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INVESTIGATION OF WHEAT GRAIN QUALITY CHARACTERISTICS UNDER WATER DEFICIT CONDITION DURING POST-ANTHESIS STAGE

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ABSTRACT

Nine wheat genotypes (DM-81-6, DM-82-1, Bahar, DN-11, DN-7, Pishtaz, WS-82-9, C-85-6 and C-84-12) were grown on research farm in Seed and Plant Improvement Institute, Karaj (Iran), under two water regimes (normal irrigation and no irrigation in post-anthesis growth stage) and in two growing seasons, to determine the effect of water regime on quality traits. Quality analyses were performed on grains: protein content, moisture content, hardness index, falling number, wet gluten, dry gluten, gluten index, zeleny sedimentation volume, bread volume and SDS sedimentation volume. The quality traits have differences among the genotypes. Water stress in the grain filling period was found to affect quality parameters. An increase in protein content, falling number, gluten index, dry gluten and SDS sedimentation volume, consistent with a decrease in grain yield, 1000 grains weight, bread volume and moisture content was observed when a terminal water stress happened. Likely water stress associated to with high temperature which in general happens under Mediterranean conditions over grain development, may have caused a higher accumulation of quality parameters.

Keywords: wheat, grain, quality traits, terminal drought stress.

INTRODUCTION

Wheat is one of the most important crops in the entire of the world. However, water is the most important restricting parameter for wheat growth. Wheat is grown under irrigated and rain-fed environments in all over the world. Under rain-fed environments the filling grains are exposed stress at grain filling stage (Wang *et al*., 2009). Certain genotypes can attract a price premium if it has a combination of suitable traits that make it desirable for bread making (Lerner *et al*., 2006).

The wheat grain quality properties are influenced by genotype, environmental parameters and interactions between genotype and environment. Undesirable environmental conditions during post anthesis period have been identified as a main limited to the wheat quality world entire (Jiang *et al*., 2009). Within a particular location, the environmental impacts on grain protein content and dough characteristics can be changed with a choice of irrigation regimes and varieties (Motzo, *et al*., 2007).

Water stress and high temperature are the principle environmental parameters affecting the wheat grain quality under Mediterranean conditions. Whereas many experiments have been conducted on the effect of high temperature on wheat quality traits, the effect of water stress has not been determined widely. It is known that yield fall that happens under drought stress environments is generally in relation to a rise in protein content (Pompa *et al*., 2009). In fact, water stress totally climbed protein content (Rharrabti *et al*., 2003b). Gooding *et al*. (2003), in experiments conducted in controlled conditions found out that the effect of moisture stress during grain filling on the quality characteristics, SDS sedimentation volume was dependent on the timing of stress. In particular, limiting water from the first to the 14th day over grain development significantly declined SDS volume compared to water stress applied later. In contrast to prior reports, Ottman *et al*. (2000) found that the impacts of irrigation frequency on wheat grain quality over grain development are contrasting. The findings differences in grain quality may cause both to differences in starch characteristics and in protein content, aggregation and composition level (Singh *et al*., 2008).

There are inconsistent reports about the effect of water stress on wheat grain quality depending on the variability of study conditions, different experimental methods, and stress imposed. So, in this article presents the effect of water stress occurring under Mediterranean conditions on grain development stage on wheat quality traits was investigated in two different crop seasons.

MATERIALS AND METHODS

Field experiments were conducted in Seed and Plant Improvement Institute, Karaj (Iran) (50◦, 57_N; 35◦, 48, E elevation 1231 m above mean sea level) over two growing seasons (2007-2008 and 2008-2009) on a loam soil. Nine wheat genotypes (DM-81-6, DM-82-1, Bahar, DN-11, DN-7, Pishtaz, WS-82-9, C-85-6 and C-84-12) were sown on November 1 in both 2007-2008 and 2008-2009, at a seeding rate of 400 seeds m^{-2}. Every year, before planting, per phosphate was added into the soil at an amount of 70 kg P ha^{-1}; nitrogenous fertilizer as ammonium nitrate was incorporated at a rate of 65 kgNha^{-1} (1/3 at sowing and 2/3 at tillering stage).

Two different water regimes were applied: irrigated, where the plots were irrigated 6 times and no irrigation in post-anthesis growth stage; in both two water regimes, water was used for establishes the field capacity of the 0.35m soil profile. In both two years, six irrigations of 480m^3 ha^{-1} were necessary: three during the vegetative period and three over the grain development period.

The experiment was conducted in a split-plot design with two factors (water regime in main-plots and wheat cultivars in sub-plots) and 3 replications; each sub-plot was 144m^2. Harvest time was July 5 in 2008 and July 9 at 2009.

In this experiment, two days before harvest about 6 square meter area of each plot were harvested at maturity and for each treatment at each replicate. Grain weighed after drying for 48 hours at 75^{0}C. Grain yield and thousand grain weight were measured in both 2 years. Thousand grain weight was measured by using a Contador seed counter (Pfeuffer GmbH, Kitzingen, Germany).

Plots were harvested; a sub-sample of nearly 600 g was taken from each plot and passed over a 2 mm sieve. These sub-samples were investigated for hardness and grain protein, using an Infra-Tec 1241 Food Analyser, as explained by Agu *et al*. (2009). For grain hardness, would have been according to the SKCS method for hardness definition (Agu *et al*., 2009).

The SDS sedimentation test was evaluated by Dick and Quick (1983), modified based on C.O. Qualset as explained in Carrillo *et al*. (1990). Breadmaking quality was evaluated using indirect factors. Indirect factors were wet gluten content (WGC) (ICC standard method 137), Zeleny sedimentation volume was measured using AACC method 56-61A. And dry gluten content by device Glutork 2020 from Perten Company by drying of the wet gluten at 160^{0}C for five minutes.

The gluten index is a test for the determination of gluten strength. It was determined using the Glutomatic system according to ICC standard 155 (ICC, 1986). Falling number was determined according to the Rapid Visco Analyser (RVA), as explained in the applications manual using the RVA falling number method.

Software analysis

For all the evaluated traits, the analysis of variance (ANOVA) was performed using a split-plot design by SAS Institute Inc, (2002). Significant differences among the mean values were assessed by Duncan's multiple range method at 0.05 probability level. The data for all variables under experiment correlations were also calculated.

RESULTS AND DISCUSSIONS

The analysis of variance (Table-1) indicated a significant effect of irrigation regime and genotype for all the quality factors evaluated with the exception of protein content and hardness index for the genotype, Zeleny sedimentation volume, hardness index and wet gluten for the irrigation regime. There are no significant interactions among mentioned factors.

As for irrigation regime, protein content, falling number, gluten index, dry gluten and SDS test increased with moisture stress (Table-2). Among the nine evaluated genotypes no significant difference was observed in protein content and hardness index, whereas significant differences among genotypes were observed in the other quality factors (Table-2).

The correlations among all the quality parameters determined are indicated in Table-3. The quality factors gluten index and zeleny sedimentation volume found to be correlated with each other. Also zeleny sedimentation volume showed a significant correlation with bread volume. A negative correlation was indicated between index and wet gluten. As expected the hardness index, falling number and bread volume were correlated with each other. High negative correlations were appeared between Protein content and Zeleny sedimentation volume as well as Protein content and SDS sedimentation volume.

In relation to water stress effect on grain quality, we observed an increase in protein content that had already been previously found by other authors in different environments (Guttieri *et al*., 2005). In Mediterranean climates, water stress in combination with high spring temperatures (Garrido-Lestache *et al*., 2005). Also quality parameters improved under water stress, by Garrido-Lestache *et al*. (2004) who observed maximum values of technological indexes when rainfall was lowest in Mediterranean conditions. Rharrabti *et al*. (2003) observed a positive relationship between SDS volume and water stress during post-anthesis stage. The positive response of gluten index to moisture stress during post-anthesis stage, observed under our experimental environments, has also been reported by Garrido-Lestache *et al*., (2005). With regard to genotype effect, these results are consistent with De Vita *et al*. (2007) who found that different cultivars have different quality traits.

The quality factors falling number, hardness index and bread volume observed to be correlated with each. In agreement with Brites and Carrillo (2001) and Clarke *et al.* (2004) we observed no correlation between protein content and gluten index. As well as we found a negative correlation between SDS test and protein content that it is agreeing with Boggini *et al*. (1997) and Rharrabti *et al*. (2003). On the contrary to our findings, Flagella *et al*. (2002) and Clarke *et al*. (2004) found a positive correlation between protein content and SDS test. These conflicting results may be shown since protein content may depend on SDS sedimentation volume.

CONCLUSIONS

The different water regimes influenced wheat quality characters in the two years. In particular, in the water stress condition achieve the highest protein content, bread volume, falling number, gluten index, dry gluten and SDS sedimentation volume. When a terminal water stress happened in post-anthesis stage an improvement in protein content was observed consistently with an increase in the amount of gluten index and SDS sedimentation volume. Therefore it seems that a water deficit that generally occur under Mediterranean conditions during grain development, may have promoted the aggregation of quality traits. A high influence of genotype was observed on all parameters, except of hardness index and protein content.

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Table-1. Analysis of variance for quality parameters, grain yield and thousand grain weight.

							Means of square						
Source of Variance	**DF**	**Grain yield**	**1000 grains weight**	**Protein content %**	**Zeleny sedimentation volume**	**Bread volume**	**Moisture content %**	**Hardness index**	**Falling number**	**Wet gluten %**	**Gluten index**	**Dry gluten**	**SDS sedimentation volume**
Year	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
year* replication	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
irrigation	1	**	**	*	NS	*	*	NS	*	NS	**	*	*
Year*irrigation	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Replication*irrigation (year)	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
genotype	8	**	**	NS	**	**	*	NS	*	**	**	*	**
Year* genotype	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
genotype *irrigation	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Year* genotype *irrigation	8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Coefficient of variation		11.0	11.8	15.1	4.9	4.9	2.3	3.4	18.3	6.6	17.6	19.9	8.2

ns. = not significant.
* $P \leq 0.05$.
** $P \leq 0.01$.

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Table-2. Effect of water regime and genotype on the quality parameters.

Genotype	**Grain yield** (ton hec^{-1})	**Thousand grains weight** (gr)	**Protein content %**	**Zeleny sedimentation volume**	**Bread volume**	**Moisture content %**	**Hardness index**	**Falling number**	**Wet gluten %**	**Gluten index**	**Dry gluten**	**SDS sedimentation volume**
DM-81-6	5.9 cd	34.9 bc	14.8	35.6abc	474.5b	11.2bc	56.4	508.4b	37.3ab	50.6c	16.8b	58b
DM-82-1	6.5 bc	33.8 bcd	14.2	36.4ab	494a	11.2bc	56.4	596.5a	35.9bc	61.4b	20.4a	63.9a
Bahar	5.7 d	27.3 f	13.7	36.7a	472.6b	11.5a	54.6	455b	33.7de	59.5b	16b	66.5a
DN-11	7.3 a	35.7 b	15	34.6c	442.6c	11.3ab	54.5	486.4	33.3de	43cd	19.8a	63.7a
DN-7	6.7 b	36.2 b	14.6	34.9bc	455.4bc	11.2bc	55.3	507.5b	35.1cd	38.5d	15.7bc	61.5b
Pishtaz	6.6 b	31.5 cd	14.9	35.5abc	469.4b	11c	56	458.7b	31.7e	86.5a	15.2c	63.3a
WS-82-9	6.4 bc	40.8 a	13.1	35bc	460.3bc	11.2bc	54.8	476.5b	38a	46cd	16.6b	63.9a
C-85-6	6.2 bcd	30.9 d	12.9	35.6abc	470.1b	11.2bc	54.8	489.6b	35.8bc	45.5cd	20.9a	65.1a
C-84-12	6.4bc	35.8b	12.5	37a	460.1bc	11.4ab	55.6	466.4b	33.6de	83.8a	15.5c	65.8a
irrigation												
Normal irrigation	7.5 a	37.5 a	11.9 b	34.8a	480.2a	11.30a	56.2	473b	37.6	52.8b	16.5b	61.7b
Terminal drought stress	5.3 b	30.2 b	13.2 a	36.6a	452.9b	11.19b	54.6	514a	32.2	61.6a	18.33a	65.3a

Values in a row followed by different letters are significantly different at P≤0.05 by Duncan's multiple range method

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Table-3. Correlation matrix of the quality parameters

	Protein content %	Zeleny sedimentation volume	Bread volume	Moisture content %	Hardness index	Falling number	Wet gluten %	Gluten index	Dry gluten
Protein content %	1								
Zeleny sedimentation volume	-0.53*	1							
Bread volume	0.06 ns	0.63*	1						
Moisture content %	-0.42 ns	0.42 ns	-0.14 ns	1					
Hardness index	0.29 ns	0.35 ns	0.63*	-0.42 ns	1				
Falling number	0.22 ns	0.05 ns	0.58*	-0.22 ns	0.53*	1			
Wet gluten %	-0.23 ns	-0.09 ns	0.24 ns	-0.06 ns	0.09 ns	0.41 ns	1		
Gluten index	-0.15 ns	0.62*	0.28 ns	-0.06 ns	0.44 ns	-0.23 ns	-0.59*	1	
Dry gluten	-0.01 ns	-0.21 ns	0.20 ns	-0.05 ns	-0.12 ns	0.56 ns	0.24 ns	-0.42 ns	1
SDS sedimentation volume	-0.62*	0.39 ns	-0.03 ns	0.48 ns	-0.54*	-0.29 ns	-0.40 ns	0.31 ns	0.11 ns

n.s. = not significant.
* P≤0.05.
** P≤0.01.