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Study of hybrid performance and heterosis in F_1 Population of Bread Wheat [*Triticum aestivum* (L.) em. Thell]

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ABSTRACT

The experiment was carried out in bread wheat to estimate the magnitude of heterosis in respect of fifteen quantitative traits. A diallel set of 10 x 10 was prepared by crossing 10 wheat genotypes [*Triticum aestivum* (L.) em. Thell] in all possible combinations excluding reciprocals and their 45 F_1s along with two checks were evaluated in randomized block design with three replications in three different environments i.e. E_1, E_2 and E_3 at different locations during *Rabi* 2020-21. The significance of ANOVA due to parents, crosses and parents v/s crosses indicated the presence of the significant amount of variability in the experimental material. Among the crosses, eight crosses HD 3086 x Raj 4079, HD 3086 x WR 544, RAJ4238xRAJ3077, Raj 4238 x Raj 4079, Raj 4238xWR544, MHD 3086203 x DBW 187, HI 1544 x Raj 4079 and HI1544xWR544 in E_2, E_3 and on pooled basis while 1 cross (Raj 4238 x Raj 3077) in E_1 out yielded the best check (Sonalika). Three crosses, RAJ4238xRAJ4079, Raj 4238 x DBW187 and MHD3086203xDBW187 exhibited significant heterobeltiosis for grain yield in all the three environments as well as on pooled basis. Five crosses *viz.*, RAJ 4238 x Raj 3077 (16.65), HD 3086 x Raj 4079 (16.33), Raj 4238 x Raj 4079 (16.30), HI 1544 x RAJ 4079 (16.15) and Raj 4238 x DBW 187 (14.62) exhibited maximum grain yield per plant than the general mean (12.69) as well as significance of heterosis over standard check. The superiority of above crosses reveals good scope for commercial exploitation of heterosis by developing superior segregants and better pure lines for crop improvement programmes.

Key words: *Bread wheat, Diallel, F_1 hybrids, Heterobeltiosis, Relative heterosis*

Introduction

Wheat [*Triticum aestivum* (L.) em. Thell] is the most pivotal and extensively cultivated comestible crop of most areas of the world and occupies striking position in India after rice. Nutritionally, it is one of the most important cereals which is crucial for the food security, indigence mitigation and meliorated livelihoods. India's wheat demand by 2030 has been estimated at 100 million metric tons to feed the burgeoning population. To accomplish this target, the wheat production has to be escalated at the rate of <1mmt per annum (Sharma *et al*., 2011). In India, it is grown on an area of 31.76 million hectares with a production of 109.52 million tones and productivity of 3464 kg/ha (Annual Report of IIW&BR, 2022).

Yield is a polygenic trait that is regulated by several attributing components. There are the opportunities for increasing its production in future due to non uniformity of improvement in productivity all over the country. Therefore, the plant breeding tools have an eminent importance in changing the present situation. Selection of desirable parents with improved genetic potential for developing better verities is the major task for the plant breeders. Hybridization is the most important technique for breaking yield barrier. The identification of distinguished parents is the important pre-requisites for beginning a systematic and effective breeding programme.

Heterosis breeding is one of the strongest tools to achieve the targeted goal by taking a quantum jump in production and productivity under various agro-climatic conditions. The exploitation of heterosis necessitates rigorous evaluation of germplasm to ascertain diverse donors with high nicking of genes, crossing aristocrat genotypes and further recognition of highly heterotic F_1 crosses, subsequently prudent segregants may be obtained from various combinations. In a self pollinated crop like wheat the scope of utilization of heterosis depends mainly on the direction and magnitude of heterosis. Estimation of heterosis over better parent (heterobeltiosis) may be useful in identifying true heterotic cross combinations but these cross combinations may be of enormous value if they exhibited superior to the standard variety or the best variety of the area. Heterotic effect is increase or decrease in vigour and productivity of hybrids those juxtaposed to their parents which is exhibited in F1's and following generations. The commercial exploitation of heterosis in wheat has bounded application because of practical complications of hybrid seed production in adequate amount.

The present study was, therefore, undertaken to estimate the magnitude of heterosis over the standard variety (economic heterosis) as well as better parent (heterobeltiosis) for yield and its component traits. These studies would be useful for hybrid development and to select potent transgressive segregants which can be further utilized for enhanced yield potential. The objective of this study was to determine the levels of heterobeltiosis and standard/ economic heterosis for different traits to identify desirable parents and develop high yield wheat varieties for the use of hybrids in wheat breeding programs.

Materials and Methods

The experimental material was comprised of 10 parents, their 45 F_1's and two check varieties *viz.*, Sonalika and HD 2967. The 45 F_1's were obtained by crossing 10 parental genotypes in half diallel fashion (without reciprocal). All the 57 genotypes (10 parents + 45 crosses + 2 checks) were grown in a randomized block design with three replications in three different environments *i.e.* Botany farm of Department of GPB, Rajasthan College of Agriculture, Udaipur (E_1), Instructional Farm, CTAE, Udaipur (E_2) and Krishi Vigyan Kendra, Badgaon, Udaipur (E_3) during *Rabi* 2020-21. Each genotype was accommodated in one row plot of 3 meter length. Row to row and plant to plant distances were 22.5 cm and 10 cm, respectively. The experiment was conducted under irrigated conditions. Recommended crop production and protection practices were followed to raise the successful crop. Observations were recorded on ten randomly selected competitive plants from each genotype in each replication for fifteen traits *viz.*, days to 50 % flowering, days to 75 % màturity, plant height, number of effective tillers per plant, spike length, number of spikelets per plant, length of awns, number of grains per spike, flag leaf area, 1000-grain weight, biological yield per plant, grain yield per plant, harvest index, total protein content in grain and total chlorophyll content in all the three environments. The mean values of parents and crosses were utilized to estimate heterosis over their respective better parent, mid parent and standard checks. The diallel cross analysis was carried out by Griffing's Model-I (fixed effect) and Method-II (parents and one set of F_1's without reciprocals) proposed by Griffing (1956).

Estimation of heterosis

Heterobeltiosis and economic heterosis are expressed as percent deviation toward desirable direction over better parent and standard check, respectively. Heterobeltiosis and economic heterosis were calculated according to the method suggested by Fonseca and Patterson (1968) and Meredith and Bridge (1972), respectively.

$$Heterobeltosis = \frac{\left(\overline{F_1} - \overline{BP}\right)}{\overline{BP}}$$ Where, BP = Better parent

$$Economic\ \ heterosis\ = \frac{\left(\overline{F_1} - \overline{BC}\right)}{\overline{BC}}$$ Where, BC=Best check

To calculate heterobeltiosis and economic heterosis parent with higher mean values were analyzed desirable for all the traits except days to 50% flowering, days to 75% maturity and plant height where negative direction was considered desirable.

Results and Discussion

ANOVA in individual environment expressed highly significant differences among genotypes for all the 15 characters in all the three environments. The effects due to mean parents were also significant in all environments except for length of awns in E_1 and 1000-grain weight in E_3. Mean squares due to crosses were also significant for all the characters. Mean square due to parents v/s crosses were also

Table 1. Mean square for different characters in bread wheat [*Triticum aestivum* (L.) em. Thell]

S. No.	Characters	Env.	Rep [2]	Genotype [54]	Parent [9]	F1 [44]	P vs. F1 [1]	Error [108]
1	Days to 50% flowering	1	1.65	38.38**	67.91**	30.27**	129.43**	5.82
		2	8.51	40.82**	51.74**	33.58**	261.33**	5.90
		3	2.41	46.92**	58.73**	39.78**	254.85**	6.65
2	Days to 75% maturity	1	1.44	59.42**	43.32**	63.32**	33.20*	5.92
		2	2.81	52.86**	47.41**	54.42**	32.99*	8.55
		3	0.53	33.61**	29.44**	34.97**	11.52	10.46
3	Plant height	1	4.74	129.32**	247.56**	108.03**	2.33	14.27
		2	49.12	81.57**	108.76**	76.11**	76.87*	17.09
		3	41.40	60.39**	65.74**	60.42**	10.87	21.52
4	No. of effective tillers per plant	1	2.55	25.15**	37.43**	22.76**	19.80*	3.01
		2	5.29	33.01**	33.45**	31.40**	100.11**	5.43
		3	0.34	3.26**	1.12**	3.45**	14.21**	0.41
5	Spike length	1	0.00	3.20**	4.07**	3.01**	3.80**	0.42
		2	0.14	2.93**	3.03**	2.77**	9.14**	0.33
		3	0.03	1.95**	2.68**	1.69**	6.79**	0.40
6	No. of spikelets per plant	1	4.99	371.64**	138.83*	396.85**	1357.68**	69.27
		2	7.59	417.45**	188.91**	417.05**	2491.59**	53.05
		3	9.53	281.11**	174.91**	241.26**	2989.83**	59.75
7	Length of awns	1	1.14*	3.46**	0.50	3.81**	14.58**	0.31
		2	0.08	2.36**	1.24**	2.58**	2.45**	0.35
		3	0.34	3.26**	1.12**	3.45**	14.21**	0.41
8	No. of grains per spike	1	2.85	62.06**	73.73**	60.72**	15.77	6.88
		2	6.16	66.99**	53.94**	70.01**	51.93*	8.65
		3	15.16	53.83**	35.56**	58.73**	2.69	8.75
9	Flag leaf area	1	0.82	22.78**	15.88**	24.46**	11.32	4.08
		2	2.01	16.90**	17.88**	17.05**	1.77	4.06
		3	0.70	23.25**	21.39**	24.01**	6.33	3.35
10	1000- Grain weight	1	3.35	14.96**	6.34*	17.06**	0.14	2.98
		2	5.18	12.80**	5.93*	14.49**	0.15	2.96
		3	8.66	9.81**	2.82	11.41**	2.26	3.40
11	Biological yield per plant	1	2.49	96.25**	19.71**	111.68**	106.05**	3.56
		2	1.00	108.29**	21.85**	126.51**	84.62**	3.72
		3	3.34	100.95**	22.83**	117.98**	54.59**	4.34
12	Grain yield per plant	1	2.15	13.82**	9.10**	15.09**	0.86	0.81
		2	0.77	18.70**	11.43**	19.90**	31.31**	0.72
		3	2.04	17.05**	10.45**	17.75**	45.43**	1.00
13	Harvest index	1	13.96	102.68**	49.01**	113.83**	95.42**	6.64
		2	8.15	157.99**	81.53**	166.28**	481.79**	9.22
		3	15.05	129.03**	90.35**	127.92**	525.94**	11.94
14	Total protein content in grains	1	0.24	0.83**	0.66**	0.88**	0.00	0.21
		2	0.30	1.17**	0.71**	1.26**	1.20*	0.19
		3	0.31	0.84**	0.93**	0.82**	1.07*	0.20
15	Total chlorophyll content	1	0.00	0.31**	0.30**	0.31**	0.42**	0.00
		2	0.01	0.41**	0.36**	0.42**	0.54**	0.00
		3	0.00	0.35**	0.30**	0.36**	0.27**	0.00

*, ** Significant at 5 and 1 percent, respectively (Model I)

significant for all the characters in all the three environments except days to 75% maturity in E_3, plant height in E_1 and E_3, number of grains per spike in E_1 and E_3, flag leaf area in E_1, E_2 and E_3, 1000-grain weight in E_1, E_2 and E_3, grain yield per plant in E_1 and total protein content in grains in E_1 (Table 1). These results are in accord with earlier findings reported by Swelam *et al.* (2014), Ismail (2015), Malav

Table 2. Extent of heterosis for grain yield per plant in bread wheat [*Triticum aestivum* (L.) em. Thell]

SN	Cross	Heterobeltiosis				Economic Heterosis			
		E1	E2	E3	Pool	E1	E2	E3	Pool
1	HD3086 x RAJ4238	-	-	-	-	-	-	1.96	-
2	HD3086 x RAJ3077	-	-	-	-	-	-	-	-
3	HD3086 x RAJ4037	-	-	-	-	-	-	-	-
4	HD3086 x MHD3086203	-	-	-	-	-	-	-	-
5	HD3086 x HI1544	-	-	-	-	-	-	-	-
6	HD3086 x RAJ4079	1.48	-	-	-	6.00	19.21**	16.67**	14.07**
7	HD3086 x MRAJ3077288	-	-	-	-	-	-	-	-
8	HD3086 x WR544	5.35	0.80	-	1.18	10.05	26.90**	19.55**	18.91**
9	HD3086 x DBW187	-	-	-	-	-	-	-	-
10	RAJ4238 x RAJ3077	5.57	8.86*	13.40*	9.36**	11.47*	18.10**	19.04**	16.29**
11	RAJ4238 x RAJ4037	-	15.30**	2.08	3.15	-	5.43	-	-
12	RAJ4238 x MHD3086203	-	14.00*	11.82*	10.36**	-	2.63	2.81	-
13	RAJ4238 x HI1544	-	-	-	-	-	-	-	-
14	RAJ4238 x RAJ4079	34.38**	20.94**	17.73**	23.44**	6.31	16.36**	18.57**	13.89**
15	RAJ4238 x MRAJ3077288	3.69	-	-	-	-	-	-	-
16	RAJ4238 x WR544	33.77**	26.10**	8.75	22.85**	5.54	23.37**	20.67**	16.69**
17	RAJ4238 x DBW187	25.01**	25.72**	20.69**	25.33**	-	4.26	3.39	2.14
18	RAJ3077 x RAJ4037	-	-	-	-	-	-	-	-
19	RAJ3077 x MHD3086203	-	-	-	-	-	-	-	-
20	RAJ3077 x HI1544	-	-	-	-	-	-	-	-
21	RAJ3077 x RAJ4079	-	-	-	-	-	-	-	-
22	RAJ3077 x MRAJ3077288	-	-	-	-	-	-	-	-
23	RAJ3077 x WR544	-	-	-	-	-	-	-	-
24	RAJ3077 x DBW187	-	-	-	-	-	-	-	-
25	RAJ4037 x MHD3086203	-	-	-	-	-	-	-	-
26	RAJ4037 x HI1544	-	-	-	-	-	-	-	-
27	RAJ4037 x RAJ4079	14.55*	4.01	4.01	10.24**	1.83	0.07	4.75	2.27
28	RAJ4037 x MRAJ3077288	-	-	-	-	-	-	-	-
29	RAJ4037 x WR544	16.72**	5.96	-	8.26**	3.76	3.67	1.18	2.83
30	RAJ4037 x DBW187	-	-	-	-	-	-	-	-
31	MHD3086203 x HI1544	2.32	-	-	-	-	-	-	-
32	MHD3086203 x RAJ4079	-	-	-	-	-	-	-	-
33	MHD3086203 x MRAJ3077288	-	-	-	-	-	-	-	-
34	MHD3086203 x WR544	11.62	-	-	-	-	-	-	-
35	MHD3086203 x DBW187	41.89**	23.95**	27.09**	30.17**	6.48	11.59*	16.85**	11.77**
36	HI1544 x RAJ4079	6.91	8.24	6.06	7.06*	-	22.24**	23.13**	12.82**
37	HI1544 x MRAJ3077288	7.41	-	-	-	-	-	1.00	-
38	HI1544 x WR544	19.45**	0.71	-	3.97	2.84	13.73**	11.85*	9.57**
39	HI1544 x DBW187	-	-	-	-	-	-	-	-
40	RAJ4079 x MRAJ3077288	6.97	5.91	-	3.88	-	4.84	0.60	-
41	RAJ4079 x WR544	1.37	-	-	-	-	-	-	-
42	RAJ4079 x DBW187	-	-	-	-	-	-	-	-
43	MRAJ3077288 x WR544	33.66**	10.40*	-	10.12**	1.69	9.29	2.83	4.59
44	MRAJ3077288 x DBW187	-	-	-	-	-	-	-	-
45	WR544 x DBW187	4.96	-	-	-	-	-	-	-

*, ** Significant at 5 and 1 percent, respectively (Model I)

Table 3. Promising crosses identified on the basis of their *per se* performance and economic heterosis with their component characters showing significant desired heterosis over environments for grain yield per plant

SN	Genotypes	*Per se* performance of grain yield	Economic heterosis	Significant heterosis for other traits in desired direction
1	HD 3086 x WR 544	17.02	18.91**	DF, SL, NSP, AL, 1000-GW, HI
2	RAJ 4238 x WR 544	16.70	16.69**	DF, DM, NETP, NSP, 1000-GW,HI, TPC, TCC
3	RAJ 423 8x RAJ 3077	16.65	16.29**	FLA, HI
4	HD 3086 xRAJ 4079	16.33	14.07**	DM, AL, NGS, 1000-GW, BYP,TCC
5	RAJ 4238 x RAJ 4079	16.30	13.89**	DF, NETP, SL, AL, FLA, HI

** Significant at 1 percent

et al. (2020) and Dhoot *et al.* (2020).

Regarding *per se* performance, parents P1, P3 and P6 were superior with respect to grain yield per plant over the environments. Among the crosses, HD3086xWR544, RAJ4238xWR544, RAJ4238 x RAJ3077 and RAJ4238 × RAJ4079 were found superior with respect to grain yield in different environments. Cross RAJ4238xRAJ3077 was also found superior for biological yield per plant while the cross HD3086xWR544 was found superior for harvest index on pooled basis. HD3086xRAJ4079 expressed ascendancy for the traits, *i.e.* number of grains per spike and 1000-grain weight as well as also had benefit of early maturity as compared to all the other cross combinations. These findings are also noticed by Devi *et al.* (2013), Desale and Mehta (2013), Dhoot *et al.* (2020) and Malav *et al.* (2020).

For economic heterosis, two checks (Sonalika and HD2967) were used in the study. Eight crosses (HD3086x RAJ4079, HD3086xWR544, RAJ4238x RAJ3077, RAJ4238 x RAJ4079, RAJ4238xWR544, MP1203 x DBW187, HI1544 x RAJ4079 and HI1544x WR544) in E_2, E_3 and on pooled basis while 1 cross (RAJ4238 x RAJ3077) in E_1 out yielded the best check (Sonalika). For other yield attributing traits like biological yield per plant, maximum hybrid vigour over the best check (Sonalika) exhibited by the cross HD3086xRAJ4079 along with the advantage of earliness in days to 50% flowering over the earliest check. Cross, HD3086xWR544 was also found superior for harvest index and total chlorophyll content over standard check over the environments while cross MP3288xDBW187 showed superiority for number of grains per spike and flag leaf area over the standard check (HD 2967) on the pooled basis. Similar finding were also reported by Desale and Mehta (2013), Mahpara *et al.* (2015), Baloch *et al.* (2016), Saren *et al.* (2018), Kumar *et al.* (2020).

The range of hybrid vigour over better parent for grain yield per plant ranged from 1.18 (HD3086xWR544) to 30.17 (MP1203xDBW187) on pooled basis. Heterobeltiosis for grain yield per plant was recorded by 8, 8 and 5 crosses in E_1, E_2 and E_3, respectively. RAJ4238xRAJ4079, RAJ4238x DBW187 and MP1203xDBW187 exhibited significant heterobeltiosis for grain yield in all the three environments as well as on pooled basis. The results are in confirmation with Ismail (2015), Kalhoro *et al.* (2015), Baloch *et al.* (2016), Rajput and Kandalkar (2018), Khokhar *et al.* (2019), Kumar *et al.* (2020) and Kajla *et al.* (2020).

With respect to other observations, number of crosses expressing significant hybrid vigour over better parent in positive direction varied from zero (spike length) to 21 (biological yield per plant), while, for negative desired characters, *i.e.* days to 50% flowering, days to 75% maturity and plant height, number of crosses varied from 02 (days to 50% flowering) to 08 (plant height). Further it is to refer that in most of the characters, variable number of crosses expressed hybrid vigour over better parent in both positive and negative direction again demonstrating that genes with positive and negative effects were dominant. These findings are in agreement with Abdullah *et al.* (2002), Rahul (2017), Rajput and Kandalkar (2018) and Kumar *et al.* (2020).

Conclusion

The present study revealed ample variability among the parents and high scope for the exploitation of heterosis for improvement of grain yield in bread wheat. The cross HD3086 × WR544, RAJ4238 × WR544, RAJ4238 × RAJ3077, HD3086 × RAJ4079 and RAJ4238 × RAJ4079 were recognized as the best heterotic cross for grain yield along with other yield components (Table 3). Therefore, these crosses can be further evaluated and utilized in hybrid breeding programme to accelerate the grain yield.

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