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GERMPLASM DIVERSITY OF WHEAT UNDER DIFFERENT WATER STRESS AND WEEDY CONDITIONS

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ABSTRACT

Drought stress is the major limiting factor for wheat productivity all over the world. Because of severe limitations imposed by drought, development of cultivars with improved productivity under water stress is important for water deficit regions. For this purpose, a set of 24 advanced wheat lines along with four check cultivars was evaluated under irrigated (non-stress) and rainfed (stress) conditions during 2009-10 at the University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan. Analysis across two environments revealed significant diversity ($P \leq 0.01$) between the two production environments for grain yield and weeds density. The available wheat germplasm was significantly different from each other and drought stress also significantly affected the grain yield of wheat genotypes. Interestingly, wheat genotypes BRF3, Pirsabak-2005 and BVI(N)12 gave better yield under water stress condition by 859, 463, and 115 kg ha^{-1}, respectively than by optimum conditions. Densities of weeds were also significantly reduced under drought stress condition. Thus, drought stress can effectively be tackled with genotypes that perform better under water stress conditions. It can be inferred that maximum wheat germplasm should be collected from different parts of the world to cope with the alarming food situation.

Key words: Irrigated, drought, stress, rainfed, germplasm, wheat, weeds

INTRODUCTION

Climatic change is the major reason of global warming. Most harmful results of these climatic changes will be increasing droughts and this is a special challenge for crop scientists, especially for

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breeders, to develop new cultivars and hybrids of crops that will be able to adapt to the changing climate (Waggoner, 1993). So the improvement of tolerant varieties for drought has been a principal goal of the majority of breeding programme for a long time because water deficit in certain stages of wheat growth is common for many wheat growing regions of the world (Moustafa *et al.*, 1996). The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important. Plants tolerate stress conditions at the cost of yield to cope with this situation the yield losses should be minimized (Ahmad *et al.*, 2006).

A decrease in wheat production severely affects the economy of our country and increases the miseries of the inhabitants (Khan *et al.,* 2011). The popularity of food made from wheat flour creates a large demand for the grains production, even in economies with significant food supplies (Ullah *et al.,* 2011). While Interest in crop response to environmental stresses has increased greatly in recent years because severe losses may result from heat, cold, drought and high concentrations of toxic mineral elements (Blum, 1988). Therefore, it is necessary to investigate genetic diversity in the currently used wheat germplasm against drought stress (Maqbool *et al.*, 2010).

Drought that occurs after weed emergence toughens or hardens plants. Drought inhibits seed germination leading to decreased weed abundance. Weed response to severe drought stress includes leaf cuticle thickening, reduced vegetative growth, and rapid flowering. A number of studies have indicated that as wild oat density increases, competition from the weed increases and consequently crop losses as well. Drought however reduces the density of wild oat and field bindweed significantly. Available soil moisture is probably the most important resource for competing plants. Wild oats and field bindweed possess an extensive and deeper root system, respectively and can compete effectively for moisture with other plants. Suggestions have been made that wild oats and field bindweed may be more tolerant to reduced soil moisture than some crop plants. Khan and Hassan (2002) are of the view that Avena *fatua and Convolvulus arvensis* are competitive weeds in wheat fields of Pakistan.

Genetic improvement of crops for drought tolerance requires a search for the exploitation of genetic variation among the cultivars. The current research in this scenario was an attempt to investigate the genetic diversity among the wheat genotypes against drought stress and to assess the response weeds densities against drought stress.

MATERIALS AND METHODS

This research was conducted at the University of Agriculture Peshawar, Pakistan during 2009-10 to exploit the genetic diversity of wheat genotypes under optimum and drought stress condition. Twenty four advanced wheat genotypes and four check cultivars, procured from the Cereal Crops Research Institute (CCRI) Pirsabak, Nowshehra, Pakistan were evaluated as independent experiments under irrigated and rainfed production systems. The 24 wheat genotypes were B-IV (N) 1, B-IV (N) 11, B-IV (N) 16, B-IV (N) 17, B-VI (N) 3, B-VI (N) 5, B-VI (N) 6, B-VI (N) 8, B-VI (N) 9, B-VI (N) 12, B-VI (N) 16, B-VI (N) 17, B-RF 1, B-RF 3, B-RF 7, B-RF 8, B-RF 15, B-RF 17, SAWYT-50, B-II (N) 1, B-II (N) 3, B-III (N) 17, B-IV (N) 6 and B-IV (N) 10. The four check cultivars were Saleem-2000, Pirsabak-2005, Pirsabak-2008 and Suleman-96. Cultivars Saleem-2000 and Pirsabak-2008 are recommended for irrigated, Suleman-96 is recommended for rainfed, while Pirsabak-2005 is recommended both for irrigated as well as rainfed environments of Khyber Pakhtunkhwa.

A randomized complete block design with three replications was used under both production systems. Both experiments were established adjacently in the same field to avoid environmental bias. However, the rainfed experiment was not irrigated throughout the growing season. A plot for each genotype consisted of 3 rows measuring 3 meter and spaced 0.30 meter apart. Both experiments were planted on 29th October, 2009 with hand hoe, using a seed rate of 110 kg ha^{-1}. Nitrogen and phosphorous were applied at the rate of 120: 60 kg ha^{-1} for irrigated, while 60:30 kg ha^{-1} for rainfed experiment. The fertilizer was applied in split doses in irrigated experiment, while in rainfed experiment it was applied as a single dose at the time of sowing. Before hoeing the crop, three random quadrats of 1 m^2 were selected in each replication under each production system. The no. of *Avena fatua* and *Convolvulus arvensis* plants were counted under each quadrat and were averaged. The data were subjected to statistical analyses using Statistix 8.1 software.

Data obtained were analyzed across the two production systems using a mixed effects model to quantify genotype-by-environment interaction effect as proposed by Anniechirico (2002). Production systems were considered as fixed, while replications and genotypes were considered as random effects in the model. Mean squares pertaining to genotype × environment interaction were used as error term to test the significance of environment and genotype main effects, while the significance of genotype × environment was tested against the mean squares of pool error.

Table-1. Analysis of variance across two irrigation systems of 28 wheat genotypes evaluated in RCBD with 3 replications

Source of Variation	DF	SS	MS	F-value
System (S)	1	---	M_1	M_1/M_3
Reps w/n S	4	---	---	---
Genotypes (G)	27	---	M_2	M_2/M_3
G × S	27	---	M_3	M_3/M_4
Error	108	---	M_4	---
Total	167	---	---	

RESULTS AND DISCUSSION

Wheat grain yield

Genotypes, environments and genotype-environment interactions exhibited highly significant variations for grain yield (Table-2). The significant genotype × environment interaction suggested a change in ranking of genotypes across the two environments which means that drought significantly affects the grain yield of the tested germplasm. Thus, high yielding genotypes under optimal conditions do not necessarily produce optimum yield under stress condition as evident from Fig. 1. Similar conclusions were also published by Talebi *et al.* (2009) who observed significant differences for grain yield while studying the effect of different water regimes on yield of various wheat genotypes.

Means of 28 genotypes including four check cultivars under irrigated and rainfed environments are given in Table-3. Genotype BIV(N)11 produced maximum grain yield of 4410 kg ha^{-1} under irrigated conditions followed by BII(N)1 and BVI(N)9 with grain yield of 3457 and 3446 kg ha^{-1}, respectively. In contrast, genotype BRF8 produced minimum grain yield of 2639 kg ha^{-1} under irrigated conditions. Maximum grain yield of 4007 kg ha^{-1} under rainfed environment was recorded for wheat genotype BRF3, while minimum for BIV(N)16 (2083 kg ha^{-1}). Thus different genotypes responded differently both under optimum as well as stressed conditions. Naserian *et al*. (2007) reported that reduction in grain yield depends on the genotype cultivated and the physiological stage of the stress occurrence because at different crop stages, drought effects the yields differently.

Averaged over 28 wheat genotypes, grain yield under irrigated and rainfed environment were 3152 and 2752 kg ha^{-1}, respectively indicating a net decrease of 12.96% under rainfed conditions. This suggests that the available germplasm has the variability and potential to be used in breeding program for the improvement of wheat yield.

Genotypes BIV(N)11 and BVI(N)9 were the most sensitive genotypes to drought stress with a reduction of 1525 and 1286 kg ha^{-1} under drought stress condition, respectively (Fig. 1). Thus, these genotypes cannot be used for cultivation under rainfed conditions because if it rains sufficiently their performance will be better but if there is a low rainfall, there will an abrupt reduction in yield of these genotypes. Performance of such genotypes never remains constant across years because of the variable distribution of rainfall over years. Besides, wheat genotypes BRF3, Pirsabak-2005 and BVI(N)12 gave more yield under water stress condition by 859, 463, and 115 kg ha^{-1}, respectively than by optimum conditions. Thus, these genotypes could be used against the climate change in terms of drought stress. Performance of these genotypes may be due to genotype × environment interaction or due to other unknown factors or maybe due their combination. Fisher and wood (1978), however, suggested that greater yield under stress was associated with total dry matter at maturity in bread wheat.

Further, wheat germplasm can be screened out for such genotypes that perform better under stress conditions to cope with the alarming food situation of the country. Sadiq *et al.* (1994) reported that yield performance of a genotype under stress is a reflection of both its yield potential and its response to stress. Other studies concluded that greater assimilates allocation to kernels play a major role in grain yield (Syrae *et al.*, 1997; Araus *et al.*, 2002).

Table-2. Mean squares for grain yield of 28 wheat genotypes across two environments (irrigated and rainfed) at Agricultural University Peshawar during 2009-10.

Sources	Degrees of freedom	Grain yield (Combined)	Grain yield (Irrigated)	Grain yield (Rainfed)
Environments (E)	1	17759302.88**		
Reps w/n E	4 (2)∫	87876.67	117968.65^{NS}	5980683.62**
Genotypes (G)	27 (27)∫	402489.37**	313495.55*	305871.66*
G x E	27	216877.84**		
Error	108 (54)∫	234373.75	181175.69	287571.82
CV (%)	----	7.99	14.11	22.66

∫ = Values in the parenthesis are the degrees of freedom for irrigated and rainfed condition

Weed density m^{-2}

Analysis of variance showed that environments significantly affected weeds density. Weeds between themselves were also diversely distributed among wheat as evident from Table-4. It is, however, evident from the analysis that response of both the weeds was similar to the drought condition and hence the interaction of weeds with environments was non significant. It might be because of the fact that both the weeds are quite tolerant to drought stress as supported by previous literature. Diversity of weeds in wheat crop have also been reported by different researchers (Hussain *et al*., 2004; Muhammad *et al.*, 2005).

Drought significantly affected the density of *Avena fatua* and *Convolvulus arvensis*. Density of *A. fatua* and *C. arvensis* was decreased from 13 to 7 and from 6 to 4 plants m^{-2}, respectively under drought stress condition (Fig. 2). Although weeds were significantly decreased under drought stress condition, still the losses due to weeds may not be lowered because of limited resources under stress. Weeds compete with crop plants for moisture, nutrients, and light. Many weeds are highly efficient at using available soil water. The combined effects of drought and weed competition can severely decrease spring wheat yields. Thus, control of weeds is important in wheat crop under normal as well as under drought stress conditions.

Table-3. Means and selection indices for grain yield (kg ha^{-1}) of 28 genotypes evaluated under irrigated and rainfed environments at Khyber Pakhtunkhwa Agricultural University, Peshawar during 2009-10.

Genotypes	Irrigated	Rainfed	Average
BIV(N)1	2963	2930	2947
BIV(N)11	4410	2885	3647
BIV(N)16	2864	2083	2473
BIV(N)17	3207	2969	3088
BVI(N)3	2778	2728	2753
BVI(N)5	3235	2829	3032
BVI(N)6	3123	2435	2779
BVI(N)8	3429	2550	2990
BVI(N)9	3446	2160	2803
BVI(N)12	3185	3300	3243
BVI(N)16	2742	2527	2635
BVI(N)17	2846	2607	2726
BRF1	3420	2903	3161
BRF3	3148	4007	3578
BRF7	2857	2590	2723
BRF8	2639	2325	2482
BRF15	2706	2496	2601
BRF17	2867	2750	2808
SAWT50	3349	2776	3062
BII(N)1	3457	3236	3346
BII(N)3	3355	2604	2980
BIII(N)1	3000	2317	2658
BIV(N)6	3260	2932	3096
BIV(N)10	2802	2541	2672
Suleman-96	3286	2389	2837
Saleem-2000	3669	2775	3222
Pirsabak-2005	3107	3570	3339
Pirsabak-2008	3108	2858	2983
Mean	3152 a	2753 b	
LSD for Genotypes under each Environment 391, 381 LSD for Genotypes over Environments 270 LSD for Environments 189 LSD for G × E interaction 177			

Table-4. Mean squares for density of *A. fatua* and *C. arvensis* m^{-2} in wheat fields

Sources	Degrees of freedom	Weeds density
Environments (E)	1	56.333
Replications	2	0.0833^{NS}
Weeds (W)	1	56.333^{**}
W x E	1	12.00^{NS}
Error	6	2.305
CV (%)	----	19.81

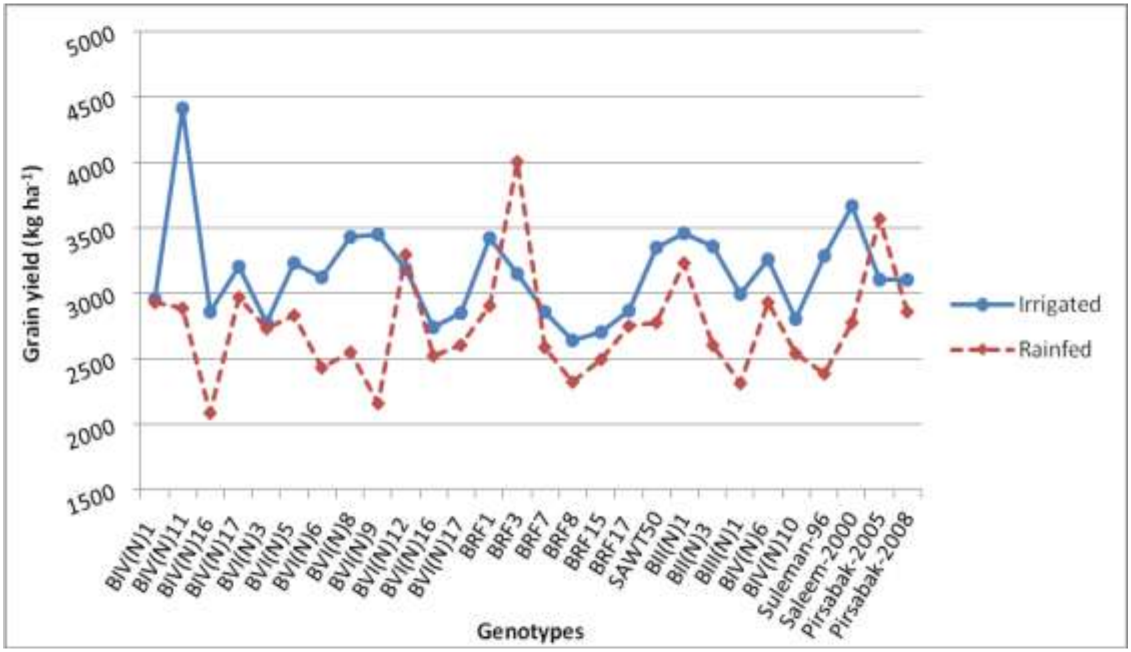

Figure 1. Yield comparison of different wheat genotypes under irrigated and rainfed conditions

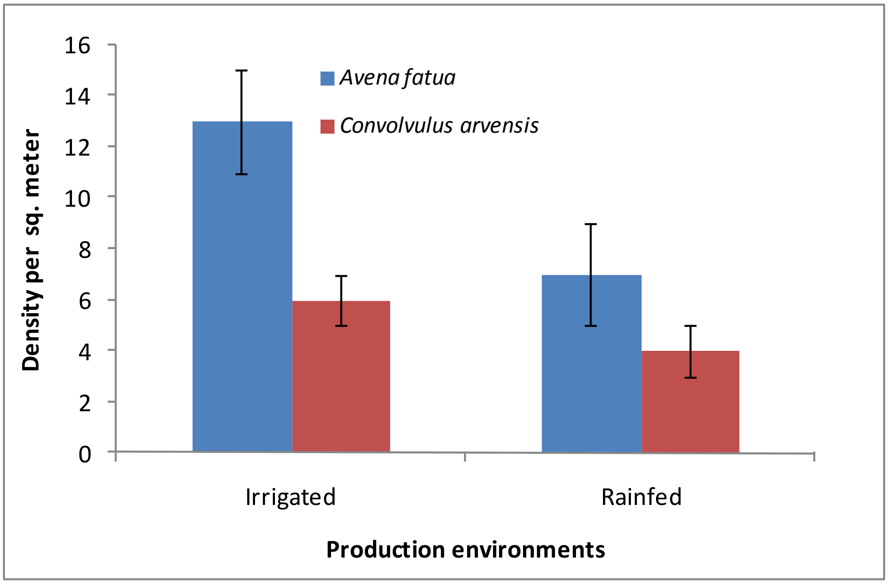

Figure 2. Effect of production environment on density of *A. fatua* and *C. arvensis* in wheat

CONCLUSION

It is concluded that wheat genotypes BRF3, Pirsabak-2005 and BVI(N)12 gave significantly higher yields under water stress conditions by 859, 463, and 115 kg ha^{-1}, respectively than by optimum conditions. Thus, these genotypes could be used against the climate change scenario in terms of drought stress. Further, wheat germplasm can be screened out for such genotypes that perform better under stress conditions to cope with the alarming food situation of the country in particular and World in general. It is also concluded that maximum germplasm should be conserved for future breeding programs to compensate the losses in yield due to the increasing drought stress. Densities of weeds were also significantly reduced by drought stress. Control of weeds however is necessary under normal as well as drought stress conditions.

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