). The soil of the experimental field was clay. Field capacity, permanent wilting point and bulk density of the soil were 33.8% (dry basis), 22.6% and 1.41 Mg m^{-3}, respectively. Climatic data was given in Table 1 [9]. Climate varies from arid to semi-arid. Total precipitation was 314 and 448 mm for the 2008 and 2009 growing seasons (Table 1), respectively.

Table 1. Minimum, maximum, average temperature and total precipitation values of experiment years

Months	Average Temperature (ºC)		Minimum Temperature (ºC)		Maximum Temperature (ºC)		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-one durum wheat genotypes (*Triticum turgidum* L. *var. durum)* were used in this study. The field trial was carried out in a Randomized Complete Block Design (RCBD) with three replications. Plot size was 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 with an experimental drill 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 to 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 analyses 20 main spikes that contained fully developed kernels were chosen randomly from each plot and taken to the laboratory for analyses. Kernel samples were washed with distilled water, put in paper bags and oven dried to constant weight at 65°C for at least 4 days [10]. Dried samples were homogenized and stored in polyethylene bottles until analysis.

The nitrogen content of kernels was determined using the Kjeldahl method [11] and the result was multiplied by the factor 5.7 [12] to calculate the protein content of kernels, this was expressed on dry weight basis. Test weight of wheat samples were determined using standard procedures [13]. Vitreousness [14] and Sodium Dodecyl Sulphate (SDS)-sedimentation value [15] was determined for the durum wheat samples. Wet and dry gluten values were determined using a glutomatic system after separating gluten from the soluble starch and protein fractions [16].

An analysis of variance (ANOVA) was performed on the two years combined for the physico-chemical characteristics to evaluate statistical differences between genotypes. Means were compared by the Duncan's multiple range test ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

Genotypes were statistically significant ($P \leq 0.01$) for thousand kernel weight, test weight, protein content, wet gluten, dry gluten and (SDS)-sedimentation value traits. Dry matter content ranged from 92.4% to 93.1% (Table 2). All of the tested genotypes had high dry matter values. Maddonni et al. [17] stated that genotypic difference might affect kernel biomass accumulation. Genotype Aningavoll gave the highest thousand kernel weight whereas the lowest value was obtained from Selcuklu-97 genotypes. Thousand kernel weight ranged from 27.5 g to 45.5 g. Thousand kernel weight of some genotypes such as Dicle -74, Harran-95, Ceylan-95, Salihli-92 and Chamber-88 were higher than those of others (Table 2). Kusaksız and Dere [18] reported that thousand kernel weight of durum wheat ranged from 42.9 to 47.9 g.

Genotypes were different from each other for test weight. Test weight values of wheat genotypes were between 79.3 kg hl^{-1} (Massara) and 85.0 kg hl^{-1}. Average test weight as 79.6 kg hl^{-1} was reported by Gangadharappa et al. [4]. Test weight values were high at the Sarıcanak-98, Salihli-92, Ceylan-95, Kiziltan-91 and Mesaphia genotypes. Test weight is influenced by both genotype and environment [19]. Increased temperature limits the duration of the grain filling period and starch biosynthesis of grains [20,21].

Vitreousness values were ranged from 92.7% (Akcakale-1001) to 99.9% (Saricanak-98). Similar findings were also reported by Bose and Bhattacharyya [22]. All of the durum wheat genotypes gave high vitreousness value in this semi-arid region conditions. The quality of wheat grain is dependent on the characteristics of starch and protein present. An effective drought and warmth in the grain filling period might cause high vitreous kernels in the semi-arid conditions.

Protein content was the lowest for Gediz-75 genotype (11.5%) while the highest value was found at Kunduru-1149 (17.9%). Protein contents of Havrani, Selcuklu-97, Cosmodor, Kiziltan-91, Sham-I and Dicle-74 genotypes were higher than those of the others. Different levels of wheat kernel protein content values were reported as 9.7-14.3% [23], 7.1-11.6% [24], 9.5% [4] and 14.9-21.54% [25] by other researchers. Genotype had an effect on grain protein concentration. The protein concentration is determined by the genetic structure [26], but is also influenced by rainfall and temperature [27].

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 water stress at different stages of kernel development. High temperature and deficit water during grain filling period had a great positive effect on grain protein composition [8]. Protein content increase under high temperature conditions [20]. Generally, protein content of genotypes in our study was high due to high temperature and low rainfall at the grain filling stage. The present research area for this study, southeastern 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 the grain filling period might cause high protein content in wheat grains under the rain fed conditions (Table 1). 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 in Sanliurfa 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 [28]. Post-anthesis heat or drought may increase grain protein content but reduce yield because of their effects on starch production [28]. In the present study, the protein content was high due to low starch content in the kernel.

Generally, a rise in temperature resulted in higher protein contents. Climatic factors significantly influence protein levels in wheat. Daniel and Triboi [29] stated that protein percent in wheat increased with the increase of air temperature. Topal et al. [30] reported that the protein content of the kernel increased with water stress.

The high wet gluten contents were found at Kunduru-1149 and Selcuklu-97 (55.4 and 53.1%) genotypes, whereas the Ege-88 had the lowest value (30.5%) (Table 3). Cosmodor, Kiziltan-91, Havrani, Sham-I, Dicle-74, Altintoprak-95 and Aningawoll genotypes had higher wet gluten value than those of the others. Gluten is the major component of flour protein that determines processing quality. Although it is a complex mixture of proteins, wet gluten reflects the gluten quality and quantity. Pasha et al. [5] reported 13.82-43.13% wet gluten content values.

Dry gluten contents varied from 9.8% (Akcakale-1005) to 16.9% (Kunduru-1149). It was shown that the content of dry gluten of Kunduru-1149, Selcuklu-97, Cosmodor, Sham-I, Havrani and Kiziltan-91 genotypes were slightly higher than other genotypes.

The present findings are in collaboration with the previous studies conducted by Curic et al. [31] who reported the range of dry gluten from 8.44% to 11.77% in flours of different wheat varieties, and Lin et al. [32] found the range of dry gluten from 7.0% to 16.7%. Gangadharappa et al. [4]

stated that dry gluten values were in the range of 7.93-9.60%. Indrani et al. [33] reported a 10.3% dry gluten value, while Pasha et al. [5] reported 4.46 -14.55% dry gluten values.

Gluten amount in wheat grain might be affected by genetic and climatic factors. Increasing environmental stress on wheat production associated with climate affects quality of wheat [19]. The contents of protein and dry gluten reflect the quality of wheat varieties [34]. 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. [7] emphasized climatic conditions affect kernel quality, protein and gluten composition of wheat kernel.

SDS-sedimentation values of durum wheat genotypes ranged between 22.0 ml (Akcakale-1001) and 46.0 ml (Kunduru-1149) (Table 3). High SDS values were found at Sham-I, Selcuklu-97, Kizilltan-91, Cosmodor, Altintoprak-98, Aningavoll and Havrani genotypes.

Table 2. Dry matter content, thousand kernel weight, test weight and vitreousness values of durum wheat genotypes

Genotypes	Dry matter (%)	Thousand kernel weight**(g)	Test weight ** (kg hl^{-1})	Vitreousness (%)
Aydin-93	92.5	38.90 b-f	85.0 a*	99.5
Harran-95	93.1	40.9 bc	82.2 b-f	98.1
Diyarbakir-81	93.0	38.8 b-f	81.2 c-h	99.5
Ceylan-95	93.1	40.4 bcd	83.0 abc	98.7
Saricanak-98	92.6	37.6 c-g	84.1 ab	99.9
Altintoprak-98	93.0	39.6 b-e	81.6 b-h	99.1
Dicle-74	92.8	43.0 ab	79.3 h	98.9
C.1252	92.8	36.6 c-h	80.8 c-h	99.3
Kiziltan-91	93.1	37.6 c-g	82.9 a-d	98.3
Kunduru-1149	92.8	35.5 e-h	80.6 c-h	98.9
Selcuklu-97	93.1	27.5 i	79.6 fgh	99.9
Akcakale-1001	92.8	40.7 bc	82.5 a-e	92.7
Akcakale-1005	93.0	40.7 bc	82.9 a-d	96.8
Gediz-75	92.8	39.6 b-e	81.0 c-h	93.2
Salihli-92	92.5	40.8 bc	84.1 ab	97.6
Sham-I	92.5	37.3 c-h	81.8 b-h	98.0
Altar-84	92.8	34.9 fgh	80.9 c-h	97.0
Zenith	93.1	36.2 d-h	81.0 c-h	98.1
Havrani	92.7	38.9 b-f	81.5 b-h	98.3
Mesaphia	92.9	37.6 c-g	82.8 a-d	98.3
Waha	93.0	34.3 gh	80.4 d-h	97.8
Korifla	93.0	36.8 c-h	80.1 e-h	98.6
Chambar-88	92.4	40.6 bc	79.4 gh	97.6
Massara	92.6	34.4 gh	79.3 h	97.4
Aningavoll	92.7	45.5 a	82.0 b-g	98.3
Cosmodor	92.7	37.3 c-h	79.6 gh	99.4
Gedifla	92.8	40.5 bcd	82.0 b-g	99.3
Firat-93	92.6	39.07 b-f	80.9 c-h	98.8
Duraking	93.0	33.1 h	81.3 c-h	95.8
Ege-88	92.9	36.0 e-h	82.7 a-e	98.1
Altintas-95	92.9	33.6 gh	82.5 a-e	98.0
Average	92.8	37.9	81.6	98.1

** 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 ≤ 0.01*

Table 3. Protein content, wet gluten, dry gluten and SDS values of durum wheat genotypes

Genotypes	Protein content** (%)	Wet Gluten** (%)	Dry Gluten** (%)	SDS** (ml)
Aydin-93	12.2 hij	35.9 j-m	11.6 k	28.0 mno
Harran-95	13.2 f-g	37.3 g-l	12.4 ijk	30.0 klm
Diyarbakir-81	14.1 c-l	38.0 f-k	12.3 jk	35.0 j
Ceylan-95	13.0 g-h	33.1 klm	11.6 k	26.0 opq
Saricanak-98	14.7 b-h	42.8 d-i	13.7 e-i	36.0 ij
Altintoprak-98	15.6 a-f	45.4 cde	14.6 b-f	41.0 def
Dicle-74	15.8 a-e	45.2 cde	14.9 b-e	40.0 efg
C.1252	15.2 b-g	43.6 d-g	13.7 e-i	38.0 ghi
Kiziltan-91	16.2 a-e	48.8 bcd	15.3 bcd	43.0 bcd
Kunduru-1149	17.9 a	55.4 a	16.9 a	46.0 a
Selcuklu-97	16.6 abc	53.1 ab	15.8 ab	44.0 abc
Akcakale-1001	12.4 hij	31.2 lm	10.1 l	22.0 s
Akcakale-1005	11.9 ij	31.5 klm	9.8 l	24.0 qrs
Gediz-75	11.5 j	33.4 klm	10.3 l	25.0 pqr
Salihli-92	13.7 e-j	37.5 f-l	12.8 h-k	37.0 hij
Sham-I	16.1 a-e	47.0 b-e	15.4 bcd	45.0 ab
Altar-84	12.4 hij	34.7 klm	11.8 k	28.0 mno
Zenith	15.2 b-g	42.4 d-j	14.4 c-g	37.0 hij
Havrani	16.9 ab	48.0 b-e	15.3 bcd	40.3 efg
Mesaphia	14.4 c-i	42.3 d-j	13.8 e-l	39.0 fgh
Waha	13.8 d-j	37.7 f-l	12.7 h-k	29.0 lmn
Korifla	14.4 b-i	41.8 e-j	13.9 e-l	39.0 fgh
Chambar-88	14.6 b-h	43.9 c-f	14.1 d-h	40.0 efg
Massara	13.2 f-j	36.3 i-m	12.2 jk	30.0 klm
Aningavoll	15.1 b-g	45.1 cde	14.9 b-e	41.0 def
Cosmodor	16.3 a-d	50.1 abc	15.7 abc	42.0 cde
Gedifla	13.9 d-j	43.3 d-h	13.2 g-j	38.0 ghi
Firat-93	15.0 b-g	42.7 d-i	13.4 f-j	32.0 k
Duraking	13.1 f-g	37.1 h-l	12.8 h-k	31.0 kl
Ege-88	12.4 hij	30.5 m	11.7 k	23.0 rs
Altintas-95	13.0 g-j	36.6 i-m	12.1 jk	27.0 nop
Average	14.3	41.02	13.3	34.7

** 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 ≤ 0.01*

Table 4. Correlation coefficients among dry matter, thousand kernel weight, test weight, vitreousness, protein content, wet gluten, dry gluten and SDS-sedimentation values

Traits	Thousand kernel weight	Test weight	Vitreousness	Protein content	Wet gluten	Dry gluten	SDS-sedimentation value
Dry matter	-0.278	-0.061	-0.007	-0.048	-0.089	-0.079	-0.137
1000 kernel weight	1	0.284	-0.120	-0.122	-0.163	-0.157	-0.039
Test weight	-	1	-0.129	-0.374*	-0.381*	-0.374*	-0.320
Vitreousness			1	0.549**	0.548**	0.584**	0.555**
Protein content	-	-		1	0.957**	0.961**	0.908**
Wet gluten	-	-		-	1	0.960**	0.938**
Dry gluten	-	-		-	-	1	0.940**

**: P ≤ 0.05, ** : P ≤ 0.01.*

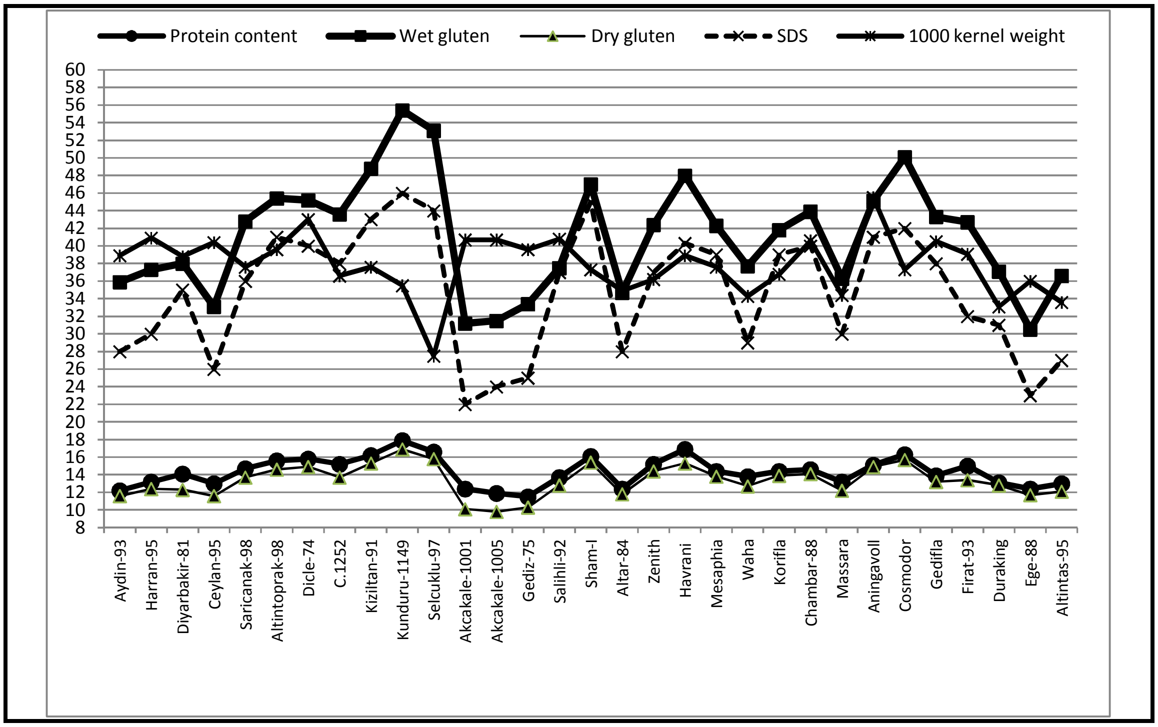

Fig. 1. Protein content (%), wet gluten (%), dry gluten (%), SDS (ml) and thousand weight (g) values of some durum wheat genotypes grown in semi-arid conditions

Sedimentation value reflects the quality of protein [13]. Pasha et al. [5] reported 19.67-36 mL SDS-sedimentation volume values. Gangadharappa et al. [4] measured 46 ml SDS-sedimentation value in wheat. Tonk et al. [25] reported higher SDS-sedimentation values of 46-95 ml in wheat. Balkan and Genctan [35] stated that SDS-sedimentation values should be between 30 ml 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-sedimentation values were below 30 ml. SDS-sedimentation values can be reduced in dry and hot environments [35]. SDS values increases with increasing temperature during grain filling up to about 30°C and then decreases as temperatures rise above 30 °C [36, 37]. 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 [6].

Regarding Correlation Coefficients relationships between quality traits have been investigated in some studies on bread wheat [7,38,39]. Correlation coefficients for some quality parameters are given in Table 4. According to correlation analysis; negative significant correlations were found between test weight and protein content, wet gluten and dry gluten at 0.05 level, respectively (Table 4). Relationships between vitreousness and protein content, wet gluten, dry gluten and SDS- sedimentation value were positive and significant ($P \leq 0.01$), respectively. Protein content was positive correlated with wet gluten, dry gluten and SDS-sedimentation value at the $P \leq 0.01$ level, respectively. Some researchers reported a correlation between protein and wet gluten [22,40,41,42,43]. A positive correlation between protein and dry gluten value is emphasized by Anjum and Walker [44]. An inverse relationship between protein content and SDS volume was reported by Rharrabti et al. [6].

Positive correlations between wet gluten and both dry gluten and SDS-sedimentation values were more and significant at level of 0.01 (Table 4). Similarly the significant positive correlation between SDS-sedimentation value wet gluten content was also reported by Ozturk and Aydin [43] and Pasha et al. [5]. There was significant correlation in positive direction between dry gluten and SDS-sedimentation value at the 0.01 level. Pasha et al. [5] emphasized a positive significant correlation of SDS-sedimentation value with dry gluten values.

4. CONCLUSION

The data obtained from our study indicate that quality characteristics of durum wheat genotypes were significantly different from each other. Kunduru-1149, Selcuklu-97, Cosmodor, Zenith, C.1252, Aningavoll, Altintoprak-98, Dicle-74, Kiziltan-91, Sham-I and Havrani genotypes were found to be of good quality among the tested genotypes. Differences in quality of durum wheat could be associated with differences environmental factors, genotypic structure and their interactions. Climatic conditions during grain filling appeared 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. 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.

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 more and significant. There was a positive significant correlation between dry gluten and SDS-sedimentation value.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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