Selection criteria for drought tolerance in spring wheat (*Triticum aestivum* L.)

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ABSTRACT

Twenty spring wheat genotypes were evaluated both under moisture stress (E_1) and non stress (E_2) environments for yield and yield contributing traits, grain weight/spike and biological yield in RBD with 3 replications. Drought susceptibility index (S) and index of drought resistance (IDR) at 2-leaf stage were worked out. Sufficient genetic variability was in existence for all the characters studied. The combined analysis of variance over environments indicated the presence of variability among the genotypes, differences in environments and the differential response of genotypes over environments as indicated from their significant mean square values, except for harvest index and tillers/plant. Grain yield and biological yield showed maximum sensitivity as affected by E_1 and grain weight showed the least. The positive correlation of grain yield with biological yield and harvest index in E_1, negative correlation of grain yield with 'S' under E_1 and significant positive correlation of grains/spike and grain weight with grain weight/spike under both the environments revealed that selection must be exercised for high biomass, grain weight/spike and harvest index for yield improvement under dry land conditions. The negative association of IDR with 'S' indicated the inherent importance of IDR as a selection criterion for assessing the drought tolerance at seedling stage which is an easy, inexpensive and rapid method of screening large germplasm to characterize drought tolerant genotypes. Path coefficient analysis revealed that biological yield and harvest index exhibited high positive direct effects on grain yield under both the environments. Tillers/plant and grain weight/spike had mainly indirect effects on grain yield via biological yield under E_1.

INTRODUCTION

Among all the factors limiting the wheat productivity, drought remains the single most important factor affecting the world security and sustainability in agricultural production. At least 60 million ha of wheat is grown in marginal rainfed environments in developing countries. For improving yields under dry land conditions, the development of new wheat cultivars with high grain yield potential through identifying drought tolerance mechanism is of great significance (Rajaram et al. 1996). The severity of drought experienced by a crop is determined by both the intensity and duration of water deficit. Selection mainly for grain yield under drought stress conditions is difficult due to its low heritability resulting from variations in the intensity of the stress throughout the field (Blum 1988). The improvement of yield under stress must combine a reasonably high yield potential with specific factors which would buffer against a severe yield reduction under stress. It appears that no singular drought-adaptive trait conferring adaptation to dry environments is predictive of plant response to stress and that multiple physiological selection criteria are required (Acevedo and Caccarelli 1989). The present study was undertaken to investigate plant traits which are associated with drought tolerance in bread wheat and to determine suitable selection criteria for selecting genotypes tolerant to drought stress conditions.

MATERIAL AND METHODS

The field experiments were conducted at the Experimental Farm situated at an elevation of about 1300 meters AMSL with 32^{o}6' N latitude and 76^{o}3' E longitude with sub-temperate climate and podsolic soil having pH ranging from 5.0-5.5. The experimental material comprised 20 diverse wheat genotypes laid out in a randomized complete block design with 3 replications both under moisture-stress (E_1) and moisture non-stress (E_2) environments. Each genotype was grown in 3mx1.38m plot with inter-row and interplant spacings of 23 cm and 5 cm, respectively. The data were recorded for grain and biological yield on plot basis and for yield contributing traits and plant height on 5 randomly selected plants from each entry in each replication. The drought susceptibility index (S) was worked out as per Fischer and Maurer (1978). An index of drought resistance (IDR) based on the seminal root length and leaf area was worked out at the two-leaf stage under glass-house conditions as outlined by Latyuk (1989). The standard statistical procedures were followed for carrying out statistical analysis of variance, correlation coefficients and path coefficient analysis.

WEATHER CONDITIONS AND SEASONAL EFFECTS

The total precipitation experienced during the entire crop season was 477.7 mm and the distribution of rainfall was highly erratic throughout the season (Table 1). The experiment under moisture stress environment thus suffered greatly from drought stress in the initial critical growth stage and the crown root initiation (CRI), had intermittent rainfall during jointing and anthesis stages and the terminal stress was also of severe nature. The mean minimum and maximum temperatures during the crop season varied from 5.2^{o}C – 16.8^{o}C and 15.0-33.8^{o}C, respectively.

RESULTS AND DISCUSSION

The combined analysis over environments indicated the existence of sufficient genetic variability among the genotypes for all the characters studied. The environments were also observed to be highly variable for all the characters except harvest index. The differential response of genotypes over environments was also revealed as evidenced from their significant mean square values for all the characters except for tillers/plant, grains/spike and plant height.

Grain yield and biological yield showed maximum sensitivity as affected by moisture-stress, whereas grain weight showed the least sensitivity to moisture stress. The index of drought resistance values varied from 85.57% to 138.43%, whereas 'S' values ranged from -0.82 to 3.23 in different genotypes. Among wheat genotypes studied, HPW 175, HPW 161, HPW 174 and HPW 170 showed the least 'S' values being 0.17, 0.35, 0.36 and 0.38, respectively. These genotypes with lower 'S' values had higher IDR values than the check variety C-306 being 108.75%, 117.77%, 124.70% and 115.53%, respectively, and thus can be identified as drought tolerant. Bruckner & Frehberg (1987) also elucidated that genotypes with low 'S' values are presumed to be drought tolerant.

The phenotypic correlations coefficients among different plant characters under E_1 and E_2 environments and with 'S' and IDR are presented in Table 2. The significant positive correlation of grain yield with biological yield and harvest index and significant negative correlation of grain yield with 'S' under E_1 reveal that selection should be practiced for higher biomass with high harvest index under dry land conditions in isolating high yielding drought tolerant wheat genotypes. This is further established from the fact that harvest index exhibited negative significant association with 'S' under E_1. These results are in conformity with the earlier results of Rana and Sharma (2001).

However, grain yield also exhibited positive significant correlation with biological yield, tillers/plant and grain weight/spike and of tillers/plant with grain weight/spike under E2 which underlines the importance of traits viz. biological yield, tillers/plant and grain weight/spike for consideration for improving grain yield under moisture-stress environment. Rajaram et al. (1996) also advocated that selection for drought tolerant lines under non-stress conditions is more efficient than under drought stress conditions as this allows the identification of lines with higher yield potential. This is further authenticated from the present results that harvest index has been found to have positive significant correlation with 'S' under a non stress environment.

Grains/spike and grain weight exhibited positive significant correlation with grain weight/spike under both the environments, thereby highlighting the importance of grain weight/spike to be amenable for yield improvement under E_1 and hence, selection for this trait should be exercised.

The negative association of grain yield, IDR and biological yield with 'S' under E_1 illustrates the inherent importance of IDR, a simple, inexpensive and rapid method as a selection criterion for drought tolerance in wheat and that wheat genotypes with higher IDR values, higher biological and grain yield should be selected. Similar findings were also reported by Sharma and Kumari (1996) who found significant negative correlation of IDR with 'S' and importance of IDR as a selection criterion for drought tolerance in wheat.

Table 1. Distribution of rainfall, temperature regimes and drought stress during the season.

Period	Temperature ^{o}C		Rainfall (mm)	Stress duration (days)	Crop growth stage
	Max.	Min.			
Nov.1-Dec.2	19.1	8.8	60.6	25(7)+	Germination
Dec.3-Dec.31	15.0	5.6	88.1	26(5)	CRI, Tillering
Jan.1-Jan.28	15.4	5.2	12.3	25(3)	Jointing
Jan.29-Feb.25	16.5	6.8	132.9	18(9)	Jointing
Feb.26-Apr.1	19.5	8.3	130.2	25(10)	Anthesis
Apr.2-April29	26.3	15.2	40.0	22(6)	Anthesis and Grain filling
Apr.30-May13	28.0	16.8	11.4	12(2)	Grain filling
May14-June3	33.8	21.6	2.2	18(3)	Dough Stage and Maturity
Total			477.7	171(45)	

+Values in parenthesis indicate number of rainy days.

Table 2. Phenotypic correlation coefficients among different plant characters under Moisture-stress (E_1) and moisture non-stress (E_2) environments.

Character	Environment	Bio. Yield	Tilers/ Plant	Grains/ Spike	100 grain weight	Grain Wt./ Spike	Plant Height	Harvest Index	IDR	S
Grain	E_1	0.79**	0.23	0.14	0.13	0.20	0.18	0.50*	0.19	-0.50*
Yield/plot	E_2	0.82**	0.50*	0.28	0.28	0.45*	0.03	0.40	0.04	0.41
Bio.	E_1		0.16	0.13	0.16	0.21	0.13	-0.06	0.09	-0.28
Yield/Plot	E_2		0.40	0.27	0.13	0.31	0.21	-0.16	0.04	0.20
Tillers/	E_1			0.04	0.18	0.15	-0.12	0.25	0.27	0.02
Plant	E_2			0.20	0.38	0.47*	0.20	0.07	-0.04	0.19
Grains/	E_1				-0.09	0.82**	0.28	0.15	0.14	-0.15
Spike	E_2				-0.024	0.56*	-0.09	0.02	-0.05	0.05
100 Grain	E_1					0.48*	0.28	0.04	0.31	0.15
Weight	E_2					0.61*	0.26	0.22	0.21	0.01
Grain	E_1						0.42*	0.14	0.31	-0.02
Weight/ Spike	E_2						0.08	0.21	0.07	0.07
Plant	E_1							0.17	0.00	-0.24
Height	E_2							-0.31	0.03	-0.20
Harvest	E_1								0.24	-0.43*
Index	E_2								-0.05	0.49*
IDR	E_1									-0.28

*Significant at P=0.05; **Significant at P=0.01

PATH COEFFICIENT ANALYSIS

The results of the path coefficient analysis showed that the biological yield and harvest index had significant positive direct effects on grain yield under both the environments. This indicates that improvement in grain yield for moisture-stress environment can be sought by selecting higher biomass. Singh et al (1990) and Sanjeev *et al.* (2005) also pointed out that total biomass to be the main selection parameter in breeding dry land wheat varieties. Tillers/plant and grain weight/spike, having significant positive correlation with grain yield under moisture non-stress environment had mainly indirect effects on grain yield via biological yield.

CONCLUSION

Sufficient genetic variability was in existence for the different plant characters studied. Based upon correlation studies among yield and yield contributing characters under drought stress and non-stress environments, drought susceptibility index and index of drought resistance, the selection for drought tolerance should aim for high biological yield, grain weight/spike, harvest index and tillers/plant for yield improvement under dry land conditions. Biological yield and harvest index also exhibited high positive direct effects on grain yield under both the environments. IDR at 2-leaf stage is an easy, inexpensive and rapid method of screening wheat genotypes.

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