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Estimates of Genetic Variability Parameters and Regression Analysis in Bread Wheat under Irrigated and Drought Stress Conditions

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Abstract: Thirty-six genotypes of bread wheat *(Triticum aestivum* L.) were evaluated for genetic variability parameters and regression analysis under irrigated and drought stress conditions. Tillers per plant, peduncle length, 1000-grain weight, grain weight of mother shoot, biomass per plant and grain yield per plant exhibited high genotypic coefficient of variability under both environments. Grain yield per plant suffered a maximum reduction of 68 percent followed by 58.9, 57.4, 42.7, 41.5 and 27.4 percent, for biomass per plant, flag leaf area, tillers per plant, grain weight of mother shoot and plant height under drought stress conditions compared to irrigated conditions, respectively. High heritability estimates 90.08, 85.01, 83.32, 76.01, 74.86 and 72.23 percent were found for 1000-grain weight, days to heading, peduncle length, spike length, plant height and spikelets per spike, respectively under irrigated conditions. High values of heritability were shown for days to heading, 1000-grain weight and spike length under drought stress conditions. Regression analysis indicated the importance of biomass per plant, harvest index and tillers per plant in influencing grain yield per plant in bread wheat. The plant height is more important than grain weight of mother shoot in case of drought stress conditions for the contribution of grain yield per plant.

Key words: Multiple regression, yield, morpho-physiological traits, wheat

Introduction

Stomata plays a pivotal role in regulating plant water status and the stomata! frequency varies from one species to another and is influenced by environmental conditions under which a plant is grown. It has also been reported by Henzell *et al.* (1975) that the stomates on adaxial surface were more sensitive to reduction in soil water potential than on abaxial surface. Hattalli *et al.* (1993) observed that the stomatal frequency (SF) was more on abaxial surface in drought tolerant wheat genotypes, whereas the drought susceptible genotypes exhibited greater stomata frequency on adaxial leaf surface. The grain yield was more in genotypes having lower stomata frequency on adaxial surface.

Shalaby *et al.* (1988) reported that drought at crown root initiation or later tillering stages caused significant reduction in flag leaf area, days to heading, plant height, peduncle and spike length and spikelets per spike. Drought at late tillering or flowering decreased harvest index. Sukhorukov (1989) revealed low yield as a result of a reduction in number of fertile tillers, number of grains per ear and 1000-grain weight. Selection for these three traits under drought stress conditions is recommended in breeding for drought resistance. Selection is also recommended for increased number of spikelets per spike, since it was correlated with number of grains per ear under drought conditions. Similarly, Atale and Zope (1991) indicated that the optimum selection criterion under irrigated and fainted conditions were, number of ears per meter. days to 50 percent flowering and/or length of ear, grain weight per ear, 1000-grain weight and yield.

Subhani and Alam (1988) reported the high heritability estimates coupled with high genetic advance for plant height, tillers per plant, grains per spike and grain yield per plant. Subhani and Khaliq (1994) observed that coefficient of variability was high for grain yield per plant as compared to other studied characters. Heritability ranged from moderate (66.20%) to high (96.95 percent). Similarly Chowdhry *et al.* (1997) reported that the heritability for flag leaf area and tillers per plant were moderate with low expected genetic advance. While moderate to high heritability were observed for plant height, spike length, grains per spike, 1000-grain weight and grain yield per plant with high genetic advance value. Raut and Khorgade (1989) indicated from the results of partial regression coefficients that the grain yield was mainly dependent on productive tillers per plant, spikelets per spike, grains per spike and 1000-grain weight. A selection index consisting of these characters and grain yield gave the highest selective efficiency (183.84 percent) compared to selection for grain yield alone. Similarly, Khan *et al.* (1991) reported the results of step wise regression analysis and indicated that 66.66, 19.53 and 12.77 percent of the variability in grain yield could be attributed due to number of spikes per plant, number of grains per spike and 1000-grain weight, respectively. They also revealed that simultaneous selection for these traits in order of their importance could be recommended to select for high yielding plants. The present study was, therefore, conducted to assess the genetic variability and to point out the most important yield attributes through regression analysis in bread wheat under irrigated as well as drought stress conditions.

Materials and Methods

Thirty six genotypes of bread wheat were grown in a randomized complete block design with three replications at the research area of Department Plant Breeding and Genetics, University of Agriculture, Faisalabad during 1995-96. The spacing between rows and plants within row was 30 cm and 15 cm, respectively.

For two sets of experiments lone under irrigated and other under drought stress conditions the field were irrigated for seed bed preparation. After planting of the experimental material, four canal irrigations were applied to normal experiment during the critical growth stages of wheat (crown root stage, boot stage, milk stage and dough stage). Whereas the other experiment entirely depends on natural precipitation and no surface irrigation was applied to drought experiment for maintaining moisture stress conditions.

Other agronomic practices like fertilizer application and weed control remained constant for both experiments.

Ten competitive plants in each plot were taken for recording the observations on stomata' frequency, flag leaf area (cm^2), specific flag leaf weight (mg/cm^2), days to heading, tillers per plant, plant height (cm), peduncle length (cm), spike length (cm), spikelets per spike, grains per spike, 1000-grain weight (g), grain weight of mother shoot (g), biomass per plant (g), grain yield per plant (g) and harvest index.

The data were subjected to analysis of variance as per standard methods given by Steel and Torrie (1980). The genetic variability parameters like genotypic and phenotypic coefficient of variability, heritability estimates in broad sense and genetic advance expressed as percentage of mean were estimated as suggested by Burton (1952) and Allard (1960). Regression analysis was worked out as described by Steel and Torrie (1980).

Results and Discussion

Analysis of variance (Table 1) for grain yield and other morpho-physiological traits revealed that the genotypes differed significantly for all traits under irrigated and drought stress conditions and pooled analysis indicating the presence of genetic variation under both environments and providing the scope to find superior genotypes through selection.

A wide range of variation was noted for all the traits under both conditions (Table 2). As would be expected, exposure to drought stress significantly affected the growth and development of the wheat plant, expressed in an altered physiological, morphological and agronomic performance for all the characters. Based on combined data of the parents and crosses, one would noticed that the stomata' frequency displayed an increase of 23.9 percent under drought stress conditions as compared to irrigated conditions. On the contrary and logically flag leaf area and specific flag leaf weight showed a reduction of 57.4 and 19.0 percent under drought stress conditions compared with irrigated conditions, respectively. Days to heading, decreased by 5.2 percent under drought stress conditions. The components of grain yield and related traits, i.e., tillers per plant, plant height, peduncle length, spike length and spikelets per spike suffered a reduction of 42.7, 27.4, 31.6, 10.4 and 8.9 percent, respectively. While those related to grain itself such as grains per spike, grain weight of mother shoot and 1000-grain weight reduction occurred to the extent of 24.7, 41.5 and 22.3 percent, respectively in drought stress conditions. Grain yield per plant suffered a maximum reduction of 68 percent followed by biomass per plant (58.9 percent), while harvest index exhibited 21 percent reduction under drought stress. The means of crosses exceeded the means of the varieties for all the characters under both the environments clearly indicating the presence of heterotic effects, The results obtained from the present studies are in good agreement with the findings of Henzell *et al*. (1975), Shalaby *et al.* (1988), Sukhorukov (1989), Atale and Zope (1991) and Hattalli *et al.* (1993).

The estimates of genotypic and phenotypic coefficient of variation were comparatively high for flag leaf area, specific flag leaf weight, tillers per plant, plant height, peduncle length, spike length, spikelets per spike, grains per spike, grain weight of mother shoot, biomass per plant and grain yield per plant (Table 2) suggested that selection for these traits would be much effective. These findings are in line with the results of Subhani and Alam (1988) who reported high coefficient of variability for grain yield per plant.

Heritability estimates were high for 1000-grain weight, days to heading, peduncle length, spike length, plant height and spikelets per spike whereas stomata' frequency, specific flag leaf weight, tillers per plant, grain weight of mother shoot and harvest index showed moderate heritability estimates and flag leaf area, grains per spike, biomass per plant and grain yield per plant recorded lowest estimates of heritability under irrigated conditions. In case of drought stress conditions, days to heading, 1000-grain weight, spike length, grain weight of mother shoot, spikelets per spike, biomass per plant, specific flag leaf weight showed high heritability estimates. Characters having high values, could be improved directly through selection since they are less affected by the environmental fluctuations under both conditions.

High estimates of heritability coupled with high expected genetic advance is more helpful in predicting gain under phenotypic selection than the heritability estimates alone (Johnson *et al.,* 1955). In the present study high to moderate heritability accompanied with high genetic advance far 1000-grain weight, peduncle length, spike length, plant height, spikelets per spike, tillers per plant, grain weight of mother shoot and specific flag leaf weight under irrigated conditions. Under drought stress conditions, high heritability coupled with high genetic advance for days to heading, 1000-grain weight, spike length, grains per spike, grain yield per plant and peduncle length. The results indicated that these characters are governed by largely through the additive gene effects and improvement in the said traits may be achieved through phenotypic selection. The findings of similar nature in bread wheat were also reported by Subhani and Khaliq (1994) and Chowdhry *et al.* (1997).

The characters like days to heading and harvest index showed high heritability estimates with low genetic advance, while stomata! frequency, flag leaf area, biomass per plant and grain yield per plant exhibited low heritability coupled with low genetic advance under irrigated conditions. For stomatal frequency and plant height high heritability along with low genetic advance was noticed whereas low heritability associated with low genetic advance were recorded for flag leaf area, tillers per plant and harvest index under drought stress conditions. Such situation may be caused by non-additive gene effects (Khorgade, 1995). Hence these traits are not likely to respond favourably to selection.

With a view to predict a value of dependent variable i.e., grain yield for unite increase in value of independent variables, partial regression coefficients were estimated alongwith their standard error for both environments and are presented in Table 3. Under irrigated conditions, the partial regression coefficient for tillers per plant, grain weight of mother shoot, biomass per plant and harvest index were observed to be significant. With a unit increase in tillers per plant, grain weight of mother shoot, biomass per plant and harvest index, there was an increase in the grain yield to the extent of 0.4074, 9.924 g, 0.4158 g and 0.8437, respectively. Thus, regression analysis revealed that grain yield per plant is mainly dependent on tillers per plant, grain weight of mother shoot, biomass per plant and harvest index. These results also confirmed by the regression analysis of variance and their sequential analysis (Table 4) that biomass per plant, harvest index, grain weight of mother shoot and tillers per plant were important independent variables for the gain of 94.6 percent variability in grain yield, respectively (Table 5). The coefficient of determination exhibited that 85.4 percent of the variation in grain was contributed by biomass per plant, 8.7 percent by harvest index, 0.3 per percent

Table 1: Analysis of variance for yield and other rnorpho-physiological traits in bread wheat under irrigated and drought stress conditions

Source of variation	df	Mean Squares														
		Stomata frequency	Flag leaf area	Specific flag leaf	Day to heading Weight	Tillers/ plant	Plant height	Peduncle length	Spike length	Spikelets/ spike	Grains/ spike	1000- grain	Grain weight of Weight	Biomass/ plant mother Shoot	Harvest index	Grain yield/ plant
Irrigated conditions																
Replications	2	32.99	9.81	8.89	6.78	0.13	154.10	2.73	1.53	0.40	195.75	1.47	0.57	5.03	2.11	17.43
Genotypes	35	60.45**	24.52**	4.76**	26.01**	5.87**	64.02**	15.34**	2.05**	4.42**	85.85**	39.92**	0.34**	230.76*	9.61**	66.89**
Error	70	17.85	11.82	1.12	1.44	1.33	6.45	0.96	0.20	0.50	34.94	1.41	0.08	118.42	2.48	34.03
Drought stress conditions																
Replications	2	70.546	3.386	4.536	3.250	2.345	19.801	13.257	0.485	1.900	64.517	9.785	0.221	4.454	18.507	0.393
Genotypes	35	55.56**	6.71**	3.37**	62.96**	2.17**	57.60**	20.36**	2.04**	4.71**	62.30**	43.58**	0.23**	40.54**	9.45*	6.59**
Error	70	14.826	2.646	0.612	2.736	1.030	15.875	4.685	0.189	0.790	13.001	2.994	0.029	6.997	5.848	1.399
Pooled																
Replications	2	59.691	4.465	8.353	4.181	1.736	33.138	2.130	1.832	1.728	233.253	7.367	0.660	4.449	17.167	11.022
Environments	1	19941.9**	3012.2*	803.46**	590.04**	1600**	47076**	7681.5**	109.5**	234.79**	20619**	5912**	127.71**	130591**	5082**	37034**
Genotypes	35	101.47**	23.62**	3.53**	81.31**	5.12**	101.52**	29.95**	3.82**	8.09**	102.25**	79.63**	0.47**	148.74**	10.63**	37.58**
E x G	35	16.87	7.61	4.60**	7.66**	2.92**	20.10*	5.75**	0.28	1.03*	45.90**	3.87*	0.11**	122.66**	7.91**	35.90**
Error	142	16.151	7.252	0.925	2.143	1.172	12.985	2.978	0.192	0.645	24.015	2.227	0.054	61.894	3.840	17.560*

*, ** = Significant at 0.05 and 0.01 level of probability, respectively

Table 2: Estimates of genetic parameters in bread wheat under irrigated and drought stress conditions

Traits	Irrigated condition						Drought stress conditions					
	Mean	Range	CV% (g)	CV% (p)	H2 (BS)	GA (as % of mean)	Mean	Range	CV% (g)	CV% (p)	H2 (BS)	GA (as % of mean
Stomata! frequency	80.75	71.40-98.80	4.67	7.01	44.30	5.28	99.97	86.17-111.43	3.84	5.33	51.92	4.71
Flag leaf area	41.12	26.60-50.97	5.00	9.74	26.313	4.37	17.51	12.28-21.29	6.64	11.42	33.83	6.51
Specific flag leaf weight	20.31	16.37-25.65	5.42	7.52	51.99	6.65	16.45	13.45-18.80	5.83	7.52	60.03	7.68
Days to heading	110.64	105.0-119.00	2.59	2.81	85.01	4.05	104.94	92.00-113.00	3.93	4.19	88.01	6.81
Tillers/plant	12.75	8.8-16.80	9.65	13.22	53.33	12.0	7.31	4.40-9.90	8.42	16.24	26.90	7.43
Plant height	107.92	92.8-117.0	4.06	4.69	74.86	5.97	78.39	61.60-93.20	4.76	6.96	46.10	5.46
Peduncle length	37.74	30.2- 42.6	5.80	6.35	83.32	9.00	25.82	16.20-35.00	8.85	12.19	52.72	10.93
Spike length	13.70	11.2-15.30	5.74	6.58	76.01	8.50	12.28	9.80-14.50	6.40	7.32	76.56	9.52
Spikelets/spike	23.29	19.6-26.60	4.91	5.77	72.23	7.09	21.21	17.60-24.00	5.39	6.83	62.33	7.23
Grains/spike	79.00	59.6-99.80	5.21	9.12	32.68	5.07	59.46	43.60-71.00	6.82	9.12	55.83	8.66
1000-grain weight	46.98	36.6-754.93	7.63	8.03	90.08	12.3	36.51	24.34-44.64	10.07	11.14	81.88	15.50
Grain weight of mother shoot	3.71	2.48-4.70	8.00	11.02	52.69	9.87	2.17	1.30-2.94	11.93	14.28	69.79	16.94
Biomass/plant	83.55	54.70-115.40	7.32	14.94	24.03	6.10	34.37	24.00-44.00	9.74	12.42	61.58	13.0
Harvest index	45.87	41.58-53.93	3.39	4.50	56.93	4.35	36.17	31.41-44.90	3.03	7.34	17.03	2.13
Grain yield/plant	38.52	23.84-54.24	8.59	17.41	24.35	7.21	12.33	7.78-16.22	10.67	14.35	55.31	13.49

Table 3: Regression coefficients and Standard errors

Independent variables		Irrigated conditions		Drought stress conditions	
		Regression coefficient	S.E. 'b'	Regression coefficient	S.E. 'b'
Stomatal frequency	X_1	-0.0054	0.0333	0.0005	00165
Flag leaf area	X_2	0.0010	0.0489	-0.0368	00505
Specific flag leaf weight	X_3	-0.0046	0.1385	-0.0676	00875
Days to heading	X_4	0.0888	0.0948	-0.0255	00336
Tillers per plant	X_5	0.4074*	0.1806	0.2212*	00889
Plant height	X_6	0.0490	0.0493	0.0305	00303
Peduncle length	X_7	-0.1508	0.1308	0.0120	00496
Spike length	X_8	-0.1223	0.3507	-0.2313	01495
Spikelets per spike	X_9	-0.2384	0.2195	0.0365	01207
Grains per spike	X_{10}	-0.3705	0.1898	0.1713	01230
1000-grain weight	X_{11}	-0.5987	0.3131	0.2254	01892
Grain weight of mother shoot	X_{12}	9.9240*	4.0100	-3.0980	31805
Biomass per plant	X_{13}	0.4158**	0.0249	0.2863**	00284
Harvest Index	X_{14}	0.8437**	0.0947	0.2083**	00346
Intercept		-21.224		-14.371	
Coefficient of Determination (R-Square)		0.951		0.832	
Multiple R		0.975		0.912	

*, ** = Significant at 0.05 and 0.01 level of probability, respectively

Table 4: Regression analysis of variance in bread wheat under irrigated and drought stress conditions

Source of variation	Df	SS	MS	F (cal)
		Irrigated conditions		
Regression	4	4501.592	1125.398	452.251**
Residual	103	256.309	2.488	
Total	107	4757.901		
Biomass/plant	1	4062.291	4062.291	1632.465**
Harvest index	1	412.807	412.807	165.8900**
Grain weight of mother shoot	1	14.005	14.005	5.628*
Tillers/plant	1	12.489	12.489	5.019*
		Drought stress conditions		
Regression	4	267.498	66.875	111.20**
Residual	103	61.943	0.601	
Total	107	329.441		
Biomass/plant	1	215.903	215.903	359.000**
Harvest index	1	41.512	41.512	69.270**
Plant height	1	4.481	4.481	7.450**
Tillers/plant	1	5.602	5.602	9.315**

*, ** = Significant at 0.05 and 0.01 level of probability, respectively

Table 5: Significant contribution of characters on grain yield of bread wheat under irrigated and drought stress conditions

	Irrigated conditions		Drought stress conditions		
Traits	R-square	% contr-ibution	Traits	R-square	% contr-ibution
Grain yield + biomass/plant	0.854	85.4	Grain yield + biomass/plant	0.655	65.5
Grain yield + biomass/plant + harvest index	0.941	94.1	Grain yield + biomass/ plant +harvest index	0.781	78.1
Grain yield + biomass/plant + harvest index + grain weight of mother shoot	0.944	94.4	Grain Yield +biomass/plant + harvest index + plant height	0.795	79.5
Grain yield + biomass/plant + harvest index + grain weight of mother shoot +tillers/plant	0.946	94.6	Grain yield +biornass/plant + harvest index + plant height + tillers/plant	0.812	81.2

by grain weight of mother shoot and 0.2 percent by tillers per plant (Table 5). The findings of Raut and Khorgade (1989) partially support the present results, while Khan *et al.* (1991) reported contradictory results. From the partial regression coefficient values given in Table 3, the following multiple regression equation was established:

$$Y = -21.224 - 0.0054X_1 + 0.0010X_2 - 0.0046X_3 + 0.0888K_4 + 0.4074X_5 + 0.0490X_6\ 0.1508X_7 - 0.1223X_8 - 0.2384X_9 - 0.3705X_{10} - 0.5987X_{11} + 9.9240X_{12} + 0.4158X_{13} + 0.8437X_{14} = 38.538$$

The coefficient of determination (R^2) and multiple correlation (R) were highly significant (Table 3). The multiple correlation coefficient measures the combined relationship between a dependent and a series of independent variables. It can also be explained as the correlation between the observed value of the dependent variable and its estimated values for the independent variate values, estimated with the help of multiple regression. When these 14 independent characters were considered simultaneously to estimate a multiple correlation coefficients (Table 3) with grain yield the dependent character, it was observed that their total contribution towards yield was 95.1 percent. From traits biomass per plant, harvest index, grain weight of mother shoot and tillers per plant had a significant multiple correlation and contributed 94.6 percent to the total yield, all other characters contributed around 0.5 percent only under irrigated conditions.

In case of drought stress conditions, significant partial regression coefficients were found for tillers per plant, biomass per plant and harvest index. Therefore, there was an increase in grain yield to the extent of 0.2212, 0.2863 g and 0.2083, respectively (Table 3). The regression analysis of variance and their sequential analysis also indicated that biomass per plant, harvest index, plant height and tillers per had the important contribution in obtaining variability in grain yield (Table 4). However, 81.2 percent (Table 5) variation in grain yield was obtain through the selection of these four traits under drought stress conditions. Raut and Khorgade (1989) also reported the tillers per plant as one of the independent variable which create variability in grain yield.

From the partial regression coefficient values given in Table 3, the following multiple regression equation was established:

$$Y = -14.371 + 0.0005X_1 - 0.0368X_2 - 0.0676X_3 - 0.0255X_4 + 0.2212X_5 + 0.0305X_6 + 0.0120X_7 - 0.2313X_8 + 0.0365X_9 + 0.1713X_{10} + 0.2254X_{11} - 3.0980X_{12} + 0.2863X_{13} + 0.2083X_{14} = 12.565$$

The coefficient of determination (R^2) and multiple correlation coefficient (R) were highly significant (Table 3) under drought stress conditions. The multiple correlation coefficient measures the combined relationship between a dependent and a series of independent variables. It can also be explained as the correlation between the observed value of the dependent variable and its estimated values for the independent variate values, estimated with the help of multiple regression. When these 14 independent characters were considered simultaneously to estimate a multiple correlation coefficients (Table 3) with grain yield the dependent character, it was observed that their total contribution towards yield was 83.2 percent . From traits biomass per plant, harvest index, plant height and tillers per plant had a significant multiple correlation and contributed 81.2 percent to the total yield, all other charabters contributed around 2 percent only under drought stress conditions.

It is concluded from the present results that maximum reduction in grain yield was observed under drought stress conditions as compared to irrigated conditions followed by biomass per plant, flag leaf area, tillers per plant, grain weight of mother shoot and plant height. The traits exhibiting high heritability alongwith high genetic advance could be improved through phenotypic selection due to the presence of additive gene effects. It is also evident from the present study that multiple regression analysis provided the information regarding relative contribution of various morpho-physiological traits for the variability of grain yield. The plant height was an important trait regarding the selection of high yield per plant as compared to grain weight of mother shoot under drought stress conditions.

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