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EFFECT OF WATER STRESS ON PHYSICO-CHEMICAL PROPERTIES OF WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract

In this study, seven water stress tolerant wheat genotypes including two exotic viz., Nesser and Dharwar dry and five local verities viz. GA-2002 Bakhar-2002, Chakwal and Inqulab-91 and Kolhistan-97 were crossed with university drought susceptible lines viz. 9244, 9247, 9252, 9258, 9267, 9316 and 9021 by using line x tester mating design. The objective of the study was to evaluate the effect of water stress on physioco-chemical properties of wheat grains. Moisture, ash, fat, protein, gluten, Zeleny, thousand kernel weight and grain yield values showed different response under normal and water stress environments. The quality traits of wheat grain were significantly affected under water stress conditions. The moisture content decreased while other constituents, predominantly protein contents increased in the entire cross breeds under water stress conditions. The protein showed positive correlations with dry gluten and Zeleny values while negative correlation with ash content of grain under normal and stress conditions The protein contents, gluten quality and contents have significantly negative correlations with grain yield and thousand kernel weights under stress condition, so it is imperative for breeders to balance these characters through genetic manipulation.

Introduction

Food security in the world is challenged by increasing food demand and threatened by declining water availability (Zwart & Bastiaanssen, 2004). The main stay of Pakistan's economy is based on agriculture. Among the major crops, wheat is a dominant crop. It contributes 13.7% to the value added in agriculture and 30% to the total GDP of the Pakistan (Anon., 2006). The wheat yield in rain fed area is approximately one half as compared to irrigated area (Anon., 2005). Wheat is a prime food cereal of the people of Pakistan and occupies a pivotal position in their daily food consumption. It is mainly consumed in the form of flat breads (chapatti, naan, roti) which have served as a staple diet to the inhabitants of this region (Nurul-Islam & Johansen, 1987). Moreover, it is the cheapest source, providing more than 72% of the calories and proteins to people of the region.

Wheat breeders are continuously trying to improve the wheat yield under water stress conditions but paying less attention on its quality characteristics. The quality of wheat grains greatly affects the quality of flat breads (Rehman *et al.,* 2006). The cultivars grown for chapatti production vary in physico-chemical, rheological and functional characteristics due to the variations in soil, weather and agronomic practices (Rehman *et al.,* 2007). Even though, the quality of wheat is governed by the interaction of many constituents but protein quality and quantity play a vital role in the production of good quality chapatti (Prabhasankar, 2002). The contents of total storage proteins and individual classes of gliadin and glutenins can be influenced during development of grains by many factors including frequency of irrigation water, rainfall and fertilizers, play a fundamental role in the viscoelastic properties of gluten (Rehman *et al.*, 1997). During production of chapatti, hydration of gluten proteins yields mass that can be sheeted but retains recoil or spring (Kuktaite *et al.*, 2004).

The quality of the end product depends upon quality of wheat grain (Finney *et al*., 1987). The wheat suitable for one particular product may have certain qualities that are totally unsatisfactory for other products (Halveson & Zeleny, 1988). The quality of wheat can be affected by winter stress (Ahmad & Arain, 1999). So, the time has come to classify the wheat genotypes on quality traits to combat world trade as well as millers, bakers and end users needs (Morris, 2002).

Keeping in view the above facts, this project was designed to determine the effect of water stress on physio-chemical properties of wheat and to characterize genotypic yield response and quality response to water stress conditions and normal as well. Another objective was to study correlation of different quality parameters.

Materials and Methods

Seven water stress tolerant wheat genotypes including two exotic *viz*., Nesser and Dharwar dry and five local verities *viz*., GA-2002, Bakhar-2002, Chakwal and Inqulab-91 and Kolhistan-97 were crossed with university drought susceptible lines *viz*., 9244, 9247, 9252, 9258, 9267, 9316 and 9021 by using line x tester mating design as described by Kempthorne (1957). F_1 seeds along with parents were sown in two experiments by using randomized complete block design with three replications. In experiment-I, the normal irrigation was given, while in experiment-II, irrigation was given after sowing. At maturity ten gendered plants from each replication in each experiment were selected randomly. The data were subjected to statistical analysis using analysis of variance (Steel *et al*., 1997). Using yield as yard stick, best yielding genotypes Nesser, Dharwar Dry, Nesser x 9244, Nesser x 9316, Nesser x 9252, Dharwar Dry x 9267, Dharwar Dry x 9316, Dharwar Dry x 9252, GA-2002 x 9252 and Inqlab-91 x 9316 from normal as well water stressed conditions were selected for quality based physico-chemical parameters such as thousand kernel weight, moisture, fat, ash, protein, gluten and Zaleny sedimentation test according to methods described in Anon., (2000).

Results

Analysis of variance was performed for all eight traits. Mean square of physico-chemical traits in wheat genotypes are given in Table 1. According to the results, differences among genotypes are highly significant for all the traits indicating high variability among genotypes.

The results of physico-chemical analysis delineated that the cross breed Nesser x 9244 contained high moisture content, while the genotype Dharwar Dry x 9252 performed best for Ash contents (Table 2). However, Nesser x 9316 showed an excellent performance in the concentration of crude fat. The genotype Nesser x 9252 performed well for protein, genotype GA-2002 x 9252 remained best for gluten contents, while genotype Nesser x 9244 showed an excellent performance in Zeleny sedimentation test indicating good quality of protein.

Table 1. Mean squares of physico-chemical traits of wheat genotypes.

S.O.V.	d.f.	Grain yield	Thousand kernel weight	Moisture	Ash	Fat	Protein	Dry gluten	Zeleny
Replication	2	0.20	0.44	0.00	0.00	0.004	0.104	0.281	1.74
Genotypes	9	30.50	27.30	0.146**	0.033**	0.024**	0.967**	1.802**	9.428**
Treatments	1	1029.60	899.08	1.601**	0.925**	2.659**	14.104**	19.55**	356.58**
GxT	9	5.74	2.30	0.047**	0.012**	0.015**	0.447**	0.147**	41.78**
Error	38	0.46	0.43	0.001	0.002	0.002	0.35	0.019	0.418

Significant at $p<0.05$ ** Significant $p<0.01$ NS = Subject

Table 2. Mean values of physico-chemical traits under normal irrigation environment.

Genotypes	Grain yield (g)	Thousand kernel wt. (g)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Dry gluten (%)	Zeleny value
Nesser	27.10a	37.78e	11.44de	1.78bc	2.11e	11.22c	13.67e	55.37d
Dharwar dry	27.30a	38.32d	11.39e	1.71d	2.21bcde	11.37c	13.91d	57.10b
Nesser x 9244	24.70e	39.40b	11.82a	1.80ab	2.27abc	12.13b	14.42c	60.07a
Nesser x 9316	26.83ab	40.29a	11.70b	1.80ab	2.33a	12.55a	14.06d	59.64a
Nesser x 9252	27.33a	36.22f	11.74b	1.55e	2.22bcd	12.78a	14.06d	55.50d
Dharwar Dry x 9267	25.87c	39.24bc	11.75b	1.73d	2.15de	12.70a	14.16d	52.92f
Dharwar Dry x 9316	25.47d	39.61b	11.50b	1.54e	2.24bcd	12.08b	13.53e	54.29e
Dharwar Dry x 9252	25.83c	35.63g	11.67b	1.83a	2.28abc	12.76a	14.03d	57.01b
GA-2002 x 9252	23.03g	33.88h	11.60c	1.77bc	2.29ab	12.72a	15.24a	56.19bc
Inqlab-91 x 9316	23.55f	40.37a	11.70bc	1.75cd	2.18de	12.11b	14.86b	56.72b

Means sharing the same letters within a column do not differ significantly at 5% probability

The grain yield, thousand kernel weight, moisture, ash, fat, protein, gluten and Zelney ranged between 23.03-27.33 g, 33.88-40.37 g, 11.39-11.82%, 1.55-1.83%, 2.11-2.33%, 11.22-12.78, 13.67-15.24% and 55.37-60.07, respectively under normal irrigation condition (Table 2). The grain yield, thousand kernel weight, moisture and fat contents were severely affected while other constituents particularly protein and gluten contents increased in all the cross breeds under water stress conditions (Table 3).

The results of correlation among the quality traits under normal irrigation and water stress conditions are presented in Table 4 and Table 5, respectively. The protein content has positive correlations with dry gluten content and Zeleny values while negative correlation with ash content under normal, while negative under water stress conditions. The yields of dry gluten fraction were closely associated with protein content of their wheat flours but the dry gluten contents were found more, might be due to the retention of starch and other non-glutinous matters (Rehman *et al.*, 2007).

Discussion

Water stress has a significant effect on the physio-chemical properties of wheat. The treatment and genotype x treatment interactions were significant for all quality traits, these results are supported by findings of Fenn *et al*., (1994) and Retenson *et al*., (1998). Cox *et al*., (1989) concluded that any decline and deterioration in the quality of wheat is caused by non genetic factors such as changes in environment. Guttieri *et al*., (2001) investigated sixteen spring wheat cultivars produced under two moisture-deficit regimes in 1995 and 1996 to determine the effects of moisture-deficit severity on grain yield, test weight and flour protein. Moisture deficit differentially and significantly influenced cultivar test weight and yield. The overall moisture-deficit-induced reduction in grain yield was due primarily to reduction in thousand kernel weight; effects of moisture deficit on yield of specific cultivars were due largely to effects on kernels per spike. Otteson *et al*., (2008) observed that the end-use value of hard wheat has been affected by many factors including grain protein content, grain volume weight, thousand-kernel weight. These quality traits can be affected by environment, genotype, seeding rate, and nitrogen management. Experiments conducted under dry land and irrigated conditions and revealed that genotype was the only factor that consistently affected the various quality traits. Similar studies were conducted by Guttieri *et al*., (2005) who observed that genotype, nitrogen fertilizer and irrigation affected grain protein concentration which differed significantly in their optimum nitrogen levels for grain yield. Reducing the amount of irrigation elevated grain protein concentration, however, it also reduced milling yield, might be due to the increase in fiber content and decrease in kernel weight under water stress condition. Moreover, the protein content depends in part on variety and class and environmental conditions during growth. Abundant rainfall during the period of grain development results in low content, whereas dry conditions during that period favour high protein content Souza *et al*., (2004). The available soil nitrogen also has a considerable effect on protein content. The sedimentation test developed by Zeleny *et al*., (1960) is useful method for estimating the gluten strength of wheat grain. This value is influenced by quantity as well as quality of the gluten. Zeleny *et al*., (1960) reported the usefulness of this test in early-generation wheat breeding work and the prospect of a micro-technique that would evaluate the strength of wheat from a single plant. Gluten quality is mainly a varietal's characteristic but high temperatures and low relative humidity during the period of grain maturing have a striking harmful effect on the quality of gluten. The water stress has played a key role to reduce the moisture percentage and fat, while it increased protein, ash, gluten contents and Zeleny sedimentation test. Similar findings have also been reported by Gudeira *et al*., (2002) and Mary *et al*., (2001).

Table 3. Mean values of physico-chemical traits under water stress environment.

Genotypes	Grain yield (g)	Thousand kernel wt. (g)	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Dry gluten (%)	Zeleny value
Nesser	21.85a	32.07b	10.90g	1.94abc	1.92a	12.47d	14.75c	60.34c
Dharwar dry	21.81a	28.11f	11.22e	1.90c	1.82b	13.19bcd	15.05b	61.33b
Nesser x 9244	15.60d	30.16d	11.37c	2.06a	1.78bc	13.92a	15.20b	62.31a
Nesser x 9316	18.40b	32.31b	11.20e	1.95abc	1.92a	13.04cd	15.27b	60.44c
Nesser x 9252	18.00bc	29.56e	11.50b	1.97abc	1.86ab	13.48b	15.17b	59.27d
Dharwar Dry x 9267	15.10d	32.13b	11.29d	2.05ab	1.73c	13.26bc	15.13b	60.95bc
Dharwar Dry x 9316	17.87c	31.72bc	11.14f	1.88c	1.72c	13.18bcd	14.37d	61.16b
Dharwar Dry x 9252	18.90b	28.02f	11.63a	1.97abc	1.80bc	13.43b	15.73b	62.54a
GA-2002 x 9252	12.20f	26.28g	11.50b	2.03ab	1.86ab	12.91d	16.18a	61.50b
Inqlab-91 x 9316	14.43e	32.96a	11.30d	2.04ab	1.63d	13.24bc	16.18a	60.48c

Means sharing the same letters within a column do not differ significantly at 5% probability

Table 4. Correlation coefficients among quality traits under normal irrigation environment.

Traits	Grain yield	Thousand kernel wt.	Moisture	Ash	Fat	Protein	Dry gluten	Zeleny value
Grain Yield	1.000							
Thousand kernel wt.	0.131	1.000						
Moisture	-0.300	0.117	1.000					
Ash	-0.241	-0.047	0.172	1.000				
Fat	-0.218	-0.180	0.307	0.168	1.000			
Protein	-0.258*	-0.540*	0.317	-0.266	0.096	1.000		
Dry gluten	-0.814**	-0.311*	0.412	0.367	0.260	0.304	1.000	
Zeleny value	-0.231*	-0.743*	0.397	0.378	0.125	0.106	0.215	1.000

Table 5. Correlation coefficients among quality traits under water stress environment.

Traits	Grain yield	Thousand kernel wt.	Moisture	Ash	Fat	Protein	Dry gluten	Zeleny value
Grain yield	1.000							
Thousand kernel wt.	0.094	1.000						
Moisture	-0.482	-0.630	1.000					
Ash	-0.768**	0.009	0.425	1.000				
Fat	0.436	-0.309	-0.147	-0.307	1.000			
Protein	-0.281*	-0.136*	0.609	0.375	-0.418	1.000		
Dry gluten	-0.620*	-0.355*	0.620	0.632*	-0.189	0.095	1.000	
Zeleny value	-0.342*	-0.782*	0.370	0.162	-0.211	0.406	0.079	1.000

Correlation coefficients were calculated to establish relationship between quality traits and grain yield (Iwona *et al*., 2004). The results of correlation of quality traits showed positive and negative responses in irrigation as well as in water stress environment (Tables 4 & 5). The protein contents, gluten quality and contents have significantly negative correlations with grain yield and thousand kernel weights under normal and stress conditions (Oury & Godlin, 2007), so it is imperative for breeders to pay attention to balance these characters through genetic exploitation.

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