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Manifestatation of Hetetrosis in Bread Wheat under Irrigated and Drought Stress Conditions

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Abstract: Six high yielding and rust resistant bread wheat parents were crossed in a diallel fashion to get all possible combinations (30 crosses). Heterosis and heterobeltiosis analysis was performed for morpho-physiological traits like, stomatal frequency, leaf venation, flag leaf area, specific flag leaf weight, days to heading, tillers per plant, plant height, spike length, grains per spike, 1000-grain weight, biomass per plant and grain yield per plant under irrigated and drought stress conditions. Significant mid and better parent heterosis values were observed in certain single crosses for all traits under both environments. The maximum heterosis of 36.39, 15.17 and 12.54 per cent was noted for grain yield per plant, tillers per plant and spike length, respectively, in cross LU26S X Roh.90 under irrigated conditions, whereas cross combination Inq.91 X 4072 manifested maximum heterosis and heterobeltiosis for 1000-grain weight under irrigated and drought stress conditions. The presence of heterosis suggests that high yielding wheat hybrids can be developed.

Key words: Diallel, heterosis, morpho-physiological traits, bread wheat, drought stress

Introduction

The attainment of maximum crop yields is an important objective in most breeding programmes. While the major emphasis in wheat (*Triticum aestivum* L.) breeding is the development of improved varieties, significant efforts have been devoted to finding the economically feasible systems for the production of F_1 hybrids. The possible heterosis exploitable in this naturally self-pollinated crop continues to be a critical question in the hybrid wheat research. Khan and Bajwa (1989) revealed that out of the 36 crosses, positive heterosis was recorded in 14, 6, 9, 16, 21 and 16 crosses for plant height, spikes per plant, spikelets per spike, grains per spike, 100-grain weight and grain yield per plant, respectively. However, level of heterosis was significant in 7 crosses for plant height, three crosses for grains per spike, two crosses for grain weight and one cross for grain yield per plant. Panialvi *et al.* (1989) revealed that heterosis and heterobeltiosis were manifested to a varying degree of magnitude for flag leaf area, height and weight of the main tiller. Krishna and Ahmad (1992) reported that highest mean heterosis was obtained for 1000-grain weight (14.6%), grain yield (12.52%) and harvest index (9.72%). Similarly, Kumar and Ganguli (1993) revealed that heterosis over the better parent was low except for harvest index. Significant heterosis for peduncle length, and 1000-grain weight was found in HD 2315 x CPAN 1962 and for harvest index in HUW 220 x HD 2315.

A diallel comprising six bread wheat varieties/lines was employed in the present study and our objectives were to: determine the degree of heterosis and investigate the performance of relationship of F_1 hybrids and derived lines.

Materials and Methods

The studies were conducted at University of Agriculture, Faisalabad during the year 1994-96. Six varieties/lines of bread wheat viz., Pak 81, LU26S, Inq.91, Roh.90, 4072 and 4943 were crossed in a diallel fashion. The thirty F_1s including reciprocals and their parents were space planted in a randomized complete block design with three replications. A single row of 3.75 meter length served as an experimental plot. Two seeds per hill were sown with the help of a dibble and later thinned to one seedling per site with a distance of 15 centimeters within rows and 30 centimeters between rows.

For two sets of experiments, one under regular irrigation and the other under non-irrigation (drought stress), the fields were irrigated for seed bed preparation. After planting of experimental population, four canal irrigations were applied to normal experiment during the active growing period. Whereas the other experiment entirely depended on natural precipitation and no surface irrigation was applied for maintaining moisture stress conditions. Normal agronomic practices like fertilizer application and weed control were applied to both experiments.

Measurements were made on only competitive plants under both environments for morpho-physiological traits like stomatal frequency, leaf venation, flag leaf area (cm^2), specific flag leaf weight (mg/cm^2), days to heading, tillers per plant, plant height (cm), spike length (cm), grains per spike, 1000-grain weight (g), biomass per plant (g) and grain yield per plant (g).

The data were subjected to analysis of variance for all the characters for individual environments (irrigated and drought stress conditions) according to the method of Steel and Torrie (1980). Estimates of heterosis over the mid parent and better parent were calculated. A "t" test was used to evaluate the difference of F_1 means from the respective mid parent and better parent values, following the method as delineated by Wynne *et al*. (1970).

Results and Discussion

Heterosis and heterobeltiosis of grain yield and other morpho-physiological traits under irrigated and drought stress conditions are presented in Table 1.

Stomatal frequency: Seven crosses showed the significant negative heterosis under irrigated conditions. Under drought stress conditions the number of crosses showing significant negative heterosis was reduced to six. Only one cross 4943 x 4072 showed significant positive heterosis under drought stress conditions. The cross Roh.90 x 4072 exhibited a minimum values of heterosis and heterobeltiosis under both environment followed by the cross 4072 x Roh.90 and Inq.91 x Roh.90 under irrigated and drought stress conditions, respectively.

Leaf venation: Only two crosses performed significantly inferior than better parents under drought stress conditions. LU26S made the most superior combination for leaf venation under irrigated conditions as it gave the highest heterosis and heterobeltiosis with Inqlab91 under irrigated conditions. Pak.81 in combination with

Table 1: Heterosis and heterobeltiosis of grain yield and some other morpho-physiological traits in bread wheat under irrigated and drought stress conditions.

	Irrigated conditions				Drought stress conditions		
Crosses	Het.%	Crosses	H.Bel.%	Crosses	Het.%	Crosses	H.Bel.%
Stomatal frequency							
Roh. 90 x 4072	-10.34**	Roh. 90 x 4072	-16.24**	Roh.90 x 4072	-9.22**	Roh.90 x 4072	-10.67**
4072 x Roh. 90	- 9.74**	4072 x Roh. 90	-15.68**	Inq.91 x Roh.90	-8.55**	Inq.91 x Roh.90	- 9.52**
Roh. 90 x Pak. 81	- 8.06*	Roh. 90 x Pak. 81	-15.78**	Inq.91 x LU26S	-5.61*	Inq.91 x 4943	- 7.97**
LU26S x 4072	- 7.82**	Pak.81 x Roh.90	-12.32**	Inq.91 x 4943	-5.29	Inq.91 x LU26S	- 6.67**
Inq.91 x LU26S	- 6.73*	LU26S x 4072	-12.26**	LU26S x Inq.91	-5.03*	Pak.81 x Roh.90	- 6.18**
Leaf venation							
LU26S x Inq.91	7.71*	LU26S x Inq.91	3.93	Pak.81 x LU26S	5.11**	4943 x Pak.81	2.90
				4943 x 4072	4.33*	4943 x 4072	2.71
Flag leaf area							
Roh.90 x 4072	22.81**	4072 x 4943	16.87**	LU26S x Roh.90	20.40**	Inq.91 x LU26S	11.09
4072 x Roh.90	19.20**	Inq.91 x 4072	16.52**	Inq.91 x LU26S	14.99*	LU26S x 4943	10.76
4072 x 4943	18.70**	Lu26S x 4072	15.70**	Lu26S x 4943	14.56*		
Roh.90 x LU26S	17.92**	4072 x Inq.91	13.08*				
Inq.91 x 4072	17.47**	4072 x LU26S	11.83*				
Specific flag leaf weight							
Inq.91 x 4072	8.34**	4072 x 4943	4.42	Roh.90 x 4072	8.36**	Roh.90 x 4943	5.77
LU26S x 4943	6.81*	Roh.90 x 4072	1.50	Roh.90 x 4943	6.30*	Roh.90 x 4072	0.26
Roh.90 x Inq.91	6.34*	4072 x Pak.81	1.25	Pak.81 x 4943	5.93*		
Days to heading							
Roh.90 x LU26S	- 3.50**	Roh.90 x LU26S	-0.63	4943 x 4072	-3.80**	Roh.90 x Pak.81	-0.32
Roh.90 x Pak.81	- 3.08**	Pak.81 x Roh.90	-0.30	4072 x 4943	-3.16**	4943 x 4072	-0.31
4072 x LU26S	- 2.85**	Inq.91 x LU26S	0.00	LU26S x 4072	-2.76**	4943 x Pak.81	-0.31
LU26S x 4072	- 2.85**	4072 x Roh.90	0.00	4943 x Pak.81	-2.46*	Pak.81 x Roh.90	-0.30
Pak.81 x LU26S	-2.72**	LU26S x Roh.90	0.31	Inq.91 x Pak.81	-2.02*	4072 x 4943	-0.32
Tillers per plant							
LU26S x Roh.90	15.17**	LU26S x Roh.90	11.29**	Roh.90 x Pak.81	8.94	Roh.90 x Pak.81	3.07
Roh.90 x LU26S	9.46	Roh.90 x LU26S	5.77	Pak.81 x Inq.91	1.91	Pak.81 x Inq.91	0.41
4072 x LU26S	4.92	4072 x LU26S	4.38				
Plant height							
Lu26S x 4943	- 5.06**	LU26S x 4943	- 2.10	4072 x LU26S	-2.09	4072 x 4943	0.00
Pak.81 x 4072	- 2.19	LU26S x Pak.81	- 0.28	Roh.90 x 4072	- 0.89	4943 x LU26S	0.78
Spike length							
LU26S x Roh.90	12.54**	LU26S x 4943	7.15**	Roh.90 x LU26S	13.93**	LU26S x Pak.81	10.46**
4072 x 4943	10.53**	Roh.90 x 4072	6.19**	LU26S x Pak.81	11.11**	Pak.81 x LU26S	6.98**
Roh.90 x 4072	10.33**	4072 x 4943	5.91**	LU26S x Roh.90	10.22**	Roh.90 x LU26S	6.98**
4072 x Inq.91	9.97**	LU26S x 4072	5.91**	Inq.91 x Roh.90	10.01**	LU26S x 4072	5.71*
Roh.90 x Inq.91	9.82**	4943 x LU26S	4.93**	Roh.90 x 4943	9.25**	4072 x 4943	5.43 *
Grains per spike							
Roh.90 x Inq.91	22.90**	Roh.90 x 4072	19.61**	LU26S x Pak.81	26.38**	Roh.90 x Pak.81	14.72**
LU26S x Roh.90	21.49**	Roh.90 x Inq.91	18.56**	Pak.81 x LU26S	23.78**	LU26S x Pak.81	14.41**
LU26S x Inq.91	20.77**	LU26S x Inq.91	16.26**	Inq.91 x LU26S	22.26**	4943 x 4072	14.15**
Roh.90 x 4072	20.57**	LU26S x Roh.90	13.63**	LU26S x 4072	20.99**	4072 x 4943	13.69**
LU26S x 4072	19.20**	LU26S x 4072	12.33**	Roh.90 x Pak.81	16.97**	Pak.81 x LU26S	12.06**
1000-grain weight							
Inq.91 x 4072	18.28**	Inq.91 x 4072	17.29**	Inq.91 x 4072	20.60**	Inq. 91 x 4072	19.16**
4072 x Inq.91	16.91**	4072 x Inq.91	15.94**	Inq.91 x Pak.81	14.71**	4072 x Inq.91	12.04**
Inq.91 x Pak.81	16.84**	Inq.91 x Pak.81	15.84**	Roh.90 x 4943	14.61**	Pak.81 x Inq.91	10.35**
Pak.81 xInq.91	12.16**	Pak.81 x Inq.91	11.21**	4072 x Inq.91	13.39**	Pak.81 x 4943	9.71*
LU26S x 4072	11.69**	Pak.81 x 4072	5.56**	4943 x Roh.90	12.76**	Inq.91 x 4943	7.70*
Biomass per plant							
Roh.90 x Pak.81	24.73**	4072 x 4943	18.53*	Roh.90 x Pak.81	18.28**	Pak.81 x LU26S	9.09*
LU26S x Roh.90	22.37*	4072 x LU26S	17.83*	Inq.91 x Roh.90	17.71**	Inq.91 x 4072	8.77*
Roh.90 x LU26S	22.20*	LU26S x Roh.90	13.71	Roh.90 x Inq.91	11.46*		
Roh.90 x Inq.91	22.11*	Pak.81 x Inq.91	13.63	Inq.91 x 4072	10.22*		
4072 x 4943	18.80*	Roh.90 x LU26S	13.54	Pak.81 x LU26S	10.09*		
Grain yield per plant							
LU26S x Roh.90	36.39**	4072 x 4943	31.10**	Inq.91 x Roh.90	28.16**	Pak.81 xLU26S	8.06
Roh.90 x LU26S	34.28**	LU26S x Roh.90	23.96*	Roh.90 x Inq.91	26.08**	Inq.91 x Roh.90	7.39
4072 x 4943	33.30**	Roh.90 x LU26S	22.04*	Roh.90 x Pak.81	20.57**	Pak.81 x 4943	7.00
Roh.90 x Pak.81	23.35*	Pak.81 x LU26S	15.31**	Inq.91 x Pak.81	6.65		
Roh.90 x 4072	22.08*			Inq.91 x LU26S	9.62	Inq.91 x 4072	6.62

Note: In case of stomatal frequency, days to heading and plant height parents with minimum values are considered to be the better parents as these desired in those traits.

LU26S showed superiority over mid parent and 4943 x Pak.81 gave the highest value of heterobeltiosis under drought stress conditions.

Flag leaf area: Positive heterosis was observed in all the crosses under both environments, with exception of 2 and 8 crosses which gave negative values under irrigated and drought stress conditions, respectively. None of the crosses performed significantly inferior than mid-parent or better parent under any environment except heterobeltiosis for cross 4072 x Rohtas-90 under drought stress conditions. Maximum heterosis and heterobeltiosis were recorded in crosses Roh.90 x 4072 and 4072 x 4943, respectively under irrigated conditions. While under drought stress conditions the greatest values of heterosis and heterobeltiosis were exhibited in cross combinations LU268S x Roh.90 and Inq.91 x LU26S, respectively.

Specific flag leaf weight: For this trait significant positive heterosis was observed in three crosses (Table 1), out of which cross Inq.91 x 4072 gave highest value of 8.34 percent under irrigated conditions, while under drought stress conditions three crosses also had significant positive heterosis and cross Rohtas-90 x 4072 gave the maximum value of 8.36 percent. None of the cross gave significantly better performance than the better parents under any environment. However, cross 4072 x 4973 exhibited highest heterobeltiosis under irrigated conditions and cross Roh.90 x 4943 showed greatest value of heterobeltiosis under drought stress conditions (Table 1).

Days to heading: Positive heterosis was observed in 8 crosses out of which three crosses exhibited significant increase over mid parent values under irrigated conditions. Nine crosses performed significantly lower than mid parent values. None of the cross performed significantly superior than mid parents under drought stress conditions. In case of heterobeltiosis none of the cross exhibited significantly lower than better parent (parent with minimum days) under any environment. The cross combination Roh.90 x LU26S revealed the lowest values of −3.50 and −0.63 percent for heterosis and heterobeltiosis, respectively under irrigated conditions. While under stress conditions cross 4943 x 4072 gave the lowest values of −3.80 and −0.31 percent for heterosis and heterobeltiosis, respectively.

Tillers per plant: Only one LU26S x Roh-90 showed the significant positive heterosis and heterobeltiosis under irrigated conditions and none of the cross performed significantly better than mid or better parent under drought stress conditions. However cross Roh.90 x Pak.81 exhibited maximum increase of 8.94 and 3.07 percent for heterosis and heterobeltiosis under drought stress conditions, respectively (Table 1).

Plant height: For plant height (Table 1), positive heterosis was observed in all the crosses under both environments, with the exception of 8 and 3 crosses which gave the negative heterotic values under irrigated and drought stress conditions, respectively. Only one cross (LU26S x 4943) showed the significant negative heterosis under irrigated conditions. None of the cross performed significantly inferior than mid-parent under drought stress conditions. Out of the total 30 crosses significant positive heterobeltiosis under irrigated and drought stress conditions was observed for 22 and 19 crosses, respectively. While none of the cross was noted to have a significant decrease over the better parent (minimum height) under both environments. The cross Pak.81 x Inq.91 exhibited as maximum increase of 6.04 percent over mid parent under irrigated conditions, while cross Roh.90 x 4943 showed the highest values of heterobeltiosis under the same environment. The highest value of heterosis of 10.93 percent was recorded in the cross Inq.91 x Roh.90 and greatest value of heterobeltiosis was shown by the cross Roh.90 x Pak.81.

Spike length: Twenty one crosses out of 30 provided significant positive heterosis under irrigated conditions and 20 under drought stress conditions (Table 1). The heterotic values ranged from 12.54 (LU26S x Roh.90) to −0.96 percent (Inq.91 x LU26S) under irrigated conditions, while a range of 13.93 (Roh.90 x LU26S) to −0.40 percent (LU26S x Inq.91) was recorded for drought stress conditions. Five crosses showed significantly positive heterotic values against better parent while the other two had significantly negative effects under irrigated conditions. The ranged limit for heterobeltiosis under irrigated conditions was 7.15 (LU26S x 4943) to −5.18 percent (Pak.81 x Roh.90) and for drought stress conditions it was from 10.46 (LU26S x to Pak.81) to −8.11 percent (LU26S x Inq.91).

Grains per spike: As regards this trait most of the hybrids displayed positive performance in relation to their mid parents (Table 1). However, three crosses gave negative values under irrigated conditions. Out of the total 12 and 23 crosses manifested significant positive heterosis under irrigated and drought stress conditions, respectively, a range 22.10 (Roh.90 x Inq.91) to −4.21 percent (4943 x Pak.81) and 26.38 (Lu26S x Pak.81) to 1.95 percent (4072 x LU26S) was observed under irrigated as well as drought stress conditions, respectively. Thirteen crosses showed significant positive heterobeltiosis under drought stress conditions as compared to only seven crosses under irrigated conditions. Among the crosses, two were found significantly inferior to their respective better parents under irrigated conditions, while there was only one under drought stress conditions (Table 1).

1000-grain weight: As is apparent from the Table 1, twenty five crosses showed significant positive heterosis under irrigated conditions, while the comparative number was fourteen under drought stress conditions. The percent heterosis ranged from 18.28 (Inq.91 x 4072) to 5.60 percent (LU26S x 4943) under irrigated conditions and from 20.60 (Inq.91 x 4072) to −0.97 percent (Inq.91 x LU26S) under drought stress conditions. Significant differences against better parents were obtained for 16 crosses under irrigated conditions, out of which only seven crosses had positive values. Under drought stress conditions, twenty three exhibited significant differences over their respective better parents. Seven of these were found to have positive expression. Inq.91 x 4072 out-performed all the crosses under irrigated and drought stress conditions by showing an increase of 17.29 and 19.16 percent, respectively over better parents.

Biomass per plant: As is evident from Table 1, eight crosses gave the significant positive heterosis, while one cross gave the significant negative heterosis under irrigated conditions. Under drought stress conditions ten crosses exhibited significant heterosis, half of these were found to have positive expression. Significant differences against better parent were obtained for five crosses under irrigated conditions, out of which only two crosses had the positive value. Under drought stress conditions 13 crosses exhibited significant heterobeltiosis, out of which crosses Pak.81 x LU26S and Inq.91 x 4072 had positive value 9.09 and 8.77 percent, respectively. Cross 4072 x 4943 out yielded all the crosses under irrigated conditions over better parent.

Grain yield per plant: As regards heterosis for grain yield per plant under irrigated conditions (Table 1), the maximum positive heterosis was recorded in a cross LU26S x Roh.90 followed by

Roh.90 x LU26S. Significant positive heterobeltiosis was observed in three crosses under the same environment. The higher value of positive heterobeltiosis appeared in cross 4072 x 4943 under irrigated conditions. Under drought stress conditions significant positive heterosis was obtained in 4 crosses with a range of 15.31 (Pak.81 x LU26S) to 28.16 percent (Inq.91 x Roh.90). Significant and negative heterobeltiosis was shown by 11 crosses. While maximum positive heterobeltiosis was exhibited by the cross Pak.81 x LU26S.

It is concluded from the present study that varying degrees of heterosis and heterobeltiosis expressed for all characters under both environments. The maximum heterosis of 36.39 percent (LU26S x Roh.90) occurred in case of grain yield per plant under irrigated conditions and 28.16 percent for cross Inq.91 x Roh.90 under drought stress conditions. Whereas cross combination Inq.91 x 4072 showed maximum heterosis and heterobeltiosis for 1000-grain weight under irrigated as well as drought stress conditions. Most crosses expressed significant heterosis and some even heterobeltiosis. Present results find confirmation from the findings of Khan and Bajwa (1989), Panialvi *et al*. (1989), Krishna and Ahmad (1992) and Kumar and Ganguli (1993) who reported the varying degree of magnitude for various characters.

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