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SCREENING OF BREAD WHEAT GENOTYPES FOR DROUGHT TOLERANCE

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ABSTRACT

Six (NIA-AA-10, NIA-AA-11, NIA-MK-122, NIA-MK-134, Khirman and Chakwal) bread wheat (*Triticum aestivum* L.) genotypes were screened out for their drought tolerance through physiological approach under water deficit environment. Two experiments were conducted for this study. Expt. 1 was conducted in pot-house and Expt. 2 was conducted in the field of Nuclear Institute of Agriculture (NIA) Tandojam, Pakistan. Both experiments were identical in drought treatments (Control and Terminal Drought (TD)), genotypes and replications (03). Expt. 1 was conducted to determine the effect of TD on nitrate reductase activity, osmotic potential and the contents of proline, glycine-betaine, total sugar and total chlorophyll. Whereas Expt. 2 was conducted up to maturity, mainly to determine the effect of terminal drought on height and grain yield traits. Generally, in both the experiments there was significant effect of terminal drought, genotypes and the interaction of terminal drought x genotypes for almost all recorded plant traits. The results obtained from Expt. 1 indicated that over all six genotypes, the wheat plants grown in TD treatment showed significantly higher values of proline, glycine-betaine, and total sugar contents and lower values for total chlorophyll content, nitrate reductase activity and osmotic potential. In the control as well as water deficit treatment, the genotypes Khirman, Chakwal, and NIA-AA-10 displayed higher values for proline, glycine betaine, total sugar contents, nitrate reductase activity and osmtotic potential as compared to the other three tested bread wheat genotypes. Similarly in the Expt. 2 plants grown in TD treatment were significantly shorter in height and had fewer spikes; hence they gave lower grain yield per plant over control. Performance of above three genotypes (Khirman, Chakwal, and NIA-AA-10) also remained outstanding in the Expt.2. These three genotypes were also able to produce taller plants with more spikes and hence gave higher grain weight per plant in normal as well as in terminal drought environment.

Keywords: morphological behavior, terminal drought, bread wheat genotypes, yield

INTRODUCTION

Wheat is an important food crop, which is grown on large scale with total production of 651 million tons all over the world and also most prominent grain crop of the world. It is an staple food of about 35% of the world masses (Pingali *et al*., 1999). A small yield increment per unit area would give a quantum jump to total production. It is estimated that till 2025, average yield of about four metric tons per year per hectare will be required to feed human population of around eight billion (Rosegrant, 1997) and this situation will become more deteriorative by the year 2050 with projected world population of 9.5 billion from current population of 6.8 billion (Geo Hive, 2009). Achievement of desired goal of yield boost is becoming impracticable mainly due to limiting constraints like drought, heat, salts, diseases and other factors. Wheat is the source of carbohydrates (70%), lipid (12%), vitamin and proteins (18%). Pakistan occupies 8th position among the largest wheat producing countries of the world. Since wheat production declined to 25,478 thousand tons during the growing year 2014-15 as compared to 25,979 thousand tons in 2013-14 which reveals 1.9 percent decline in annual wheat production. The average grain yield in Pakistan is relatively lower. The main reason for low grain productivity is the scarcity of freshwater (Ashraf *et al.,* 1994). Food insecurity is a crucial and greater hindrance to social and economic development of the country and it requires critical scientific inquiry, and idea of

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viewing this issue in terms of climate change carries with its multipronged strategy to address the issue seriously (Chachar *et al*., 2016). Water shortage seems to be one of the most limiting factors in harvesting potential yield from field crops in arid and semi-arid regions of the world. In most of the developing countries bread wheat is grown with limited irrigation, and the crop experiences periodical water shortage spells during one or more growth stages causing overall potential reduction in the grain yield (Pokharel and Pandey, 2012). Plant experiences water stress either when the water supply to the roots becomes difficult or when the transpiration rate becomes very high. These two conditions often coincide under arid and semi-arid climates. Water stress tolerance is seen in almost all plant species but its extent varies from species to species (Chaitanya *et al*., 2003). With increase in population, deficit of water resources and degrading eco-environmental condition on the globe, crop stress physiology has become the hot topics of plant biology (Chaves *et al*., 2003; Deng *et al*., 2004). About 60% of the world belongs to arid and semi-arid zones (Shao *et al*., 2005). In developing countries 37% of the area is semi-arid in which available moisture is the primary constrained to wheat production (Dhanda *et al.,* 2002).

Drought stress often causes serious problems and is a major threat to productivity of wheat crop. In Pakistan about 20% of the total wheat acreage is planted under rain-fed condition. Yield of the crop in these areas is much lesser than that in irrigated area, mainly due to occurrence of drought spells. Insufficient water is the primary limitation from wheat production all over the world. On the bases of climatic conditions Pakistan falls into arid and semi-arid regions. These regions constitute about 88% of the country's total geographic area and are mainly dependent on the scanty and erratic rainfall (Mujtaba and Alam, 2002). An increase in the irrigated area from 15.48 to 18.22 million hectares has occurred in Pakistan from 1982 to 2002. The irrigated area under wheat has also been increased from 5.96 in 1985-86 to 7.00 million hectares in 2002-2003. The major part of irrigation water is not utilized by the crops, because of leakage, wastage and seepage which amount to 40% loss. Present emerging climate change is another future threat that will affect agriculture to a great extent. Food security issues may arise in the developing world, due to change in rain fall patterns leading to yield reduction. The yield loss disturbs the equilibrium of supply and demand, causing food security issues. Less sensitive well adapted germplasm can perform better in changing climate (Hellin *et al*., 2012). Reduction in uptake of nutrients, hampered flowering, less and small spikes, shortening of grain filling period and reduction in grain number and weight is also featured with water stress (Taiz and Zeiger, 2006; Hussain *et al*., 2008). The present scenario demands systematic efforts to improve food availability for ever increasing population. Water relation directly or indirectly provides the information about the water status of plants under water deficit conditions that may be in the form of relative water content, leaf water potential, leaf osmotic potential and turgor potential (Ashraf *et al*., 1994; Akram, 2011). Water is necessary to maintain the optimum growth and physiological activities involved in different processes necessary for plant growth, development and ultimately yield (Taiz and Zeiger, 2006; Hussain *et al*., 2008). The yield potential, yield stability and drought tolerance are complex quantitative characters affected by genotype environment interaction. The need is to develop physiologically and genetically more stable genotypes which could perform better under limited moisture. Drought is the stress that has adverse effect on the growth of the plants and crop yield. The physiological response to this stress arises from the changes in the cellular gene expression profile, and a number of genes are induced by exposure to such conditions (Shinozaki and Yamaguchi, 2000). The constraints with the conventional breeding approaches are complexity of drought traits (Zhang, 2004) with low genetic variance of yield component under stress conditions, which make it very difficult due to lack of the proper screening procedure (Alan, 2007) and absence of suitable genetic model systems. Hence, breeders are extremely interested in new technologies that could make this procedure more efficient. This study was assisted to select the best drought tolerant wheat genotypes by observing the physiological and morphological traits, because these tools play a vital role to identify the drought tolerant wheat genotypes.

MATERIALS AND METHODS

Two experiments were conducted for this study, both were identical. Expt. 1 was conducted in a pot-house (controlled condition), whereas Expt. 2 was conducted in a field. Further details of each experiment are given as below:

Pot house experiment

The study was conducted is a pot house of the Plant Physiology Division, Nuclear Institute of Agriculture, Tandojam. Six (NIA-AA-10, NIA-AA-11, NIA-MK-122, NIA-MK-134, KHIRMAN and CHAKWAL-86) bread wheat genotypes were tested for their physiological performance for drought tolerance under controlled conditions using cemented tanks (size 3x3x1 cubic meter) filled with sandy clay loam soil. Two drought tolerant wheat genotypes i.e., Chakwal-86 and Khirman were included in the study as local check to compare the genotypes under control (normal four irrigations) and terminal drought conditions.

The experiment was laid out in a Randomize Complete Block Design (RCBD) with 3 replications. The space between rows and plants was 20x10 (cm). Nitrogen and phosphorous fertilizers were applied in the form of urea @ 120 N kg ha^{-1} and DAP (diammonium phosphate) @ 70 kg P_2O_5 ha^{-1}. Drought treatment was imposed in four cemented tanks by withholding irrigation water application after sowing, whereas control tanks were regularly irrigated (four irrigations). Soil moisture content was monitored regularly till harvest. The data were recorded on the contents of: proline (µmol g^{-1} fresh weight), glycine-betaine (µmol g^{-1} fresh weight), total sugars (mmol g^{-1} fresh weight), total chlorophyll (mg g^{-1} fresh weight), nitrate reductase activity (mmol g^{-1} fresh weight hr^{-1}), and osmotic potential (-MPa).

Field experiment

Same six bread wheat genotypes were included in this experiment. The experiment was conducted at the field of NIA, Tandojam experimental farm with two drought treatments [Irrigated and non-irrigated (terminal drought)] in plots measuring 20 x 40 m. Basic dose of N and P fertilizer was applied before sowing in the form of Urea and DAP (diammonium phosphate) @ 120 kg N ha^{-1} and @ 70 kg P_2O_5 ha^{-1}, respectively.

The experimental design was Randomized Complete Block Design (RCBD) with three replications. The plant to plant and row to row distance was 10 and 20 cm, respectively. The experiment was continued up to maturity. Morphological observations recorded were: plant height (cm), number of spikes $plant^{-1}$ and grain weight (g $plant^{-1}$).

Statistical analysis

Statistical analysis was carried out by Mstat 8.1.

RESULTS

Pot house experiment

The results obtained from Expt-1. Indicated that there was significant effect of TD on the synthesis and accumulation of proline, glycine betaine, total sugars, total chlorophyll, nitrate reductase activity and osmotic potential in bread wheat (Table 1). The difference between genotypes (G) and the interaction of TD x G also remained significant for all these traits. Overall the performance of genotype Khirman, followed by Chakwal-89 and NIA-AA-10 remained significantly better than the other three genotypes (NIA-AA-11, NIA-MK-122, NIA-MK-134) in terms of synthesis and accumulation of proline, glycine betaine, total sugars, total chlorophyll, nitrate reductase activity and osmotic potential under normal as well as water deficit environment.

Field experiment

The results obtained from this field experiment (Table 2) also indicated significant effect of terminal drought, genotypes and the interactions of terminal drought x genotypes on plant height (cm), number of spikes per plant, and grain weight (g per plant). The wheat plants grown in the terminal drought treatment plots were significantly shorter in height with fewer spikes and gave lower grain weight per plant over control treatment plots. Over both drought treatments, the performance of Khirman, Chakwal-86 and NIA-AA-10 genotypes was found to be better than the other genotypes included in the study. Generally, these three genotypes were able to produce tallest plants with more spikes and give higher grain weight per plant in normal as well as terminal drought treatment plots.

DISCUSSION

Artificial management of drought under field as well as green-house conditions has been found an effective way of screening plant germplasm for drought tolerance. We created artificial water deficit environment in field and green-house, just to screen out six important local bread wheat genotypes. We found highly significant effect of terminal drought on wheat plants in both the environments. The difference among genotypes for almost all the recorded traits under water deficit environment also remained highly significant. This suggests that the germplasm pool selected for this study could be a rich source of genetic diversity for breeding purposes. Thus, the germplasm pool can be exploited to identify genotypes with high level of stress tolerance, including heat, salt and drought. The significant effect of terminal drought on plants can be the outcome of the improper uptake of nutrients from soil solution by the plants; which was probably adversely affected by low soil moisture regime. Similar effects of drought on plants have also been observed by other workers, including Blum (2010). Selecting wheat genotypes for improved grain yield under both water deficit and normal moisture conditions allows genotypes to maintain ranks for high yields, since the same genotype will be expected to perform well in either situation. The observed maintenance of high yields under stressed and optimum conditions by some genotypes; such as Khirman, Chakwal-86, and NIA-AA-10 also supports the ideas of Foulkes *et al*. (2007) that genotypes performing well under optimum soil moisture conditions retain high grain yield under water deficit environment.

Table 1. Effect of terminal drought on proline content (µmol g^{-1} fresh weight), glycine-betaine content (µmol g^{-1} fresh weight), total sugars content (mmol g^{-1} fresh weight), total chlorophyll content (mg g^{-1} fresh weight), nitrate reductase activity (mmol g^{-1} fresh weight h^{-1}) and osmotic potential (-MPa) of wheat genotypes under pot house condition (Expt.1).

Treatments	**Bread wheat genotypes**						**Mean**
	NIA-AA-10	**NIA-AA-11**	**NIA-MK-122**	**NIA-MK-134**	**KHIRMAN**	**CHAKWAL-86**	
Proline content (µmol g^{-1} fresh weight)							
Control	10.03	9.91	8.76	6.42	16.72	16.43	11.38
TD	19.42	15.4	15.35	11.59	63.1	57.28	30.36
Mean	14.72	12.65	12.50	9.01	39.94	36.85	---
Glycine-betaine content (µmol g^{-1} fresh weight)							
Control	71.12	66.57	66.26	61.74	107.6	71.53	74.13
TD	105.22	87.73	83.06	70.42	124.87	115.69	97.83
Mean	88.17	77.15	64.66	66.08	116.23	93.61	---
Total sugars (mmol g^{-1} fresh weight)							
Control	o.98	0.83	0.71	0.7	1.28	1.02	0.92
TD	1.48	1.45	1.32	1.21	1.88	1.75	1.51
Mean	1.23	1.14	1.02	0.96	1.58	1.39	---
Total chlorophyll content (mg g^{-1} fresh weight)							
Control	1.11	1.08	0.97	0.87	1.28	1.22	1.09
TD	0.77	0.67	0.66	0.55	1.08	0.84	0.76
Mean	0.94	0.87	0.81	0.71	1.18	1.03	
Nitrate reductase activity (mmol g^{-1} fresh weight hr^{-1})							
Control	0.40	0.42	0.39	0.39	0.37	0.37	0.39
TD	0.28	0.28	0.02	0.17	0.30	0.31	0.22
Mean	0.34	0.3	0.20	0.29	0.33	0.34	---
Osmotic potential (-MPa)							
Control	0.70	0.63	0.61	0.58	0.93	0.73	0.70
TD	0.99	0.88	0.87	0.74	1.06	1.00	0.92
Mean	0.84	0.76	0.74	0.66	1.00	0.87	---

Parameters	**Treatment (T)**	**Genotypes (G)**	**G x T**
Proline content (µmol g^{-1} fresh weight)			
SE	2.6442	4.5798	6.4768
LSD	2.6442	14.161	23.348
Glycine-betaine content (µmol g^{-1} fresh weight)			
SE	7.2760	12.602	17.822
LSD	14.980	38.968	64.247
Total sugars (mmol g^{-1} fresh weight)			
SE	0.0691	0.1197	0.1693
LSD	0.1423	0.1197	0.6101
Total chlorophyll content (mg g^{-1} fresh weight)			
SE	0.0343	0.0594	0.0840
LSD	0.0706	0.1838	0.3030
Nitrate reductase activity (mmol g^{-1} fresh weight hr^{-1})			
SE	5.33803	9.2450	0.0131
LSD	0.0110	0.0191	0.0270
Osmotic potential (-MPa)			
SE	0.0192	0.0332	0.0470
LSD	0.0395	0.1027	0.1694

Table 2. Effect of terminal drought on plant height (cm), number of spikes plant^{-1}, grain weight plant^{-1} (g) and leaf area plant^{-1} (cm^2) of wheat genotypes under field conditions (Expt. 2)

Treatments	Bread wheat genotypes						Mean
	NIA-AA-10	NIA-AA-11	NIA-MK-122	NIA-MK-134	KHIRMAN	CHAKWAL-86	
Plant height (cm)							
Control	85.00	79.33	79.66	64.66	98.00	93.33	83.33
TD	71.33	61.66	70.66	61.66	82.66	73.00	70.16
Mean	78.16	70.50	75.16	63.16	90.33	83.16	---
Number of spikes (plant^{-1})							
Control	4.33	3.33	3.33	3.00	5.00	4.33	3.88
TD	3.33	2.66	3.00	2.33	4.66	3.66	3.27
Mean	3.83	3.00	3.16	2.66	4.83	4.00	---
Grain weight (g plant^{-1})							
Control	7.54	6.02	7.47	5.80	9.37	8.77	7.49
TD	5.25	5.00	5.02	4.56	6.27	5.28	5.23
Mean	6.40	5.51	6.25	5.18	7.82	7.02	---

Parameters	Treatment (T)	Genotypes (G)	G x T
Plant height (cm)			
SE	3.3800	5.8543	8.2792
LSD	7.0134	18.237	30.106
Number of spikes (plant^{-1})			
SE	0.2112	0.3658	0.5174
LSD	0.4383	1.1397	1.8813
Grain weight (g plant^{-1})			
SE	0.8673	1.5021	2.1243
LSD	1.7995	4.6794	7.7247

The marked variations among the genotypes particularly under water deficit environment were strongly associated with the accumulation and synthesis of some organic compounds (osmo-protectants), including proline, glycine betaine, total sugars and total chlorophyll contents as well as nitrate reductase activity and osmotic potential. This was possibly due to the osmtotic adjustment mechanism exhibited by some wheat genotypes under water deficit situation. The marked variations in these physiological traits have also been observed in different bread wheat genotypes under both deficit and well-watered regimes (Rampino *et al*., 2006; Vendruscolo *et al*., 2007; Nio *et al*., 2011; Qayyum *et al*., 2013). These results provide good practical insight. The association of proline, glycine betaine, and other biochemicals with grain weight per plant, height and number of spikes per plant observed in this study suggests that the accumulation of proline, glycine betaine, etc. can be used as good indicator of drought tolerance in bread wheat; which can be considered as useful trait during genotype selection.

CONCLUSION

It was concluded from the study that the bread wheat genotypes “Khirman, Chakwal-86 and NIA-AA-10” can be listed as drought tolerant local bread wheat genotypes.

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