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Heterosis, Inbreeding Depression and Line Performance in Crosses of *Triticum aestivum*

[1]M. Aslam Chowdhry, [1]Muhammad Iqbal, [2]Ghulam Mahboob Subhani and [1]Ihsan Khaliq
[1]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan
[2]Wheat Research Institute, AARI, Faisalabad, Pakistan

Abstract: Analysis of variance showed that the genotypic differences for these characters were highly significant. The phenomenon of heterosis and heterobeltiosis occurred in varying degrees in almost all crosses for the characters under study. Additive type of gene action and additive with the involvement of over-dominance type of gene action were present in almost all the traits. Inbreeding depression was exhibited to varying degree in almost all the crosses for yield and yield components.

Key words: Heterosis, inbreeding depression, economic yield

Introduction

The possible heterosis exploitable in this naturally self-fertilized crop continues to be a critical question in hybrid wheat. Fewer studies, however, have investigated significant heterosis and inbreeding depression for grain yield per plant (Sharma and Ahmad, 1978) whereas, significant heterosis over better parental value was observed for grain yield per plant, 1000-grain weight, number of tillers per plant, number of grains per spike and biomass per plant (Iqbal and Sharma, 1989). Pronounced heterosis in F_1 also showed marked inbreeding depression in the F_2 indicating non-additive gene action (Jatasra *et al.,* 1980). While both additive and non-additive type of gene action were present for the expression of plant height, number of tillers per plant, peduncle length, yield and its components, whereas, inbreeding depression was not so pronounced in F_2 generations (Ahmed, 1981). Heterosis over mid parent for grain yield per plant, number of grains per spike, 1000-grain weight, spike length, number of tillers per plant, number of spikelets per spike and plant height was observed (Alam and Chowdhry, 1990). Whereas, in almost all the crosses heterotic effects were apparent in F_1 generation to varying extent for plant height, number of tillers per plant, number of spikelets per spike, number of kernels per spike, 1000-grain weight and grain yield per plant.

Most previous studies have measured heterosis in wheat crosses to ascertain their potential as sources of high yielding inbred lines. The F_1 hybrids in these studies have not yielded significantly better than the best lines selected from the corresponding crosses.

An attempt is made to analyse a 5 × 5 diallel cross of spring wheat with the objectives (a) to determine the degree of heterosis present and (b) to examine the inbreeding depression from the F_1 hybrids to the F_2 generations.

Materials and Methods

The experimental material consisted of five spring wheat varieties/lines viz., Pak. 81, LU26S, 4072, 4770 and Pasban 90. Seeds of F_1 and F_2 crosses along with their parents were planted in a triplicated randomized complete block design at Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Each F_1 cross and parent comprised 22 plants, while F_2 population consisted of 66 plants. Distance within and between the plants was 22.5 and 30 cm, respectively. At maturity 10 plants of F_1 and their parents, whereas, 30 plants of F_2 population from each replication were marked at random and data were recorded on the plant parameters like plant height, flag leaf area, number of tillers per plant, peduncle length, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight, economic yield and biological yield per plant.

To determine the significant differences among hybrids and parents, the data were subjected to the analysis of variance technique (Steel and Torrie, 1980). The percent increase (+) or decrease (-) of F_1 over mid parent as well as better parent was calculated to estimate the possible heterotic effects (Fonseca and Patterson, 1968). The "t" value for heterosis was obtained by using the formula as reported by Wynne *et al.*, 1970. Inbreeding depression was estimated by calculating the percent increase or decrease of F_2 population over F_1 hybrids (Singh, 1973).

Results and Discussion

The analysis of variance for plant height, flag leaf area, number of tillers per plant, peduncle length, spike length, spikelets per spike, number of grains per spike, 1000-grain weight, economic yield and biological yield per plant manifested highly significant differences ($p<0.01$) among parents, F_1 and F_2 hybrids except plant height, which is significant for F_2 hybrids. The estimates of heterosis, heterobeltiosis and inbreeding depression for plant height, yield and its components are presented in Table 1-3. Good negative heterosis and heterobeltiosis of -6.91 and -7.53% were observed for plant height in F_1 hybrid Pak 81 × 4072. Maximum positive heterosis and heterobeltiosis of 4.07 and 3.78% were found in Pasban 90 × LU265 for plant height. Out of twenty crosses only 4 and 3 crosses showed positive heterosis and heterobeltiosis, respectively. Minimum inbreeding depression of 0.12% was observed in the cross combinations 4770 × LU265 and maximum value was exhibited by cross Pasban 90 × Pak. 81. No inbreeding depression was observed in hybrid 4770 × 4072. Generally the crosses with low F_1 means showed high inbreeding depression for plant height. The results clearly indicated that plant height showed partial dominance with considerable involvement of additive type of gene action but in some crosses where heterobeltiosis was observed, over dominance might be involved (Alam and Chowdhry, 1990).

Thirteen F_1 crosses out of twenty showed positive heterosis over mid parent, while eight crosses exhibited an increase over the better parents. Maximum heterosis over mid parent and better parent was observed in the F_1 crosses viz., LU265 × 4770 and Pasban 90 × 4770 for flag leaf area, respectively.

Table 1: Heterosis (%) in F_1 for plant height, yield and its components in wheat

Cross	Plant height	Flag leaf area	Tillers per plant	Penduncle length	Spike length	Spikelets per spike	Grains per spike	1000 weight	Economic yield/plant	Biological yiely per plant
Pak.81 × LU265	-2.99	-7.74*	2.77	-1.25	-7.69*	0.00	4.15	5.70**	18.67*	10.12
Pak.81 × 4072	-6.91**	-13.50**	5.38	-3.84	-4.17	-4.50	-6.59	-9.58**	29.53**	26.49**
Pak.81 × 4770	-3.62*	15.77**	-6.78	8.06**	3.09	-2.22	-0.94	0.57	-1.88	0.10
Pak.81 × Pasban	-4.53	6.01	13.45*	5.00*	4.65	1.50	-5.94	-5.72**	9.18	10.64
LU26S × Pak.81	-0.45	-4.23	-15.65*	1.41	4.98	4.76	0.54	1.75	6.90	3.52
LU26S × 4072	-0.13	-1.37	5.58	4.60*	6.14*	3.12	26.99**	-0.58	35.52**	4.61
LU26S × 4770	-0.79	26.01**	-2.34	-1.21	8.28**	6.98**	4.15	4.83**	1.96	6.41
LU26S × Pasban	-6.55**	-6.01	-9.31	3.72	5.66	1.57	2.46	-0.43	-4.63	-6.84
4072 × Pak.81	0.02	8.55*	0.16	-1.50	3.21	-2.98	-2.94	-7.56**	24.34**	14.44*
4072 × LU265	-2.22	5.88	-2.75	1.52	2.05	4.66	-10.43	-0.06	2.68	3.43
4072 × 4770	-1.00	18.59**	2.56	1.12	5.89	-3.66	-8.93	2.56	24.87**	12.47*
4072 × Pasban	2.39	16.58**	-25.57**	6.39*	1.25	-2.96	8.59	-4.83**	-18.22*	-27.98*
4770 × Pak.81	-2.63	8.94*	-11.40	4.64*	4.32	-0.76	-6.10	4.21**	-3.78	-15.63*
4770 × LU26S	-2.14	4.02	- 9.67	8.05**	5.26	-2.33	9.44	-1.52	1.01	2.06
4770 × 4072	-2.33	5.53	-14.51*	7.15**	5.89	0.73	5.40	2.14	0.50	-12.22*
4770 × Pasban	-2.07	13.50**	-20.74**	8.48**	1.26	-6.72**	0.73	-0.70	6.30	-9.80
Pasban × Pak.81	-3.83*	-3.71	-19.92**	6.44**	4.11	2.98	3.29	-9.19**	10.99	2.21
Pasban × LU26S	4.07*	2.98	9.31	5.03*	16.45**	7.80**	19.26**	-0.56	32.76**	20.09**
Pasban × 4072	1.69	-15.59**	-18.59**	5.70*	6.34	-2.21	3.84	-1.79	-0.49	-4.19
Pasban × 4770	-2.07	14.62**	2.16	4.04	1.26	1.46	12.04*	-8.23**	18.92*	1.76

*,** significant at the 0.05 and 0.01 probability levels, respectively

Table 2: Heterobeltiosis (%) in F, for plant height, yield and its components in wheat

Cross	Plant height	Flag leaf area	Tillers per plant	Penduncle length	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Economic yield/plant	Biological yiely per plant
Pak.81 × LU26S	-5.16*	-9.96*	-2.26	-3.15	-5.00	-4.55	-14.77*	2.87	16.33	3.08
Pak.81 × 4072	-7.53**	-15.95**	o.23	-6.66**	-6.00	-5.91*	-13.51*	-10.88**	20.19*	-26.56**
Pak.81 × 4770	-6.12**	2.06	-12.88	7.37**	-1.17	-4.35	-10.97	-1.91	-3.69	-6.66
Pak.81 × Pashan	-6.41**	-6.53	1.98	-6.15**	1.50	0.00	-9.71	-6.36**	4.39	6.06
LU26S × Pak.81	-2.68	-6.53	-19.77**	-2.63	2.36	0.00	-17.72**	-0.97	4.79	-3.09
LU26S × 4072	-1.72	-1.81	5.58	5.73*	5.50	-2.96	-10.95	-1.84	28.14**	-2.15
LU26S × 4770	-5.47**	13.51**	-12.88	-2.50	6.41	0.00	-6.35	4.60*	-1.86	-6.66
LU26S × Pasban	-6.81**	-15.32**	-22.02**	-8.87**	0.00	-4.41	-13.31*	-3.73*	-10.53	-16.16*
4072 × PAK.81	-0.64	5.48	-4.74	-4.39*	1.23	-4.41	-10.13	-8.89*	15.37	14.34*
4072 × LU26S	-3.78	5.41	-2.75	0.45	1.43	-1.50	-21.74**	-1.33	-2.91	-3.26
4072 × 4770	-4.19*	7.25	-8.50	-1.24	3.45	-4.35	-11.84	1.48	13.89	4.95
4072 × Pasban	1.03	5.45	-35.99**	-7.37**	-3.62	-2.96	4.58	-6.83**	-27.18**	-30.91**
4770 × Pak.81	-5.15**	-3.96	-17.19*	3.97	0.00	-2.91	-15.61*	1.64	-5.56	-21.34**
4770 × LU26S	-6.75	-6.30	-19.41**	6.64**	3.45	-8.70**	-1.59	-1.73	-2.78	-10.48
4770 × 4072	-5.47**	-4.55	-23.73**	4.66*	3.45	0.00	2.04	1.06	-8.33	-18.09**
4770 × Pashan	-6.43**	13.48**	-24.00**	-3.59	-5.72	-7.39**	-5.97	-3.79*	3.50	-12.38*
Pasban × Pak.81	-5.73**	-15.10**	-28.01**	4,86*	0.98	1.46	-0.85	-9.80**	6.13	-2.02
Pasban × LU26S	3.78	-7.22	-6.00	-7.72**	10.21**	1.46	0.91	-3.85*	24.55**	8.08
Pasban × 4072	0.34	-23.64**	-29.99**	-7.97**	1.23	-2.91	0.00	-3.85*	-11.39	-8.08
Pasban × 4770	-6.43**	14.59**	-2.04	-7.54**	-5.72	1.46	4.58	-11.08**	15.79	-1.14

, " significantly at the 0.05 and 0.01 probability levels, respectively

Table 3: Inbreeding depression (%) for plant height, yield and its components in wheat

Cross	Plant height	Flag leaf area	Tillers per plant	Penduncle length	Spike length	Spikelets per spike	Grains per spike	1000-grain weight	Economic yield/plant	Biological yiely per plant
Pak.81 × LU26S	3.28	24.20	7.69	2.97	12.52	6.33	9.16	1.34	7.19	10.67
Pak.81 × 4072	5.09	24.36	9.98	3.86	12.08	15.56	14.81	11.68	17.04	-5.03
Pak.81 × 4770	0.92	15.20	6.30	5.01	11.86	2.73	9.23	16.41	13.47	10.96
Pak.81 × PA5.90	1.82	14.01	9.00	3.49	9.70	6.97	4.98	7.85	17.82	21.27
LU26S × Pak.81	4.57	14.97	4.03	5.14	12.49	9.09	6.32	6.49	15.77	20.24
LU26S × 4072	2.13	28.54	3.71	6.71	11.98	6.05	17.48	1.29	16.52	10.45
LU26S × 4770	0.68	22.71	11.48	3.50	7.39	0.09	-5.05	1.98	12.45	15.62
LU26S × Pasban	3.69	23.56	10.23	2.92	12.36	3.74	6.75	4.69	12.41	18.72
4072 × Pak.81	1.02	16.59	4.42	7.84	9.86	4.85	11.83	6.47	12.80	25.46
4072 × LU26S	4.90	27.79	2.14	6.55	12.96	5.15	-20.03	7.29	11.82	18.21
4072 × 4770	0.33	32.65	9.21	3.73	7.00	4.82	-3.34	5.77	21.83	14.31
4072 × Pasban	0.34	26.95	2.72	3.13	17.18	4.45	10.70	3.33	6.76	2.81
4770 × Pak.81	1.15	30.46	4.03	8.55	8.97	5.87	5.10	8.63	17.44	8.73
4770 × LU26S	0.12	21.08	6.33	5.52	6.67	19.05	0.26	-0.37	16.91	11.35
4770 × 4072	0.00	29.83	2.91	3.39	9.33	5.70	7.99	7.05	21.00	16.41
4770 × Pasban	1.49	18.80	9.47	-3.18	12.87	0.52	6.89	2.95	11.16	1.84
Pasban × Pak.81	6.19	18.21	4.25	-5.61	13.25	5.39	9.24	2.76	10.89	9.92
Pasban × LU26S	0.34	12.64	12.32	-6.20	3.56	9.48	4.81	1.77	12.68	16.42
Pasban × 4072	1.06	20.50	8.40	-2.75	10.14	6.67	9.67	3.31	16.87	9.8
Pasban × 4770	0.62	-8.41	13.72	-7.34	9.66	5.70	21.25	4.10	13.80	9.34

Pronounced inbreeding depression for this trait was found ranging from 12.64 to 32.65%, however, negative inbreeding depression was observed in cross Pasban 90 × 4770. The results indicated that additive type with partial dominance gene action was present. But the involvement of over dominance in some crosses was also exhibited due to heterobeltiosis for the said trait.

The maximum positive heterosis over mid parent and over better parent for number of tillers per plant was noted in cross combinations Pak 81 × Pasban 90 and LU265 × 4072, respectively. The results showed that the additive type of gene action was involved for the expression of number of tillers per plant, however, due to positive heterobeltiosis some crosses like LU26S × 4072 and Pak 81 × Pasban 90 were appeared to be controlled by over dominance type of gene action (Iqbal and Sharma, 1989). Maximum inbreeding depression was found in the cross Pasban 90 × 4770, where it was low for 4770 × 4072.

Positive heterotic effects for peduncle length ranged from 1.12 to 8.48 percent. Hybrid Pak 81 × 4072 showed maximum negative value of -3.84% over mid parent and -6.66% over better parent. The maximum and highly significant heterobeltiosis was found in crosses Pak 81 × 4770 and 4770 × LU26S. The maximum and minimum inbreeding depression for peduncle length was observed in crosses 4770 × Pak 81 and Pasban 90 × 4770, respectively. The results indicated that peduncle length was controlled by additive type of gene action with the involvement of over-dominance effect (Ahmad, 1981). Since peduncle length contributes in the total plant height and F_2 crosses had considerable variation in peduncle length thus provide a wide range to plant breeder for the selection of dwarf segregants from this material. Additive type of gene action for this character may also be helpful. Positive and highly significant heterosis and heterobeltiosis were observed for spike length in cross Pasban 90 × LU265. Only two out of twenty crosses showed negative heterosis over mid parents, while 6 crosses were lower than their respective better parents. It is apparent from Table 3 that the inbreeding depression ranged from 3.56 to 17.18 percent. The results showed that additive with over-dominance effects of gene action were involved for the expression of spike length. Maximum positive heterosis and heterobeltiosis for number of spikelets per spike was observed in cross combination Pasban 90 × LU26S followed by LU26S × 4770. It is clear from the Table 1 that eleven out of twenty crosses exhibited positive increase ranging from 0.73 to 7.8% over their mid parent. Two hybrids namely 4770 × LU26S and 4770 × Pasban 90 revealed highly significant and negative heterosis over their better parents. Inbreeding depression ranged from 0.09 to 19.05 percent. The results further proved the presence of considerable additive effects in the inheritance of number of spikelets per spike. Additive, partial and over-dominance type of gene action has also been reported earlier (Ahmad, 1981).

Table 1 indicated that out of twenty F_1 hybrids, thirteen showed an increase over mid parent and hybrid LU26S × 4072 showed better performance with highest value of 26.99% over mid parent for number of grains per spike. The results suggested additive and over dominance type of gene action for this trait. The maximum inbreeding depression was exhibited by the cross Pasban 90 × 4770. Hybrid cross 4770 × LU26S was an obvious exception, it exhibited relatively good positive heterosis and considerable tolerance to inbreeding depression in F_2 and this proved as a more promising combination for the exploitation of heterosis in advanced generations (Ahmad, 1981). The cross Pak.81 × LU26S manifested maximum positive heterosis and heterobeltiosis for 1000-grain weight followed by LU26S × 4770 showing 4.83 and 4.60% heterosis and heterobeltiosis, respectively. These results indicated the presence of over dominance and additive type of gene action with the involvement of partial dominance for this attribute. Inbreeding depression ranged from -0.37 to 16.41% in hybrids 4770 × LU26S and Pak.81 × 4770, respectively (Ahmad, 1981).

Fifteen crosses have positive heterosis for grain yield per plant ranging from 0.50% to 35.50% over mid parent. While eleven crosses manifested positive heterosis over better parent with maximum value of 28.14% followed by 24.55 percent. The F_1 hybrids LU26S × 4072 and Pasban 90 × LU26S reflected maximum positive heterosis and heterobeltiosis for grain yield per plant indicating overdominance type of gene action for this character, while the remaining crosses manifested small increases over their mid parent showing the additive type of gene action with the involvement of partial dominance. Seven crosses exhibited significant increase over respective mid parental values, whereas five yielded more than the better parents. The lowest inbreeding depression of 6.67% was exhibited by the cross combination 4072 × Pasban 90 and the highest by 4072 × 4770 (Ahmad, 1981; Iqbal and Sharma, 1989).

The F_1 hybrids Pasban 90 × LU26S and 4072 × Pak.81 showed maximum positive heterosis and heterobeltiosis for biological yield per plant, respectively. Two crosses showed significant positive heterotic effects over mid as well as better parents. The results manifested additive type of gene action with over-dominance. High to low inbreeding depression was observed in crosses 4072 × Pak.81 and 4770 × Pasban 90. The results also indicated the involvement of additive with partial dominance type of gene action for this attribute (Iqbal and Sharma, 1989).

It is concluded that the hybrid combinations LU26S × 4072 and Pasban 90 × LU26S should provide the best opportunities for selecting high yielding plants accompanied with the combination of other desirable attributes like plant height, tillers per plant, peduncle length, spike length, spikelets per spike and grains per spike. Negative and lowest values of inbreeding depression in some crosses for yield and its components reflected that these hybrids have the potential for maintaining the hybrid vigour to a desirable extent in succeeding generations.

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