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Study of Heterotic performance of F_1 crosses for Grain yield and its component traits in bread wheat (*Triticum aestivum* L. em Thell)

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ABSTRACT

The present investigation was conducted to ascertain the extent of heterosis in F1 generation to identify superior cross combinations in bread wheat. A set of 36 F_{1s} was generated by crossing 12 female lines with three testers in line × tester mating design. F1s along with 15 parental lines and two check varieties were evaluated in randomized block design with three replications. Estimation of heterosis over mid parent (relative heterosis), better parent (heterobeltiosis) and two check varieties (economic heterosis) expressed as percent increase or decrease was carried out. Based on results of this study, nineteen out of 36 F1s were recognized as the best heterotic hybrids for different traits. Results revealed that the best heterotic cross for grain yield per plant was DBW 88 × WH 1105 followed by DBW 88 × UP 2672, WH 1139 × HD 3059, DBW 88 × HD 3059 and PBW 644×WH 1105. Therefore, identified superior cross combinations could be utilized in yield improvement programmes.

Keywords: *Bread wheat, Grain yield, Heterosis, Line x tester.*

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INTRODUCTION

Wheat is an important cereal crop of the world and is used in making of a wide range of products from chapatti to processed foods and numerous industrial products. It is considered as staple food in India and play important role in fulfilling the countries food requirements. Wheat plant is widely adapted to different regions of the world. In India its cultivation extends from about 90N Palni hills in Tamil Nadu to about 300N Srinagar, Jammu and Kashmir [1].Wheat has good nutrition profile with about 12.0 per cent protein, 1.8 per cent lipids, 1.8 per cent ash, 2.0 per cent reducing sugars, 6.7 per cent pentosans, 59.2 per cent starch, 70 per cent total carbohydrates and provides 314 K cal/100g of food. It is also a good source of minerals and vitamins *viz.,* calcium (37mg/100g), iron (4.1 mg/100g), thiamine (0.45 mg/100g), riboflavin (0.13mg/100g) and nicotinic acid (5.4mg/100g) [2]. Wheat is consumed in the form of a wide range of products from chapatti to processed foods and numerous industrial products for which its flour is specifically suitable[3].This versatile suitability of wheat flour is provided by the virtue of gluten, a protein formed by the combination of gliadin and glutenin. Its baking quality makes it relatively more important as a human food than any other cereal grains. India is the second largest producer of wheat in the world after China [4].In India during 2015-16, 30.23 million hectares area was under wheat cultivation with 93.50 million tonnes production and 3093 kg/ha productivity [5].

Much of the emphasis in wheat breeding has been placed on increasing productivity of wheat crop in response to the pressure for an adequate food supply caused by continuously increasing population of India and the world as a whole. One way to achieve this target is through heterosis breeding, a strong tool to take a quantum jump in production and productivity under various agro-climatic conditions[6].The concept of heterosis breeding has been extensively used in breeding of open pollinated crops, such as maize. At present, hybrid breeding is also being focussed in self pollinated crops, including wheat.

Heterosis refers to the superiority of F1 hybrids in one or more characters over its parents. This superiority is estimated over the mid parent, known as average heterosis or relative heterosis, over better parent referred to as heterobeltiosis and in relation to the best commercial variety of the crop, known as economic, standard or useful heterosis. Standard heterosis is the only estimate of heterosis having practical value [7].Hybrid vigour term is also used as a synonym for heterosis and is articulated as an increase in vigour, size, growth rate, yield or other characteristics. Wheat being a highly self-pollinated crop, scope for exploitation of hybrid vigour depends on the direction and magnitude of heterosis, biological feasibility of crop and nature of gene action. It is realized that high yielding lines may not necessarily be able to transmit their superiority to their hybrids [8].The present line × tester study was, therefore, conducted to ascertain the extent of heterosis in F1 generation to identify superior cross combinations for further use in improvement programmes in wheat.

MATERIAL AND METHODS

A set of 36 F_{1s} was generated by crossing 12 female lines of bread wheat *viz*., HD 3091, UP 2848, PBW 644, WH 1139, PBW 681, DBW 88, UP 2845, UP 2696, WH 1126, HD 3123, UP 2425 and UP 2554 with three testers *viz*., WH 1105, UP 2672 and HD 3059 in Line x Tester mating design. All the F1s along with 15 parental lines and two check varieties were evaluated in randomized block design with three replications at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. The experimental material was planted in two rows of one metre length. Row to row spacing was maintained at 20 cm and plant to plant spacing was 10 cm. Observations were recorded on fourteen biometrical characters. Data were recorded on five randomly selected competitive plants per plot for number of tillers per plant, peduncle length, plant height, spike length, flag leaf area, number of spikelets per spike, number of grains per spike, 1000 grain weight, grain weight per spike, harvest index, biological yield per plant and grain yield per plant. Two characters namely days to 75% heading and days to maturity were recorded on per plot basis.

Estimation of heterosis

Heterosis was estimated as percent deviation in the performance of F1 hybrid over the mid-parent (average or relative heterosis), better parent (heterobeltiosis) and check parent (standard heterosis) [9] for each character using the following formulae:

a) Relative heterosis $= \frac{\overline{F1} - \overline{MP}}{\overline{MP}} \times 100$

b) Heterobeltiosis $= \frac{\overline{F1} - \overline{BP}}{\overline{BP}} \times 100$

c) Standard heterosis $= \frac{\overline{F1} - \overline{CP}}{\overline{CP}} \times 100$

Where,

$\overline{F1}$ = Mean performance of F1 hybrid
$\overline{MP}$ = Mean mid-parental value i.e. (P1+P2)/2
$\overline{BP}$ = Mean performance of better parent
$\overline{CP}$ = Mean performance of check parent

The significance of heterosis was tested with‘t’ test.

RESULTS AND DISCUSSION

Estimates of heterosis over better parent (heterobeltiosis), mid parent (relative heterosis) and check variety (standard heterosis) expressed as percent increase or decrease are expressed for different characters in the **Table 1**and are described below.

1. Days to 75 % heading

Seven hybrids exhibited significant negative heterosis over their mid- parental values. The highest significant negative heterosis was expressed by the cross DBW 88 × WH 1105 (-5.243%) followed by UP 2848 × UP 2672 (-2.868). Highest significant positive heterosis showed by HD 3123 × HD 3059 (3.661). Nine hybrids showed significant negative heterosis over their respective earlier parent. Cross DBW 88 × WH 1105 (-5.948) showed highest significant negative heterobeltiosis followed by UP 2696 × HD 3059 (-3.746). HD 3123 × HD 3059 showed highest significant positive heterosis over better parent. Four hybrids, DBW 88 × WH 1105 (-4.178), UP 2554 × HD 3059 (-3.796), UP 2848 × UP 2672 (-3.792) and WH 1139 × UP 2672 (-3.034) exhibited significant negative standard heterosis over the checkHD 2967 and crosses DBW 88 × WH 1105 (-6.988) followed by UP 2848 × UP 2672 (-6.622) and UP 2554 × HD 3059 (-6.621) exhibited highest negative heterosis over check UP 2526.In high intensity crop rotation areas of northern India, where most of wheat area is under assured irrigation, the major emphasis is on the development of short duration varieties. Cross DBW 88 × WH 1105 showed highest values of significant negative relative heterosis, heterobeltiosis and standard heterosis over both the checks in relation to early flowering [6,10].

Days to Maturity

Two crosses PBW 644 × UP 2672 (-2.558), and PBW 644 × HD 3059 (-2.557) possessed significant negative values of heterobeltiosis for days to maturity. None of the hybrids showed significant positive or negative heterosis over the check HD 2967 and UP 2526.Presently, development of early maturing genotypes seems to be a priority to fit the wheat varieties in intensive cropping system and for this purpose negative heterotic response for maturity is desirable. Crosses, PBW 644 × UP 2672 and PBW 644 × HD 3059 identified as early maturing **[11, 12].**

Number of effective tillers per plant

Twelve crosses showed positive significant heterosis over the mid parental values and highest value was observed for DBW 88 × WH 1105 (29.365)followed by HD 3091 × WH 1105 (20.715).Nine crosses exhibited positive significant heterobeltiosis and highest value was found for DBW 88 × WH 1105 (28.684).Twenty two hybrids out of thirty six had significant positive standard heterosis over the check HD 2967 in which cross DBW 88 × WH 1105 (35.494) showed highest value. However, wenty five crosses had significant positive standard heterosis over check UP 2526and cross DBW 88 × WH 1105 (40.517) possessed highest value followed by WH 1126 × UP2672 (34.195). Higher number of effective tillers per plant is one of the most important and desirable characters required for getting high yield. The results revealed that the cross DBW 88 × WH 1105 showed highest significant positive relative heterosis, heterobeltiosis and standard heterosis over the check HD 2967 and UP 2526 [12, 13, 14].

Plant height

Eleven crosses showed significant positive mid parent heterosis out of which WH 1126 × HD 3059 (9.512) showed highest heterosis followed by UP 2554 × HD 3059 (9.496). UP 2554 × HD 3059 (8.938) showed significant positive heterosis and DBW 88 × HD 3059 (-7.710)showed significant negative heterosis over the better parent. Significant negative economic heterosis exhibited by only one cross DBW 88 × HD 3059 (-7.153)and ten crosses possessed positive significant heterosis over the check HD 2967. The cross PBW 644 × UP 2672 (13.074) exhibited highest significant positive heterosis followed by DBW 88 × UP 2672 (10.345).Significant negative heterosis over the check UP 2526exhibited by only two crosses namely, DBW 88 × HD 3059 (-9.040) and PBW 681 × WH 1105 (-7.063) and five crosses possessed positive significant heterosis, out of those PBW 644 × UP 2672 (10.766) exhibited highest significant positive economic heterosis. Significant negative heterosis for plant height is desirable in the development of dwarf, high yielding varieties with lodging resistance, high fertilizer responsiveness and it should be stiff strawed. For plant height negative significant relative heterosis, heterobeltiosis and standard heterosis exhibited by cross DBW 88 × HD 3059. PBW 681 × WH 1105 also showed significant negative standard heterosis over the check UP 2526[15,16, 17].

Flag leaf area

Out of thirty six F1 hybrids, twenty four showed positive significant relative heterosis and highest value was observed forWH 1126 × UP2672 (36.815) followed by UP 2554 × WH 1105 (35.401).Twelve crosses exhibited significant positive heterobeltiosis and maximum value was observed for WH 1126 × UP 2672 (34.102).Thirty four hybrids out of thirty six showed significant positive economic heterosis over check HD 2967 and out of these, cross UP 2425 × UP 2672 (73.470) showed highest value followed by UP 2696 × UP 2672 (67.546).The standard heterosis over the check UP 2526 varied from -33.529 to 28.199. Seven hybrids showed significant positive standard heterosis over UP 2526 and crosses UP 2425 × UP 2672 (28.199) possessed highest positive value over the check. Flag leaf area is important for grain filling because it is responsible for more than 70% photosynthesis. Highest significant positive relative heterosis and heterobeltiosis were recorded in the cross WH 1126 × UP 2672, and highest positive standard heterosis over both checks by hybrid UP 2425 × UP 2672.

Peduncle length

Twenty four crosses showed significant positive relative heterosis out of which HD 3091 × HD 3059 (12.759) exhibited highest value followed by UP 2425 × HD 3059 (10.516). Significant positive heterobeltiosiswas possessed by five crosses out of which HD 3091 × HD 3059 (11.477) showed highest value. Significant standard heterosis over the check HD 2967 for peduncle length was observed for twenty seven crosses and UP 2425 × UP 2672 (26.051) exhibited highest value followed by PBW 644 × UP 2672 (23.913).Standard heterosis over the check UP 2526 was found positively significant for four crosses in which UP 2425 × UP 2672 (9.854)exhibited highest significant positive value. For peduncle length highest positive relative heterosis and heterobeltiosis was exhibited by the cross HD 3091 × HD

3059 and highest significant positive standard heterosis over the checks HD 2967 and UP 2526 by the cross UP 2425 × UP 2672.

Spike length

Thirty one hybrids showed significant positive relative heterosis and cross UP 2425 × UP 2672 (15.567) showed highest significant positive heterosis followed by WH 1126× UP 2672 (13.182).Significant positive heterobeltiosis was observed for twenty seven crosses and highest value was observed for DBW 88 × UP 2672 (12.685). Significant positive economic heterosis over check HD 2967 was observed for thirty five crosses and highest value was exhibited by UP 2425 × UP 2672 (21.367).Standard heterosis over the check UP 2526 was found positively significant for three hybrids namely UP 2425 × UP 2672 (4.809), WH 1126 × UP 2672 (1.292) and UP 2848 × UP 2672 (2.656). Spike length is one of the most important yield components that contributes towards productivity and should be taken into consideration during the selection procedure. Thus, significant positive heterosis for spike length is desirable. Highest significant positive relative heterosis and standard heterosis over the check UP 2526 was shown by the cross UP 2425 × UP 2672 and heterobeltiosis by cross DBW 88 × UP 2672 [12,18, 14, 15].

Number of spikelets per spike

Twenty two crosses out of thirty six showed significant positive relative heterosis and PBW 644 × WH 1105 (9.936) showed highest significant positive value. Fourteen crosses exhibited significant positive heterobeltiosis and cross WH 1126 × WH 1105 (7.717) showed maximum value. Significant positive standard heterosis for number of spikelets per spike over the check HD 2967 was showed by four hybrids out of which PBW 644 × WH 1105 (4.273) with highest value. Twelve F1s were identified with significant standard heterosis over check UP 2526 out of which PBW 644 × WH 1105 (8.218)exhibited highest value. Number of spikelets per spike is an important yield contributing character. Therefore, positive heterosis for this character is essential for the development of improved cultivars. In present study, highest positive significant relative heterosis showed by PBW 644 × WH 1105, heterobeltiosis by the cross WH 1126 × WH 1105. PBW6 44×WH1105 showed highest significant positive standard heterosis over checks HD 2967 and UP 2526 **[12,15, 18].**

Number of grains per spike

Out of 36 F1s studied, twenty three possessed positive significant relative heterosis and cross UP 2696 × HD 3059 (57.692) expressed highest value. Fourteen hybrids showed significant positive heterobeltiosis and the same cross UP 2696 × HD 3059 (49.635) exhibited highest positive significant heterosis over better parent. Twenty two hybrids showed significant positive economic heterosis and the cross HD 3123 × WH 1105 (58.003) exhibited highest positive value followed by UP 2696 × HD 3059 (56.476)over the check HD 2967.Whereas,Two crosses HD 3123 × WH 1105 (19.646) and UP 2696 × HD 3059 (18.490) showed significant positive standard heterosis over the check UP 2526.Number of grains per spike is one of the important component characters of grain yield, so heterosis in positive direction for this character is desirable to develop high yielding cultivars. UP 2696 × HD 3059 expressed highest positive and significant relative heterosis and heterobeltiosis, HD 3123 × WH 1105 showed highest positive significant standard heterosis over both the checks [14,15, 19].

Grain weight per spike

All the thirty six crosses showed significant values for relative heterosis and out of these eighteen exhibited positive values. UP 2845 × UP 2672 (54.902) expressed highest significant positive relative heterosis followed by UP 2845 × HD 3059 (53.846).Nine hybrids showed significant positive heterosis over better parent and cross UP 2845 × UP 2672 (41.071) exhibited highest value. One cross PBW 644 × HD 3059 showed equality in grain weight per spike with better parent. Eight hybrids showed significant positive economic heterosis over the check HD 2967 and the cross UP 2845 × HD 3059 (31.752) exhibited highest value. Eight crosses showed significant positive economic heterosis over the check UP 2526 and UP 2845 × HD 3059 (26.742) showed highest value. Grain weight per spike is also one of the important yield contributing traits; positive heterosis for the character is desirable for increasing yield. The cross UP 2845 × UP 2672 exhibited the high magnitude of positive relative heterosis and heterobeltiosis, UP 2845 × HD 3059 highest standard heterosis over both the checks [14,19].

1000-grain weight

For this trait, fourteen hybrids possessed significant positive mid parent heterosis and HD 3123 × WH 1105 (27.757) expressed highest value. Significant positive heterobeltiosis was observed in eleven hybrids and the cross showing highest positive value was HD 3123 × WH 1105 (19.149).Out of 36 crosses, twenty four hybrids showed significant positive economic heterosis over the check HD 2967 and WH 1139 × HD 3059 (29.096) exhibited highest value. Seventeen crosses showed significant positive heterosis over the check UP 2526 and HD 3091 × HD 3059 (18.486) exhibited highest value. Positive heterosis is favoured in case of 1000-grain weight, as it has direct effect on grain yield. The cross HD 3123 × WH 1105 exhibited highest magnitude of positive relative heterosis and HD 3123 × WH 1105 showed highest heterobeltiosis. HD 3091 × HD3059 and WH 1139 × HD 3059 exhibited highest magnitude of standard heterosis over the checks HD 2967 and UP 2526 respectively [10, 14, 19].

Table 1: Estimation of heterosis for different characters in bread wheat

crosses	1. Days to 75% heading				2. Days to maturity				3. Tillers/plant			
	Relative heterosis	Heterobeltiosis	Standard heterosis		Relative heterosis	Heterobeltiosis	Standard heterosis		Relative heterosis	Heterobeltiosis	Standard heterosis	
			HD2967	UP2526			HD2967	UP2526			HD2967	UP2526
HD3091×WH1105	-0.952	-1.887	-1.523	-4.413**	-0.262	-1.039	-0.522	-1.297	20.715**	7.713**	12.219**	16.379**
HD3091×UP2672	0.383	0.000	-0.7644	-3.680**	-1.167	-1.295	-0.525	-1.297	-4.545**	-17.848**	-6.899**	-3.448**
HD3091×HD3059	1.538	1.538	0.005	-2.944*	0.260	0.260	0.786	-0.002	-7.786**	-16.111**	-16.320**	-13.218**
WH1139×WH1105	1.354	-1.132	-0.766	-3.680**	0.392	-0.518	0.268	-0.520	0.744	-5.581**	12.496**	16.666**
WH1139×UP2672	-0.389	-2.290*	-3.034**	-5.885**	1.036	1.036	1.837	1.033	-23.480**	-25.349**	-11.055**	-7.758**
WH1139×HD3059	0.391	-1.154	-2.658	-5.518**	0.130	0.000	0.784	-0.002	12.658**	3.488**	23.302**	27.873**
PBW681×WH1105	-0.385	-2.264	-1.892	-4.783**	0.922	0.789	0.004	-0.779	-2.632*	-3.646**	2.521*	6.321**
PBW681×UP2672	1.741	0.382	-0.385	-3.312**	1.567	0.777	1.563	0.774	-4.161**	-7.090**	5.292**	9.195**
PBW681×HD3059	0.971	0.000	-1.527	-4.415**	-0.915	-1.558	-1.054	-1.816	-5.349**	-8.307**	-2.438*	1.178
DBW88×WH1105	-5.243**	-5.948**	-4.178**	-6.988**	-0.130	-1.289	0.000	-0.779	29.365**	28.684**	35.494**	40.517**
DBW88×UP2672	-2.448*	-3.717**	-1.893	-4.782**	-0.258	-0.515	0.787	-0.002	-32.066**	-34.474**	-25.741**	-22.988**
DBW88×HD3059	-0.567	-2.230	-0.383	-3.312**	-1.940	-2.320	-1.058	-1.816	18.919**	15.789**	21.917**	26.436**
WH1126×WH1105	-0.576	-2.264	-1.894	-4.782**	0.524	-0.260	0.268	-0.520	12.929**	9.674**	21.252**	25.747**
WH1126×UP2672	-0.386	-1.527	-2.275	-5.150**	-0.389	-0.518	0.266	-0.520	15.594**	14.181**	29.398**	34.195**
WH1126×HD3059	0.775	0.000	-1.522	-4.415**	0.260	0.260	0.785	-0.002	1.186	-3.759**	6.400**	10.344**
UP2848×WH1105	-0.760	-1.509	-1.141	-4.047**	0.529	0.264	-0.790	-1.556	-15.909**	-19.952**	-7.730**	-4.310**
UP2848×UP2672	-2.868**	-3.053**	-3.792**	-6.622**	1.180	0.000	0.785	-0.002	-5.358**	-6.154**	8.174**	12.183**

UP2848×HD3059	3.263**	3.065**	1.893	-1.106	0.787	-0.260	0.261	-0.520	-4.149**	-10.601**	3.047*	6.867**
PBW644×WH1105	-1.313	-1.866	-0.385	-3.312**	0.260	-1.279	0.785	-0.002	13.941**	13.032**	17.761**	22.126**
PBW644×UP2672	-0.377	-1.493	0.001	-2.944*	-1.931	-2.558*	-0.526	-1.297	4.750**	-0.245	13.050**	17.241**
PBW644×HD3059	-2.273*	-3.731**	-2.273	-5.150**	-1.804	-2.557*	-0.522	-1.297	-8.767**	-10.000**	-7.730**	-4.310**
HD3123×WH1105	1.145	0.000	0.384	-2.577*	0.263	0.000	-0.525	-1.297	-1.164	-3.778**	5.846**	9.770**
HD3123×UP2672	2.111*	1.527	0.767	-2.209	0.130	-0.518	0.268	-0.520	-3.226**	-4.645**	8.063**	12.068**
HD3123×HD3059	3.661**	3.462**	1.895	-1.106	-0.522	-1.039	-0.528	-1.297	-0.396	-5.038**	4.461**	8.333**
UP2845×WH1105	0.379	0.000	0.384	-2.577*	0.915	0.000	0.780	-0.002	-1.215	-2.660	1.413	5.172**
UP2845×UP2672	0.190	0.000	-0.385	-3.312**	0.000	0.000	0.784	-0.002	-16.796**	-21.271**	-10.778**	-7.471**
UP2845×HD3059	2.103*	1.521	1.149	-1.841	0.130	0.000	0.784	-0.002	2.345*	1.644	2.798*	6.609**
UP2696×WH1105	-1.128	-1.498	-0.384	-3.312**	-0.130	-1.786	0.528	-0.261	-4.132**	-4.512**	0.277	3.994**
UP2696×UP2672	-2.836**	-3.745**	-2.654	-5.510**	-0.771	-1.531	0.789	-0.002	-6.091**	-9.535**	2.521*	6.321**
UP2696×HD3059	-2.467*	-3.746**	-2.655	-5.517**	-0.386	-1.276	1.044	0.256	13.667**	10.818**	16.375**	20.689**
UP2425×WH1105	-1.866	-2.952*	-0.386	-3.312**	0.649	-1.020	1.307	0.515	13.726**	7.979**	12.496**	16.666**
UP2425×UP2672	1.689	0.000	2.654	-0.371	0.000	-0.765	1.568	0.774	6.024**	-3.178*	9.725**	13.793**
UP2425×HD3059	1.318	-0.738	1.895	-1.106	0.644	-0.255	2.098	1.292	-5.731**	-8.611**	-8.839**	-5.459**
UP2554×WH1105	3.053**	1.887	2.275	-0.738	1.951	0.513	2.352	1.551	-2.983**	-6.596**	-2.687*	0.919
UP2554×UP2672	0.960	0.382	-0.385	-3.312**	1.031	0.513	2.357	1.551	-4.359**	-11.491**	0.304	4.022**
UP2554×HD3059	-2.119*	-2.308*	-3.796**	-6.621**	-1.419	-2.051	-0.263	-1.038	-8.475**	-10.000**	-10.224**	-6.896**

Continued...........

Table 1 Continued...........

crosses	**4. Plant height**				**5. Flag leaf area**				**6. Peduncle length**			
	Relative heterosis	**Heterobeltiosis**	**Standard heterosis**		**Relative heterosis**	**Heterobeltiosis**	**Standard heterosis**		**Relative heterosis**	**Heterobeltiosis**	**Standard heterosis**	
			HD2967	**UP2526**			**HD2967**	**UP2526**			**HD2967**	**UP2526**
HD3091×WH1105	5.020	3.780	-0.752	-2.770	28.634**	23.463**	37.685**	1.754	0.424	-5.952**	-1.652	-14.295**
HD3091×UP2672	2.283	-2.532	2.903	0.807	18.337**	8.604	33.306**	-1.482	6.626**	-3.327	8.525**	-5.436**

HD3091×HD3059	6.384*	6.154	1.964	-0.114	24.565**	19.387**	22.432**	-9.516*	12.759**	11.477**	1.774	-11.318**
WH1139×WH1105	6.601*	3.657	2.452	0.365	23.693**	20.512**	41.681**	4.708	3.039*	-1.184	12.565**	-1.916
WH1139×UP2672	5.445	2.079	7.771*	5.577	3.259	1.081	24.077**	-8.306	3.670*	2.914	17.235**	2.164
WH1139×HD3059	6.310*	4.811	3.593	1.482	11.460**	0.301	17.923**	-12.851**	4.045**	-7.231**	5.678**	-7.915**
PBW681×WH1105	-2.624	-6.508	-5.133	-7.063*	10.912**	-4.300	47.065**	8.687*	-3.757*	-5.770**	2.845	-10.388**
PBW681×UP2672	-0.589	-2.521	2.914	0.818	-2.780	-12.564**	34.374**	-0.697	-1.406	-2.773	9.147**	-4.895**
PBW681×HD3059	3.698	0.928	2.415	0.328	-12.695**	-29.638**	8.135	-20.089**	-0.837	-9.886**	-1.655	-14.299**
DBW88×WH1105	1.991	-1.673	-1.085	-3.091	3.655	3.333	15.247**	-14.835**	-6.645**	-13.036**	-9.065**	-20.758**
DBW88×UP2672	7.034*	4.515	10.345**	8.096*	6.138	0.985	23.951**	-8.393	10.512**	-0.314	11.900**	-2.493
DBW88×HD3059	-5.572	-7.710*	-7.153*	-9.040**	21.175**	11.991**	24.124**	-8.273	2.428	1.839	-8.085**	-19.905**
WH1126×WH1105	2.523	-3.336	1.913	-0.165	19.655**	16.429**	37.248**	1.427	0.049	-1.256	6.033**	-7.604
WH1126×UP2672	1.856	1.783	7.463*	5.270	36.815**	34.102**	64.600**	21.648**	9.400**	7.024**	20.145**	4.695**
WH1126×HD3059	9.512**	4.643	10.322**	8.074*	16.406**	4.630	23.336**	-8.851*	9.055**	-0.164	7.206**	-6.585**
UP2848×WH1105	2.985	-2.121	1.463	-0.608	30.506**	18.185**	62.484**	20.078**	-1.147	-4.613**	7.275**	-6.526**
UP2848×UP2672	3.581	2.639	8.362*	6.156	21.374**	14.870**	57.924**	16.710**	2.493	2.399	15.164**	0.356
UP2848×HD3059	6.561*	2.652	6.401	4.238	-5.326	-20.288**	9.594*	-19.010**	6.173**	-4.797**	7.075**	-6.704**
PBW644×WH1105	1.984	-5.280	3.143	1.040	8.387*	-1.680	34.662**	-0.479	1.078	-2.638	9.904**	-4.234*
PBW644×UP2672	5.442	3.838	13.074**	10.766**	6.883	1.335	38.794**	2.572	10.083**	9.779**	23.913**	7.984**
PBW644×HD3059	6.338*	0.069	8.964**	6.746*	12.969**	-4.738	30.477**	-3.575	6.294**	-4.844**	7.414**	-6.404**
HD3123×WH1105	2.385	-1.541	-0.433	-2.452	3.524	-0.931	20.885**	-10.660*	5.981**	0.724	5.333**	-8.210**
HD3123×UP2672	0.291	-1.819	3.662	1.545	5.068	4.758	28.586**	-4.970	9.146**	0.370	12.673**	-1.824
HD3123×HD3059	2.654	0.074	1.212	-0.852	12.698**	-0.230	21.746**	-10.028*	4.751**	1.982	-3.933*	-16.285**
UP2845×WH1105	6.814*	4.684	1.812	-0.261	18.378**	5.459	50.447**	11.183*	1.845	1.290	5.922**	-7.695**
UP2845×UP2672	5.031	0.892	6.524	4.348	-2.334	-9.150*	29.608**	-4.218	6.109**	1.941	14.435**	-0.286

UP2845×HD3059	5.571	4.917	2.045	-0.040	8.107*	-10.318*	27.947**	-5.450	8.993**	1.505	4.995**	-8.514**
UP2696×WH1105	2.245	-5.294	3.734	1.619	14.817**	1.928	46.588**	8.327	4.293**	-2.106	16.694**	1.696
UP2696×UP2672	2.118	0.275	9.835**	7.594*	25.708**	16.503**	67.546**	23.817**	5.764**	2.681	22.404**	6.665**
UP2696×HD3059	4.542	-1.891	7.465*	5.270	1.110	-16.390**	20.246**	-11.140*	7.417**	-6.092**	11.945**	-2.457
UP2425×WH1105	3.532	-1.209	1.552	-0.520	13.717**	3.040	41.472**	4.556	0.370	-6.055**	12.675**	-1.827
UP2425×UP2672	-1.988	-3.281	2.113	0.033	33.413**	26.340**	73.470**	28.199**	8.579**	5.104**	26.051**	9.854**
UP2425×HD3059	3.920	0.513	3.322	1.213	30.783**	10.173*	51.273**	11.794**	10.516**	-3.633*	15.572**	0.7141
UP2554×WH1105	7.333*	6.376	1.136	-0.925	35.401**	13.437**	26.506**	-6.507	6.418**	1.984	6.652**	-7.064**
UP2554×UP2672	7.450*	2.104	7.804*	5.602	24.959**	0.829	23.767**	-8.534	7.278**	-0.555	11.633**	-2.720
UP2554×HD3059	9.496**	8.938**	4.635	2.504	6.209	-4.345	-10.062*	-33.529**	8.969**	5.195**	0.845	-12.127**

Continued..........

Table 1 Continued..........

crosses	7. Spike length				8. Spikelets/spike				9. Grains/spike			
	Relative heterosis	Heterobeltiosis	Standard heterosis		Relative heterosis	Heterobeltiosis	Standard heterosis		Relative heterosis	Heterobeltiosis	Standard heterosis	
			HD2967	UP2526			HD2967	UP2526			HD2967	UP2526
HD3091×WH1105	7.234**	3.279**	4.744**	-9.547**	0.651	-1.278	-6.060**	-2.508**	17.054**	14.394**	15.258**	-12.721**
HD3091×UP2672	6.250**	2.466**	3.634**	-10.504**	-0.980	-3.195**	-7.893**	-4.401**	-23.944**	-28.947**	-17.563**	-37.575**
HD3091×HD3059	-0.284	-3.836**	-2.748**	-16.008**	-3.395**	-6.567**	-4.855**	-1.246	-21.190**	-22.628**	-19.090**	-38.731**
WH1139×WH1105	7.945**	7.650**	9.171**	-5.719**	6.463**	3.987**	-4.855**	-1.246	5.042*	-0.794	-4.587	-27.749**
WH1139×UP2672	2.058**	1.918**	3.082**	-10.983**	4.949**	2.843**	-6.523**	-2.981**	17.424**	1.974	18.311**	-10.409**
WH1139×HD3059	4.774**	4.630**	5.825**	-8.614**	1.286*	-5.970**	-4.242**	-0.615	-13.253**	-21.168**	-17.563**	-37.575**
PBW681×WH1105	3.656**	0.591	8.424**	-6.365**	1.378*	-2.074**	-3.858**	-0.205	-8.014**	-18.012**	0.755	-23.703**
PBW681×UP2672	-1.777**	-4.807**	2.600**	-11.390**	-5.788**	-9.288**	-10.931**	-7.556**	-58.466**	-59.627**	-50.385**	-62.429**
PBW681×HD3059	-0.637	-3.702**	3.805**	-10.361**	-3.040**	-4.776**	-3.022**	0.646	-1.342	-8.696**	12.205**	-15.033**
DBW88×WH11	4.396*	3.825*	5.294*	-	5.414	1.223	0.622	4.432*	18.216	11.189*	21.364	-

05	*	*	*	9.069**	**			*	**	*	**	8.097**
DBW88×UP2672	13.150**	12.685**	13.972**	-1.579**	2.332**	-2.049**	-2.636**	1.056	15.932**	12.500**	30.524**	-1.161
DBW88×HD3059	5.997**	5.562**	6.765**	-7.800**	2.205**	0.985	2.847**	6.736**	1.429	-0.699	8.388**	-17.923**
WH1126×WH1105	8.224**	5.822**	12.303**	-3.015**	9.477**	7.717**	1.848*	5.694**	53.774**	29.365**	24.417**	-5.785*
WH1126×UP2672	13.182**	10.522**	17.298**	1.292*	6.557**	4.502**	-1.203	2.539**	6.723**	-16.447**	-3.060	-26.593**
WH1126×HD3059	7.834**	5.300**	11.758**	-3.493**	5.573**	1.791*	3.667**	7.587**	44.395**	17.518**	22.891**	-6.941*
UP2848×WH1105	2.807**	-4.329**	12.669**	-2.704**	3.175**	-1.216	-1.206	2.539**	9.244**	3.175	-0.770	-24.859**
UP2848×UP2672	8.608**	0.941	18.874**	2.656**	0.318	-4.255**	-4.249**	-0.615	33.333**	15.789**	34.340**	1.728
UP2848×HD3059	0.506	-6.588**	10.005**	-5.001**	-0.301	-1.194	0.622	4.432**	46.185**	32.847**	38.920**	5.196
PBW644×WH1105	4.947**	2.228**	9.345**	-5.575**	9.936**	6.192**	4.273**	8.218**	-25.246**	-36.313**	-12.983**	-34.107**
PBW644×UP2672	10.599**	7.591**	15.074**	-0.622	0.643	-3.096**	-4.855**	-1.246	-2.115	-9.497**	23.654**	-6.363*
PBW644×HD3059	6.152**	3.264**	10.452**	-4.618**	-0.608	-2.388**	-0.592	3.170**	-6.962**	-17.877**	12.205**	-15.033**
HD3123×WH1105	5.303**	1.995**	3.442**	-10.672**	2.730**	1.726*	-5.066**	-1.467*	55.056**	46.809**	58.003**	19.646**
HD3123×UP2672	7.910**	4.658**	5.853**	-8.590**	0.660	-0.651	-7.287**	-3.770**	-35.836**	-38.158**	-28.249**	-45.667**
HD3123×HD3059	5.367**	2.192**	3.355**	-10.744**	3.115**	-1.194	0.624	4.432**	7.914**	6.383*	14.495**	-13.299**
UP2845×WH1105	5.177**	4.891**	6.951**	-7.633**	5.822**	2.658**	-6.065**	-2.508**	13.488**	-3.175	-6.877*	-29.483**
UP2845×UP2672	4.775**	4.348**	6.403**	-8.111**	4.811**	2.007**	-7.288**	-3.770**	4.564	-17.105**	-3.824	-27.171**
UP2845×HD3059	6.412**	5.978**	8.064**	-6.676**	3.236**	-4.776**	-3.029**	0.646	15.044**	-5.109	-0.770	-24.859**
UP2696×WH1105	5.365**	4.645**	6.123**	-8.351**	0.327	-1.286	-6.673**	-3.139**	15.663**	14.286**	9.915**	-16.767**
UP2696×UP2672	4.022**	3.452**	4.635**	-9.643**	5.902**	3.859**	-1.813*	1.908*	8.364**	-1.974	13.731**	-13.877**
UP2696×HD3059	1.653**	1.096	2.244**	-11.701**	0.619	-2.985**	-1.205	2.539**	57.692**	49.635**	56.476**	18.490**
UP2425×WH1105	6.983**	3.308**	12.504**	-2.847**	9.931**	6.645**	-2.423**	1.277	24.627**	17.606**	27.471**	-3.473
UP2425×UP2672	15.567**	11.450**	21.367**	4.809**	6.186**	3.344**	-6.066**	-2.508**	8.163**	4.605	21.364**	-8.097**
UP2425×HD3059	8.918**	5.038**	14.381**	-1.220*	-1.942**	-9.552**	-7.893**	-4.401**	-1.792	-3.521	4.572	-20.813**

UP2554×WH1105	10.335**	7.924**	9.459**	-5.479**	2.640**	1.967**	-5.464**	-1.877*	32.468**	21.429**	16.784**	-11.565**
UP2554×UP2672	10.490**	8.219**	9.459**	-5.479**	5.629**	4.590**	-3.027**	0.646	27.626**	7.895**	25.181**	-5.207
UP2554×HD3059	2.378**	0.274	1.415*	-12.419**	-0.937	-5.373**	-3.638**	0.015	19.835**	5.839*	10.678**	-16.189**

Continued...........

Table 1 Continued...........

crosses	**10. Grain weight/spike**				**11. 1000 grain weight**				**12. Biological yield/plant**			
	Relative heterosis	**Heterobeltiosis**	**Standard heterosis**		**Relative heterosis**	**Heterobeltiosis**	**Standard heterosis**		**Relative heterosis**	**Heterobeltiosis**	**Standard heterosis**	
			HD2967	**UP2526**			**HD2967**	**UP2526**			**HD2967**	**UP2526**
HD3091×WH1105	-23.377**	-34.444**	-22.266**	-25.221**	-4.082**	-18.023**	5.216**	-3.431**	23.888**	9.977	13.923*	-1.439
HD3091×UP2672	32.727**	14.063**	-3.820**	-7.477**	-31.928**	-34.302**	-15.678**	-22.608**	10.352	-4.568	5.065	-9.102
HD3091×HD3059	-14.493**	-20.270**	-22.266**	-25.221**	5.810**	0.581	29.095**	18.486**	-2.216	-10.141	-13.859*	-25.474**
WH1139×WH1105	-9.202**	-17.778**	-2.503**	-6.210**	-24.113**	-33.125**	-20.155**	-26.717**	2.464	-2.986	12.457*	-2.706
WH1139×UP2672	-22.689**	-36.986**	-39.393**	-41.698**	-3.125**	-3.125**	15.663**	6.157**	-30.662**	-32.404**	-21.644**	-32.210**
WH1139×HD3059	-15.646**	-16.216**	-18.313**	-21.419**	9.841**	8.125**	29.096**	18.485**	24.294**	13.541*	31.615**	13.868*
PBW681×WH1105	-19.126**	-20.430**	-2.503**	-6.210**	17.886**	16.935**	8.201**	-0.692	4.630	3.830	7.555	-6.948
PBW681×UP2672	26.619**	-5.376**	15.942**	11.533**	-6.338**	-16.875**	-0.754	-8.910**	6.954	3.025	13.424*	-1.871
PBW681×HD3059	-29.341**	-36.559**	-22.266**	-25.221**	20.430**	8.387**	25.364**	15.061**	-5.061	-7.919	-6.074	-18.739**
DBW88×WH1105	-1.987**	-17.778**	-2.503**	-6.210**	9.929**	-3.125**	15.663**	6.157**	25.522**	22.240**	26.625**	9.551
DBW88×UP2672	10.280**	-3.279**	-22.266**	-25.221**	-20.000**	-20.000**	-4.485**	-12.335**	15.520**	9.265	20.294**	4.073
DBW88×HD3059	3.704**	-5.405**	-7.773**	-11.280**	4.127**	2.500**	22.379**	12.321**	19.589**	18.183**	16.021**	0.377
WH1126×WH1105	1.370**	-17.778**	-2.503**	-6.210**	15.217**	3.247**	18.648**	8.897**	24.228**	21.853**	31.243**	13.546*
WH1126×UP2672	21.569**	10.714**	-18.313**	-21.419**	-7.006**	-8.750**	8.947**	-0.007	12.467*	11.247	22.476**	5.961
WH1126×HD3059	35.385**	18.919**	15.942**	11.533**	9.385**	9.032**	26.110**	15.745**	3.445	-2.243	5.290	-8.907
UP2848×WH1105	-27.950**	-35.556**	-23.583**	-26.489**	-7.958**	-20.359**	-0.754	-8.910**	-13.057*	-15.100*	-7.718	-20.161**
UP2848×UP26	4.274*	-	-	-	1.529*	-0.599	23.871	13.691	9.894	9.197	20.219	4.008

72	*	14.085**	19.631**	22.686**			**	**			**	
UP2848×HD3059	-3.448**	-5.405**	-7.773**	-11.280**	-9.317**	-12.575**	8.947**	-0.007	-24.404**	-28.867**	-22.682**	-33.107**
PBW644×WH1105	9.202**	-1.111**	17.259**	12.801**	-18.367**	-30.233**	-10.454**	-17.814**	19.074**	15.979**	20.139**	3.940
PBW644×UP2672	-17.647**	-32.877**	-35.441**	-37.896**	-23.494**	-26.163**	-5.231**	-13.020**	-5.253	-10.369	-1.323	-14.628*
PBW644×HD3059	0.680**	0.000	-2.503**	-6.210**	-10.092**	-14.535**	9.693**	0.678	34.261**	32.661**	30.276**	12.710*
HD3123×WH1105	4.636**	-12.222**	4.084**	0.126**	27.757**	19.149**	25.364**	15.061**	-7.312	-12.211*	1.687	-12.025
HD3123×UP2672	-23.364**	-32.787**	-45.981**	-48.035**	-21.595**	-26.250**	-11.947**	-19.184**	-10.122	-12.348*	1.528	-12.162*
HD3123×HD3059	-14.074**	-21.622**	-23.583**	-26.489**	8.108**	3.226**	19.394**	9.582**	4.001	-4.964	10.082	-4.762
UP2845×WH1105	16.438**	-5.556**	11.989**	7.731**	-21.502**	-32.749**	-14.186**	-21.238**	9.467	6.682	10.509	-4.392
UP2845×UP2672	54.902**	41.071**	4.084**	0.126**	-13.595**	-16.374**	6.708**	-2.062*	-13.627*	-18.246**	-9.994	-22.131**
UP2845×HD3059	53.846**	35.135**	31.752**	26.742**	-1.227	-5.848**	20.140**	10.266**	-7.582	-8.736	-10.272	-22.371**
UP2696×WH1105	-22.667**	-35.556**	-23.583**	-26.489**	12.741**	6.569**	8.947**	-0.007	-15.018**	-20.054**	-17.185**	-28.352**
UP2696×UP2672	20.755**	6.667**	-15.678**	-18.884**	4.377**	-3.125**	15.663**	6.157**	30.625**	19.484**	31.544**	13.806*
UP2696×HD3059	22.388**	10.811**	8.0368**	3.929**	16.438**	9.677**	26.856**	16.430**	4.931	2.441	-1.798	-15.039**
UP2425×WH1105	-0.680**	-18.889**	-3.820**	-7.477**	13.699**	-2.353**	23.871**	13.691**	30.012**	14.213*	18.310**	2.357
UP2425×UP2672	12.621**	1.754**	-23.583**	-26.489**	-29.091**	-31.176**	-12.693**	-19.869**	22.508**	4.881	15.467*	-0.103
UP2425×HD3059	-19.084**	-28.378**	-30.171**	-32.826**	-41.538**	-44.118**	-29.110**	-34.936**	11.013*	0.909	-3.267	-16.310**
UP2554×WH1105	-34.211**	-44.444**	-34.123**	-36.628**	-17.391**	-25.974**	-14.932**	-21.923**	-13.618*	-18.043**	-15.103*	-26.550**
UP2554×UP2672	40.741**	22.581**	0.131**	-3.675**	8.280**	6.250**	26.856**	16.430**	-1.566	-9.218	-0.055	-13.532*
UP2554×HD3059	-10.294**	-17.568**	-19.631**	-22.686**	0.971	0.645	16.409**	6.842**	-17.969**	-19.204**	-22.547**	-32.991**

Continued..........

Table 1 Continued...........

SN.	crosses	13. Grain yield/plant				14. Harvest index			
		Relative heterosis	Heterobeltiosis	Standard heterosis		Relative heterosis	Heterobeltiosis	Standard heterosis	
				HD2967	**UP2526**			**HD2967**	**UP2526**
1	HD3091×WH1105	4.186	1.932	16.503**	22.146**	-16.740**	-27.534**	0.092	16.392**
2	HD3091×UP2672	-9.557**	-11.422**	1.240	6.144*	-20.144**	-32.091**	-6.197*	9.078**
3	HD3091×HD3059	-7.033**	-11.899**	0.695	5.572*	-6.131*	-17.695**	13.692**	32.206**
4	WH1139×WH1105	0.024	-3.766	13.859**	19.374**	-1.602	-3.016	-0.764	15.396**
5	WH1139×UP2672	-16.630**	-19.707**	-5.001	-0.400	21.574**	20.000**	19.256**	38.676**
6	WH1139×HD3059	31.789**	22.886**	45.394**	52.436**	5.431*	3.039	7.265*	24.732**
7	PBW681×WH1105	6.027*	1.717	21.068**	26.932**	1.659	-3.256	9.586**	27.431**
8	PBW681×UP2672	7.338**	3.080	22.690**	28.633**	-0.032	-7.298*	5.005	22.105**
9	PBW681×HD3059	-0.856	-7.809**	9.730**	15.045**	4.300	0.079	13.355**	31.815**
10	DBW88×WH1105	51.437**	49.427**	63.396**	71.310**	20.349**	18.317**	25.292**	45.695**
11	DBW88×UP2672	37.560**	35.593**	48.583**	55.779**	19.083**	13.972**	20.689**	40.343**
12	DBW88×HD3059	39.530**	36.833**	45.653**	52.708**	15.953**	14.971**	21.746**	41.571**
13	WH1126×WH1105	23.870**	21.747**	33.129**	39.577**	-0.434	-3.789	-1.559	14.471**
14	WH1126×UP2672	17.872**	15.732**	26.819**	32.962**	4.011	3.268	-0.043	16.234**
15	WH1126×HD3059	28.811**	26.816**	33.919**	40.406**	24.407**	19.221**	24.116**	44.328**
16	UP2848×WH1105	5.501*	1.712	19.828**	25.632**	21.443**	19.436**	26.385**	46.966**
17	UP2848×UP2672	0.048	-3.447	13.750**	19.260**	-9.232**	-13.098**	-8.043**	6.932*
18	UP2848×HD3059	-7.738**	-13.800**	1.554	6.472*	21.993**	21.004**	28.045**	48.897**
19	PBW644×WH1105	23.339**	18.248**	40.938**	47.764**	3.068	-3.829	13.602**	32.102**
20	PBW644×UP2672	0.161	-3.876	14.568**	20.117**	5.183	-4.310	13.040**	31.448**
21	PBW644×HD3059	22.227**	13.583**	35.377**	41.935**	-9.069**	-14.468**	1.033	17.486**
22	HD3123×WH1105	14.853*	11.790**	22.240**	28.161**	24.831**	15.418**	18.086**	37.316**
23	HD3123×UP2672	24.717**	21.266**	32.884**	39.320**	37.300**	30.268**	26.102**	46.637**
24	HD3123×HD3059	17.895**	17.220**	21.341**	27.218**	10.307**	1.188	5.327	22.479**
25	UP2845×WH1105	13.379**	9.783**	20.046**	25.861**	4.142	3.626	6.032	23.298**
26	UP2845×UP2672	-9.398**	-12.362**	-3.966	0.686	5.657*	3.310	4.664	21.709**
27	UP2845×HD3059	0.067	0.027	2.439	7.401**	7.881**	6.432*	10.787**	28.828**
28	UP2696×WH1105	-8.034**	-14.257**	-6.241*	-1.700	8.607**	7.927*	10.435**	28.419**
29	UP2696×UP2672	10.795**	3.196	13.083**	18.560**	-15.272**	-17.047**	-16.190**	-2.542
30	UP2696×HD3059	-0.325	-4.115	-1.881	2.872	-3.644	-5.062	-1.172	14.922**
31	UP2425×WH1105	14.905**	5.683*	15.563**	21.160**	-11.808**	-16.302**	-4.659	10.867**
32	UP2425×UP2672	6.828**	-1.841	7.563**	12.773**	-13.466**	-19.969**	-8.827**	6.021
33	UP2425×HD3059	16.125**	10.148**	12.715**	18.174**	3.935	-0.548	13.304**	31.755**
34	UP2554×WH1105	6.484**	-1.147	8.095**	13.330*8	23.919**	21.537**	24.357**	44.608**
35	UP2554×UP2672	1.696	-5.683*	3.352	8.358**	5.285*	4.439	2.754	19.487**
36	UP2554×HD3059	-5.555*	-9.549**	-7.441**	-2.958	14.784**	11.633**	16.207**	35.130**

Biological yield per plant

For this trait, thirteen hybrids showed positive significant heterosis and PBW 644 × HD 3059 (34.261)expressed highest heterosis in positive direction. Eight hybrids showed significant positive heterosis over better parent and cross showing highest positive value was PBW 644 × HD 3059 (32.661).Fifteen crosses showed significant positive heterosis over the check HD 2967 and WH 1139 × HD 3059 (31.615) showed highest value. Results of standard heterosis over the check UP 2526 revealed thatonly four hybrids showed significant positive heterosis and highest positive value was observed for WH 1139 × HD 3059 (13.868).In general, higher biological yield can be correlated with higher economic yield. Hence, heterosis in positive direction is desirable. The cross PBW 644 × HD 3059 showed highest positive significant value for relative heterosis and heterobeltiosis both and the cross WH 1139 × HD 3059 showed highest significant standard heterosis over both the checks [6, 17].

Grain yield per plant

Significant positive relative heterosis was exhibited by twenty one hybrids and the cross DBW 88 × WH 1105 (51.437) identified as having maximum value. Significant positive heterobeltiosis was observed in fifteen hybrids and the cross showing highest positive value was DBW 88 × WH 1105 (49.427).Standard positive economic heterosis over the check HD 2967 was observed for twenty six crosses and cross DBW 88 × WH 1105 (63.396) was identified having highest value followed by DBW 88 × UP 2672 (48.583) and DBW 88 × HD 3059 (45.653).Thirty one crosses showed significant positive heterosis over UP 2526. Highest positive significant standard heterosis was observed for DBW 88 × WH 1105 (71.310) followed by DBW 88 × UP2672 (55.779). When selection is performed, yield per plant receives the maximum attention. Therefore, positive heterosis for grain yield per plant is highly desirable. The results obtained revealed that the cross DBW 88 × WH 1105 expressed highest significant positive relative heterosis, heterobeltiosis and standard heterosis over both the checks [14, 19, 20].

Harvest index

Seven crosses showed significant positive relative heterosis and the highest positive value was recorded forHD 3123 × UP 2672 (37.300).Thirteen crosses out of thirty six exhibited positive heterosis over better parent and the cross showing highest positive heterosis was HD 3123 × UP 2672 (30.268).Twenty four crosses exhibited significant positive heterosis over the check HD 2967 in which UP 2848 × HD 3059 (28.045) observed with highest value. Likewise thirty four hybrids showed significant positive economic heterosis and the same cross UP 2848 × HD 3059 (48.897) exhibited highest value. Higher value of harvest index is the indicator of better grain yield, so efforts should be concentrated for higher positive heterosis for harvest index. The cross HD 3123 × UP 2672 exhibited highest positive significant relative heterosis and heterobeltiosis and UP 2848 × HD 3059 showed highest positive standard heterosis over both checks namely HD 2967 and UP 2526 [14, 16, 21].

CONCLUSION

In the present investigation, relative heterosis, heterobeltiosis, and standard heterosis were observed for all the characters. Nineteen out of 36 F1s viz., DBW 88 × WH 1105, PBW 644 × UP 2672, PBW 644 × HD 3059, DBW 88 × HD 3059, PBW 681 × WH 1105, HD 3091 × HD 3059, UP 2425 × UP 2672, UP 2425 × UP 2672, DBW 88 × UP 2672, PBW 644 × WH 1105, WH 1126 × WH 1105, UP 2696 × HD 3059, HD 3123 × WH 1105, UP 2845 × UP 2672, UP 2845 × HD 3059, HD 3123 × WH 1105, WH 1139 × HD 3059, HD 3123 × UP 2672, UP 2848 × HD 3059 were recognized as the best heterotic hybrids for different characters. The best heterotic cross for grain yield per plant was DBW 88 × WH 1105 followed by DBW 88 × UP 2672, WH 1139 × HD 3059, DBW 88 × HD 3059 and PBW 644×WH 1105.The heterotic crosses maybe further exploited for the isolation of transgressive segregants.

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