Original Research Article

Heterosis and Inbreeding Depression for Quantitative Characters in Bread Wheat (*Triticum aestivum* L. em.Thell.)

Abstract

Aim : Determine the magnitude of heterosis, heterobeltiosis and inbreeding depression in bread wheat and identified superior cross combinations for commercial production of hybrid wheat.

Study design: The experiment was laid out in Randomized block design with three replications.

Place and Duration of Study: The experimental material was evaluated during Rabi 2021-22 at RARI, Durgapura.

Methodology: The ten genotypes of wheat viz. Raj 3077, Raj 4079, Raj 3765, PBW 343, PBW 590, DBW 17, HD 2967, HD 3059, WH 1021 and UP 2425 were crossed in all possible combinations excluding reciprocals during Rabi 2018-19 to generate F_1's. In *kharif* 2019, half of F_1's seed was raised at IARI Regional Station Wellington (Tamil Nadu) to get F_2's seed for experimentation. Final experimental material comprising 10 parents along with 45 F_1's and 45 F_2's were evaluated during Rabi 2021-22 at RARI, Durgapura.

Results : The cross combinations Raj 4079 x Raj 3765, Raj 3765 x PBW 343, Raj 3765 x WH 1021, Raj 4079 x HD 2967, Raj 3765 x HD 2967 and Raj 4079 x PBW 343 exhibited significant and desired heterobeltiosisis over better parent for grain yield per plant and also showed significant and desirable heterobeltiosis for other yield attributing traits. For grain yield Raj 3077 x HD 3059, PBW 590 x HD 2967 and HD 2967 x WH 1021 showed significant and negative inbreeding depression.

Conclusion : Nature and magnitude of heterosis helps in identifying superior cross combinations to obtain better transgressive segregants. Six superior hybrids may be exploited commercially for getting benefits of heterosis for grain yield and its component traits in wheat.

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Introduction

Bread wheat (*Triticum aestivum* L. em. Thell) is staple food for all over the world which belongs to Poaceae (Gramineae) family. It is annual self-pollinated crop with allohexaploid chromosome number 2n = 6x = 42. It is popularly known as ‘Stuff of life or King of the cereals’ because of its high cultivation area and production (Sharma *et al.*, 2019) and the prominent position it holds in the international food grain trade. Wheat grain contains starch (60- 68%), protein (6-21%), fat (1.5-2.0%), cellulose (2.0-2.5%), minerals (1.8%) and vitamins. The uniqueness of wheat in contrast to other cereals is that wheat contains gluten protein which enables leavened dough to rise by forming minute gas cells and this property enables bakers to produce light breads. In India, it is grown in about 30.54 million hectares with the production of about 106.41 million tonnes with an average productivity of 3484 kg/ha [1].

The exploitation of heterosis is a milestone innovation in modern agriculture and it is considered to be one of the pillars of global food security. In a self pollinated crop like wheat, the utilization of heterosis depends mainly upon the direction and magnitude of heterosis. The study of heterosis and inbreeding depression has a direct bearing on the breeding methodology to be employed for varietal improvement. In case of self-fertilizing crops where identification of superior cross combinations is the breeding objective heterobeltiosis is more useful then heterosis from the breeder’s point of view. However, heterosis in wheat crop will not be worthwhile unless, it is practicable for development of hybrid varieties. F_1 hybrid carrying heterotic effects, which are featured in all crop species, the yield gains are limited to the F_1 generation. The F_2 and succeeding generations obtained through selfing are discarded since reduced yields and developmental characters (Wang *et al.*, [2]). Heterosis is considered as the superiority of the hybrids in comparisons to either of its parents. It is the allelic or non-allelic interaction of genes under the influence of specific environment. Heterosis has been estimated in a range of cultivated crops and has been the purpose of considerable importance to study as mean of increasing productivity of crop plant. The present study has been carried out to estimate the heterosis (%) over mid parent (MP), and better parent (BP) and inbreeding depression (ID) for quantitative and qualitative traits in a 10x10 diallel set in bread wheat to identify parental lines that could be used for commercial production of hybrid wheat as well as isolation of pure lines among the progenies of heterotic F_1 for further amelioration of grain yield in bread wheat.

Materials and Methods

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The experimental material consisted of ten genetically diverse bread wheat varieties, viz. Raj 3077, Raj 4079, Raj 3765, PBW 343, PBW 590, DBW 17, HD 2967, HD 3059, WH 1021 and UP 2425. These genotypes were crossed in all possible combinations excluding reciprocals during Rabi 2018-19 to generate F_1s. In *kharif* 2019, half of F_1's seed was raised at IARI Regional Station Wellington (Tamil Nadu) to get F_2's seed for experimentation. Final experimental material comprising 10 parents along with 45 F_1s and 45 F_2s were evaluated during Rabi 2021-22 at RARI, Durgapura. The genotypes under study were planted in a Randomized Block Design with three replications per entry and one row (3m) per replication. Plant to plant spacing of 10 cm and row-to-row spacing of 30 cm were maintained. Standard agronomic practices were used for raising and maintenance of the plants.

Data were recorded on plot basis for days to heading and days to maturity, while rest of the characters *viz.* plant height (cm), productive tillers per plant, flag leaf area (cm^2), spike length (cm), number of grains per spike, 1000-grain weight (g), biomass per plant (g), grain yield per spike (g), grain yield per plant (g) and harvest index (%) were recorded on 10 randomly selected plants for parents, F_1's and while 40 plants for F_2's. Analysis of variance, heterosis, heterobeltiosis and inbreeding depression were calculated as per standard procedures given by Fonseca and Patterson [3] and Panse and Sukhatme [4].

Results and Discussion

The analysis of variance (Table 1) depicted significant differences among the genotypes, parents and generations for all studied characters, established the circumstances that characters displayed the presence of ample genetic diversity among the genotypes, parents and generations. Likewise, F_1 and F_2 generations also exhibited significant differences for all studied characters. The mean squares due to F_1 *vs* F_2 were found significant for all studied characters. Correspondingly, the differences among the parents *vs* generations were significant for all studied characters revealed the presence of heterosis. The results are in agreement with those of others obtained for different characters Zare-Kohan and Heidari [5], Singh *et al*. [6] and Nageshwar *et al*. [7].

The magnitude of heterosis provides information on the extent of genetic diversity in parents of a cross and helps in choosing the parents for superior F_1's, so as to exploit hybrid vigour. The extent of heterosis in a crop depends on its exploitation uses and achievability of hybrid seed production. The appropriate technique of hybrid seed production at commercial scale is not yet available in wheat due to its self-pollinating nature. Therefore, currently in this crop heterosis *per se* may not be of any economic importance. However, it indicates genetic potential of parental combination and if the heterosis is due to epistatic gene effects, particularly of additive x additive type or due to repulsion phase linked loci, exhibiting partial or complete dominance, it is possible to fix the alleles at interacting state to preserve the heterotic effects in the pure lines (Arunachalam *et al*. [8]). Means transgressive segregants are possible. The allopolyploid nature of wheat will also favour preservation of such hybrid vigour for a considerable number of generations. Nevertheless, understanding of degree and extent of heterosis is imperative for determining the direction of imminent breeding programme and the selection of promising crosses to achieve superior segregants in advance generations for future improvement of grain yield in bread wheat.

Heterosis over better parent or heterobeltiosis is more imperative and useful in determining the feasibility of commercial exploitation of heterosis and also specifying the parental combination capable of producing the maximum level of Transgressive segregants. Hence, the heterosis measured in terms of superiority over the better parent is more treasured, which decides whether an experimental hybrids is worth exploiting or not.

The magnitude of heterosis and number of cross combinations showing heterosis over better parent and inbreeding depression for grain yield per plant and its related characters are present in Table 2. Grain yield per plant in wheat is the character of economic importance for which 28 hybrids over mid parent and 14 hybrids over better parent exhibited significant and positive heterosis while 5 crosses exhibited significant inbreeding depression. Several hybrids exhibited significant and desirable direction of heterobeltiosis and inbreeding depression for various characters such as days to 50% heading (15 hybrids); days to maturity (15 and 1 hybrids); plant height (20 and 1 hybrids); number of productive tillers per plant (20 hybrids); flag leaf area (18 and 5 hybrids); spike length (15 hybrids); number of grains per spike (13 and 1 hybrids); 1000 grain weight (15 and 5 hybrids); biomass per plant (17 and 2 hybrids); grain yield per spike (14 and 5 hybrids) and harvest index (9 and 20 hybrids), respectively. No inbreeding depression was observed in any cross for the days to 50% heading, productive tillers per plant, spike length and grain yield per spike which can be used for maintain the specific gene pool for

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further utilization of improvement of wheat. The hybrid, PBW 343 x WH 1021 for days to 50% heading, days to maturity, flag leaf area and biomass per plant, HD 2967 x WH 1021 for days to maturity, Raj 3765 x HD 2967 for flag leaf area, Raj 3765 x WH 1021 for spike length, Raj 3765 x UP 2425 for number of grains per spike, PBW 343 x HD 2967 for 1000-grain weight, WH 1021 x UP 2425 for biomass per plant, Raj 4079 x Raj 3765 for grain yield per plant and PBW 590 x HD 2967 for harvest index showed significant and maximum heterosis over better parent. Similar finding was reported by Gaur *et al*. [9].

The utility of hybrid breeding technique lies in identification of the most heterotic and useful combinations in order to make commercial cultivation of hybrid beneficial. The Table 3 reveals a significant relation between heterobeltiosis for grain yield per plant and its associated traits *i.e*. crosses which have desirable heterobeltiosis for grain yield, also exhibited desirable heterobeltiosis for most of the other yield attributes. The high yielding hybrids were in general the most heterotic crosses which indicated close association between hybrid mean performance and manifestation of heterosis. The relative ranking of hybrids based on the mean performance. This suggested that selection of hybrids should be based on *per se* performance. Similar findings have been reported by Kumar *et al*. [10].

The cross combinations Raj 4079 x Raj 3765, Raj 3765 x PBW 343, Raj 3765 x WH 1021, Raj 4079 x HD 2967, Raj 3765 x HD 2967 and Raj 4079 x PBW 343 exhibited significant and desired heterobeltiosisis over better parent for grain yield per plant and also showed significant and desirable heterobeltiosis for Days to 50 % heading, days to maturity, plant height, productive tillers per plant, flag leaf area, Spike length, number of grains per spike, 1000-grain weight, biomass per plant, grain yield per spike and harvest index. These three superior hybrids may be exploited commercially for getting benefits of heterosis for grain yield and its component traits in wheat. The result of the present investigation clearly showed that considerable heterosis did occur for all the characters studied. Hence, it is obvious that increase in yield of F_1 hybrids is the result of increase in values of other yield contributing characters. Similar results were also reported by Thomas *et al.* [11], Kumar *et al.* [12] and Choudhary *et al.* [13].

Generally, the heterotic expression decreases in F_2 generation as the dominance or dominance interaction effects dissipate in this generation due to decreased heterozygosity, resulting into inbreeding depression. For grain yield the crosses Raj 3077 x HD 3059, PBW 590

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x HD 2967 and HD 2967 x WH 1021 revealed significant and negative inbreeding depression, indicated F_2 plants accomplished higher grain yield per plant as compared to F_1 hybrids. The significant and negative inbreeding depression for grain yield and other component characters reported by several earlier researchers such Kumar *et al.* [12] and Nagar *et al.* [14].

Inbreeding depression based on genetic variability indicated the positive and negative expression of genes in the population which could not be fixed for heterosis breeding. The heterosis and inbreeding depression jointly implement the criteria for positive selection. As indicated in the present study the succeeding generations showed the significant amount of dominance in the population with accumulation of additive and epistatic genes. Bailey *et al.* [15] observed that F_2 progenies performance for inbreeding depression might be a good indicator of predicting heterosis performance in F_1 hybrid of wheat.

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Table 1: Analysis of variance (mean squares) for parents, F_1's and F_2's for yield and its contributing traits

Characters	Source of variation								
	Replication	**Genotypes**	**Parents**	**Generation**	**F_1's**	**F_2's**	**F_1 *vs* F_2**	**Parents vs generation**	**Error**
Df	**(2)**	**(99)**	**(9)**	**(89)**	**(44)**	**(44)**	**(1)**	**(1)**	**(198)**
Days to 50% heading	0.57	101.46**	41.49**	107.83**	86.49**	130.69**	40.83**	73.67**	3.5
Days to maturity	0.37	131.06**	30.81**	139.88**	119.41**	160.65**	126.76**	248.43**	7.62
Plant height	39.2	242.74**	97.27**	258.57**	214.92**	302.45**	248.39**	143.69**	20.54
Productive tillers/plant	0.43	5.68**	2.07**	5.78**	3.81**	7.79**	3.95**	29.46**	0.37
Flag leaf area	10.04	218.75**	59.01**	232.29**	216.42**	252.86**	25.35*	452.01**	5.5
Spike length	0.99	6.98**	1.62**	7.48**	6.51**	8.54**	3.73**	10.81**	0.43
Number of grains/spike	0.06	77.59**	23.98**	81.12**	66.46**	96.8**	36.36*	245.84**	5.77
1000-grain weight	2.58	21.96**	9.4**	21.72**	20.39**	23.36**	7.9*	156.3**	1.57
Biomass/plant	5.23	93.31**	37.11**	92.11**	67.81**	117.19**	57.57*	706.03**	10.79
Grain yield/plant	1.01	63.51**	13.75**	65.99**	60.85**	69.49**	138.07**	290.83**	4.2
Grain yield/spike	0.01	0.64**	0.41**	0.64**	0.56**	0.73**	0.18**	2.4**	0.02
Harvest index	0.25	109.41**	16.12*	119.25**	100.84**	120.89**	857.07**	73.11**	8.33

*, ** significant at 5 and 1% per cent levels, respectively

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Table 2: Magnitude of heterosis (H), heterobeltiosis (HB) and inbreeding depression (ID) for different traits in bread wheat

Traits	Range of heterosis							Number of cross combinations showing heterosis		Number of cross combinations showing Inbreeding depression
	Heterosis (%)		Heterobeltiosis (%)			Inbreeding depression (%)				
	Min.	Max.	Min.	Max.	Best cross with heterotic effect	Min.	Max.	Heterosis (%)	Heterobeltiosis (%)	
Days to 50% heading	-12.79	11.35	-8.02	13.04	PBW 343 x WH 1021	-16.67	3.51	27	15	-
Days to maturity	-10.11	8.47	-8.33	10.22	PBW 343 x WH 1021	-10.54	5.15	26	15	1
Plant height	-15.11	14.87	-14.04	22.38	HD 2967 x WH 1021	-28.89	10.79	24	20	1
Productive tillers/plant	-10.20	31.01	-16.98	21.71	Raj 3765 x HD 2967	-11.07	29.07	30	20	-
Flag leaf area	-36.24	41.39	-46.15	31.86	PBW 343 x WH 1021	-16.48	17.25	27	18	5
Spike length	-21.61	23.22	-27.19	15.95	Raj 3765 x WH 1021	-5.57	16.43	25	15	-
Number of grains/spike	-17.16	14.59	-18.80	13.10	Raj 3765 x UP 2425	-10.55	6.38	24	13	1
1000-grain weight	-7.31	13.48	-8.05	10.00	PBW 343 x HD 2967	-6.18	5.58	28	15	5
Biomass/plant	-9.33	23.42	-11.96	19.92	WH 1021 x UP 2425	-12.36	10.26	30	17	2
Grain yield/spike	-12.01	47.96	-21.65	29.86	PBW 343 x WH 1021	-4.70	17.13	30	15	-
Grain yield/plant	-26.22	38.73	-34.21	31.26	Raj 4079 x Raj 3765	-16.19	10.79	28	14	5
Harvest index	-29.26	15.10	-31.56	13.98	PBW 590 x HD 2967	-27.02	9.98	16	9	20

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Table 3: Promising hybrids identified on the basis of per se performance and heterobeltiosis for grain yield per plant

S. No.	Hybrids	*Per se performance* of grain yield per plant (g)	Heterobeltiosis (%)	Significant heterobeltiosis for other traits in desired direction
1.	Raj 4079 x Raj 3765	32.68	31.26	DH, DM, PH, PTP, FLA, SL, GS, GW, BY, GYS, HI
2.	Raj 3765 x PBW 343	31.13	30.24	DH, DM, PH, PTP, FLA, SL, GS, GW, BY, GYS, HI
3.	Raj 3765 x WH 1021	28.85	29.86	DH, DM, PH, PTP, FLA, SL, GS, GW, BY, GYS, HI
4.	PBW 343 x HD 2967	31.04	29.33	DH, DM, PH, PTP, FLA, SL, GW, BY, GYS, HI
5.	Raj 4079 x HD 2967	32.06	28.77	DH, DM, PH, PTP, FLA, SL, GS, GW, BY, GYS, HI
6.	Raj 3765 x HD 2967	30.78	28.24	DH, DM, PH, PTP, FLA, SL, GS, GW, BY, GYS, HI
7.	Raj 4079 x PBW 343	31.59	26.88	DH, DM, PH, PTP, FLA, SL, GS, GW, BY, GYS, HI

DH: Days to 50 % heading, DM : days to maturity, PH : plant height, PTP : productive tillers per plant, FLA : flag leaf area, SL : Spike length, GS : number of grains per spike, GW : 1000-grain weight, BY : biomass per plant, GYS : grain yield per spike and HI : harvest index

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