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GRAIN QUALITY ATTRIBUTES OF WHEAT LINES HAVING DIFFERENTIAL PHOTOSYNTHETIC EFFICIENCY UNDER PROLONGED DROUGHT STRESS

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Abstract

Twenty wheat lines were tested for drought tolerance in terms of relative chemical composition and physical properties of grains. These wheat lines were selected on the basis of maintaining their photosynthetic potential under drought stress. There were two treatments of drought stress, normal irrigation and no irrigation throughout crop growth period. Exposure of wheat plants to continuous drought stress (rain fed) led to an increase in total proteins and gluten contents in grain. Grain zeleny concentration of water stressed plants was significantly lower than those of normally irrigated plants. Average grain diameter differed non-significantly but grain hardness decreased significantly in plants experiencing long term drought compared with drought untreated ones. A wheat lines had a differential response to water limited environment in terms of grain quality attributes and their performance was not dependent on their photosynthetic potential.

Introduction

Water, the main component of a plant body (Ulukan, 2008), is the major abiotic limiting factor for plant growth and development (Zhao *et al.*, 2009; Ji *et al.*, 2010), adversely affecting crop yield and food grain production (Bandurska & Stroinski, 2003). Agricultural sector is on the top, for consumption of fresh water (70%) globally (Siebert, 2010). Out of total world crop land area, about 25% (0.407 billion hectare) is irrigated and rain fed areas of the world are three times greater (1.13 billion hectare) than irrigated areas (Biradar *et al*., 2008; Felix *et al*., 2010). Scientists have indicated that future agricultural practices will take place under water scarcity (Fereres & Soriano, 2006). Under the circumstances, there is need to increase crop production per unit water used to get maximum benefits of available water (Ritchie & Basso, 2008).

Wheat, the most commonly consumed cereal crop by human beings is among the broad spectrum nutritious appealing foods (Morris *et al.,* 2002). Wheat grains trade at international level is mainly based on grain hardness attributes and physical and chemical changes affects market value of grains. The wheat growing areas of world are also facing the problem of water shortage and irregular rainfall pattern (Bagci *et al.*, 2007). Drought stress induces many biochemical and physiological changes in wheat plant (Ashraf *et al.,* 1998; Ashraf, 2010; Iqbal *et al*., 2011), which ultimately affects grain yield and quality (Zhang *et al.*, 2010). Hence, it is necessary to explore the genetic potential of wheat genotypes, having drought tolerance potential in terms of both grain yield and quality.

Wheat grain quality varies, depending upon the selection of genotypes (Otteson *et al.*, 2008) and environmental conditions (Acuna *et al.*, 2005). Nutritive value of wheat grains mainly depends upon the concentration of different macromolecules (Behboudian *et al.*, 2001), especially starch and protein (Singh *et al*., 2008). Advanced wheat lines generally have less grain proteins than their ancestors (wild lines), indicating that plant breeders give more emphasis on improving grain yield and not quality (Acuna *et al*., 2005). Water stress causes reduction in protein synthesis resulting reduced grain protein, the most important factor in yield determination (Wang *et al*., 2006; Pierre *et al*., 2007). Synthesis of starch is another main factor determining grain yield in cereals (Emes *et al.*, 2002). Water stress has varying effects on starch biosynthesis depending upon the crop stage and genotype selection. It is well reported that grain quality attributes depends upon supply of assimilates at anthesis stage (Rotundo *et al*., 2009; Seebauer *et al*., 2009) and assimilate availability directly depends on photosynthetic activity (Kuanar *et al*., 2010). It was hypothesized that physiological variations within wheat lines under water limited environment will reflect in yield attributes.

In our previous work, it was observed that different wheat genotypes showed varying responses towards drought stress in terms of flag leaf photosynthesis (unpublished data). The present study was conducted to find out weather wheat genotypes with better photosynthetic potential under drought stress also show their superiority towards grain quality attributes.

Materials and Methods

The study was carried out to explore the effects of continuous water shortage on grain quality of 19 newly developed CIMMYT wheat lines with a local check. In a previous study, we categorized these wheat lines on the basis of maintaining photosynthetic potential under drought stress. The wheat lines showing less than 5% reduction in photosynthetic rate were categorized in group A, and wheat lines which showed 10-20% and more than 20% reduction were categorized in groups B and C, respectively. Following wheat lines were used in present experiment.

i. Group A

(L-1) WBLL4//OAX93.24.35/WBLL1
(L-2)
MILAN//PRL/2*PASTOR/4/CROC_1/AE.SQUARROSA(213)//PGO/3/BAV92

(L-3) TC870344/GUI//TEMPORALERA M 87/AGR/3/2*WBLL1
(L-4) SERI/BAV92//WBLL1
(L-5) QT9155//JUN/BOMB/3/FILIN/2*PASTOR
(L-6) W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1

ii. Group B

(L-7) FSD 08 (local check)
(L-8) CHRZ//BOW/CROW/3/WBLL1/4/CROC_1/AE.SQUARROSA (213)//PGO
(L-9) SOKOLL/3/PASTOR//HXL7573/2*BAU
(L-10) SUNCO/2*PASTOR//EXCALIBUR
(L-11) CHRZ//BOW/CROW/3/WBLL1/4/CROC_1/AE.SQUARROSA(213)//PGO
(L-12) CROC_1/AE.SQUARROSA (224)// OPATA/3/RAC655
(L-13) (213)//PGO/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/ SERI/7/VEE#10/8/OPATA
(L-14) TC870344/GUI//TEMPORALERA M 87/AGR/3/2*WBLL1
(L-15) MEX94.27.1.20/3/SOKOLL//ATTILA/3*BCN

iii. Group C

(L-16) PASTOR//HXL7573/2*BAU/3/SOKOLL/WBLL1
(L-17) BOW//BUC/BUL/3/KAUZ/4/CHOIX/5/HEILO
(L-18) QT9155//JUN/BOMB/3/FILIN/2*PASTOR
(L-19) CROC_1/AE.SQUARROSA
(L-20) NS-732/HER/3/PRL/SARA//TSI/VEE#5/4/FRET2

Healthy grains of all wheat lines were selected and sown at field area of Wheat Research Institute, Faisalabad, Pakistan using randomized complete block design (RCBD) with four repeats. The wheat lines were subjected to two drought stress treatments, normal irrigation and no irrigation throughout crop season (rain fed). The mean value for pH was 6.3 and electrical conductivity of the soil 2.4 dS m^{-1}. Total rainfall during the months (Nov-Apr) of crop growth season was 16.3 mm. The crop was harvested at maturity and grain quality attributes were recorded. Seed protein, gluten and zeleny were estimated by Kernelyzer/ Omega analyzer (Bruins Instruments, USA). Single kernel characterization system (Model SKC 4100: Perten Instruments, Australia) was used to determine moisture per grain, grain hardness and grain diameter. Analysis of variance (ANOVA) technique was applied to analyze the data using COSTAT computer program. The Student Newman Keuls Test was applied to test the significance of differences among mean values (Steel *et al.*, 1997).

Result

Analysis of variance of data revealed that wheat plants grown under normally irrigated conditions differed highly significantly for grain protein from those grown under water limited environment. In general, wheat lines showed increasing trend in total grain proteins, except three wheat lines with moderate reduction photosynthetic rate under drought stress viz., L-9, L-11, L-12 (Fig. 1), and one with more reduction in photosynthetic rate, L-19 (These 4 lines showed decreasing trend in grain protein).

A marked reduction in grain moisture was observed due to drought stress (Fig. 2). Wheat plants growing under normally irrigated conditions showed 15% higher value for grain moisture than those growing under water limited conditions. Wheat line, L-20 though have reduced photosynthetic efficiency under drought stress, showed less reduction (5%) in grain moisture followed by L-12 (7.7%) and L-13 (9.8%). Grain gluten contents of drought stressed plants were slightly higher (2%) than unstressed plants. All wheat lines showed varying behavior towards grain gluten (Fig. 3).

All wheat lines showed differential behavior towards grain zeleny contents. Plants grown under normal irrigated conditions showed 8 % higher value for grain zeleny than those grown under water limited conditions (Fig. 4). Wheat lines, with high photosynthetic efficiency L-5 and moderately efficient lines L-14 and L-7 showed an increasing trend in zeleny concentration due to drought stress. In contrast, these wheat lines having normal photosynthetic rate L-13, L-12 and L-8 showed less value for grain zeleny when grown under drought environment in comparison with normally irrigation.

Analysis of variance of data revealed that wheat plants grown under normally irrigated conditions differed highly significantly for grain hardness from those grown under water limited environment. Plants grown under normally irrigated conditions showed 4% higher value for grain hardness than those grown under water limited conditions. Average photosynthetic ability carrying wheat lines, L-15 and L-9 (Fig. 5) showed minimum values for grain hardness under both normally irrigated and drought stressed environment.

Statistical analysis of the data revealed that wheat plants grown under normally irrigated conditions did not differ significantly for average grain diameter from those grown under water limited conditions. Drought stress also increase average grain diameter (Fig. 6).

Discussion

Wheat grain quality attributes are affected by various physiological processes taking place at different developmental stages (Niu *et al.*, 2010). The present study was conducted to find out weather drought tolerance ability of different wheat genotypes in term of flag leaf photosynthesis also reflects in their grain quality attributes. Among different attributes, grain protein percentage is the main selection criteria for determination of grain quality (Pettigrew, 2008). In present study grain quality measurement revealed differential response of wheat genotypes regardless of their photosynthetic potential. Most of the wheat genotypes showed higher value for grain protein when subjected to continuous drought stress. Some other scientists working on wheat x drought interaction also reported an increasing potential percentage under drought stress (Gooding *et al.*, 2003; Weightman *et al.*, 2008; Noorka *et al.*, 2009). In contrast, Pierre *et al.*, 2008 observed decreased value for grain protein in wheat growing under drought stress.

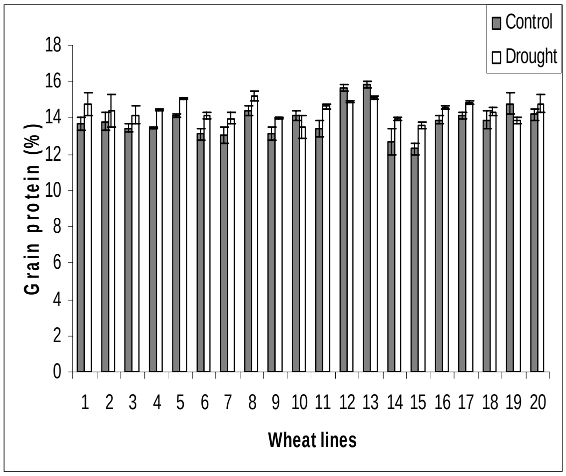

Fig. 1. Grain protein (%) at maturity of twenty wheat lines grown under normal and water limited environment

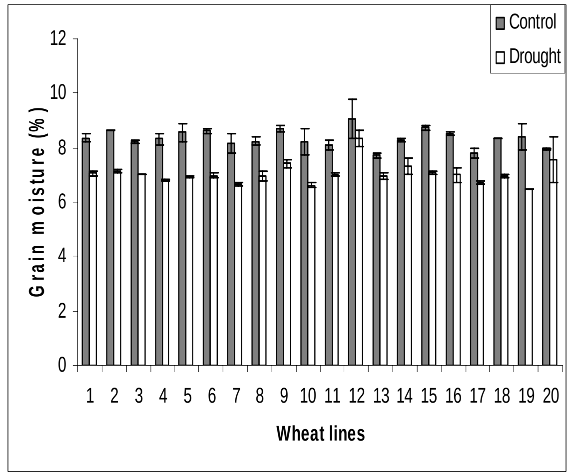

Fig. 2. Grain moisture (%) in grains at maturity stage of twenty wheat lines grown under normal and water limited environment.

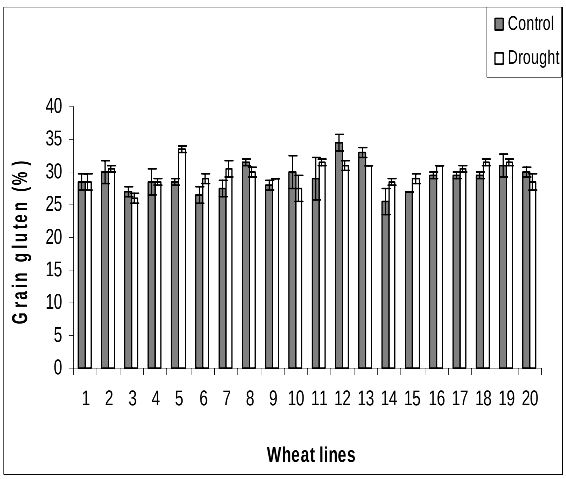

Fig. 3. Grain gluten (%) at maturity stage of twenty wheat lines grown under normal and water limited environment.

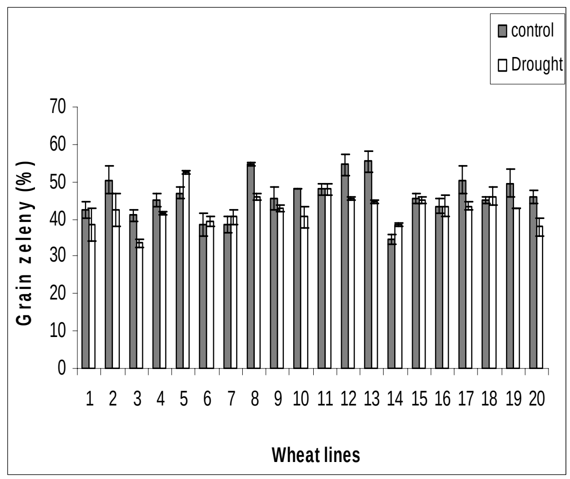

Fig. 4. Grain zeleny (%) at maturity stage of twenty wheat lines grown under normal and water limited environment.

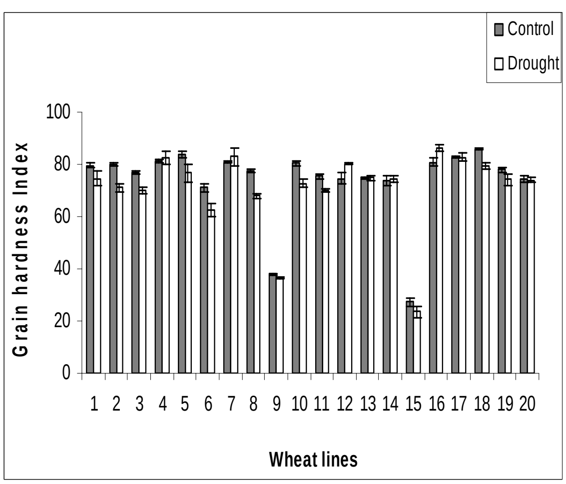

Fig. 5. Grain hardness index of grains at maturity stage of twenty wheat lines grown under normal and water limited environment.

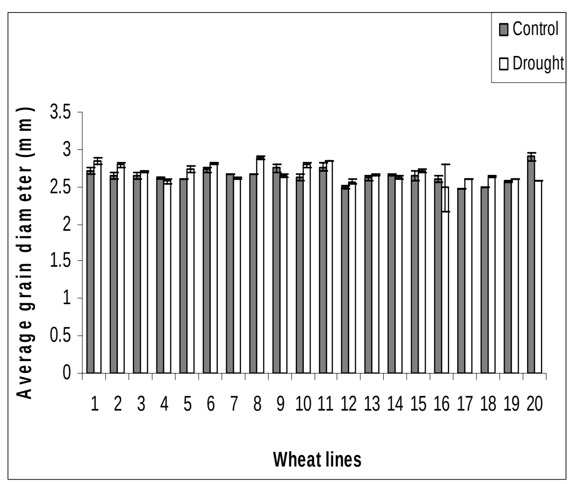

Fig. 6. Average grain diameter (mm) of grains at maturity stage of twenty wheat lines grown under normal and water limited environment.

Table 1. Mean squares (MS) values from analysis of variance (ANOVA) of data showing the effects of drought stress on grain protein, moisture, glutein, zeleny, hardness and average grain diameter.

	Protein	Miosture	Glutein	Zeleny	Hardness	Grain diameter
Blocks	0.82^{ns}	0.01^{ns}	7.81^{ns}	0.08^{ns}	4.24^{ns}	0.48^{ns}
Drought	6.21^{***}	33.86^{***}	7.81^{ns}	245.17^{***}	174.93^{***}	0.09^{ns}
Genotypes	2.10^{***}	0.38^{*}	210.74^{**}	72.60^{***}	872.46^{***}	0.30^{ns}
D x G	0.49^{ns}	0.13^{ns}	4.65^{ns}	23.57^{ns}	22.39^{**}	0.33^{ns}
Error	0.38	0.18	3.88	14.26	7.03	0.30

NS= Non-significant (p>0.05); *= Significant (p<0.05); ** = Highly significant (p<0.01)

Gluten, the major wheat grain protein increased under drought stress (Noorka *et al.,* 2009). In our study a slight increase in grain gluten value was recorded due to drought stress, again the wheat genotypes showed varying response towards this biochemical attribute and grain gluten values were not related with their photosynthetic potential.

Grain hardness is the important factor that improves end use quality of wheat. It is also reported that drought stress increased grain hardness (Weightman *et al.,* 2008). In contrast, the present study clearly indicated that drought stress has non-significant effect on grain hardness. The response of wheat genotype to drought stress in terms of grain hardness was also not associated with photosynthetic potential of these genotypes. Grain volume is the main factor that contributes to the end-use quality of wheat (Otteson *et al.,* 2008). It is also reported that diameter are significantly affected by water stress (Wei *et al.*, 2005; Pierre *et al.*, 2007; Xue, 2008). Under water stress 2% decrease was observed here. Moisture analysis of grains showed decreasing trend under water limited conditions. Since drought stressed plant receive less amount of moisture than normally irrigated ones, the decrease in grain moisture due to drought stress was expected (Noorka *et al*., 2009). Working on wheat also reported decreased grain moisture under water limited environment.

It is clear from this study that water shortage significantly affected the grain quality attributes and the response of wheat lines to water limited environment was not related to their photosynthetic potential.

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