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Heterosis and Inbreeding Depression Analysis for Yield and Its Components Traits in Bread Wheat (*Triticum aestivum* L. em. Thell.) Over Environments

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ABSTRACT

Heterosis was analyzed using a half diallel of ten parents in bread wheat (Triticum aestivum L. em. Thell.). Based on heterosis, heterobeltiosis, SCA effects and per se performance the crosses DBW 17 x WH1021 in E_1*; PBW 343 x DBW 17 in* E_2 *and PBW 343 x WH 1021 in* E_3 *emerged as good crosses for grain yield per plant. These crosses were the product of good x good, good x poor or poor x poor general combiners. The graphical and component analysis indicated partial dominance to over dominance for various characters in different sowing dates.Based on heterosis and inbreeding depression the crosses DBW 17 x DBW 621 in* E_1*; PBW 343 x WH 1021 in* E_2 *and DBW 17 x WH 1021 in* E_3 *exhibited heterosis as well as heterobeltiosis and also showed high desirable inbreeding depression for grain yield per plant. The good general combiners and specific cross combinations in* E_3 *may be used in breeding programme for high temperature tolerance.*

Key words: *Wheat, Heterosis, Heterobeltiosis*

INTRODUCTION

Wheat was one of the first domesticated food crops and for 8000 years has been the basic staple food of the major civilizations of Europe, West Asia and North Africa. Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans. Its production leads all crops, including rice, maize and potatoes. Wheat is one of the ancient grain crops consumed as primary food by human beings since the dawn of civilization. Among different wheat species, *T. aestivum*, the bread wheat (hexaploid) has major share of cultivation and *T. durum* or *durum* wheat (tetraploid) is the second species in some parts of the world. However, *T. dicoccum* is also cultivated in some parts of the world. Globally wheat annual production is about 729.5 million tons[1]. China is the largest producer of wheat with 17.6% global wheat production from about 11% area under wheat.

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The major wheat producing countries are India, the United State of America, Russia and Australia. These five countries together contribute more than half of the global wheat production. Less developed countries grow about 110 million hectares and produce about 307 million tons. During the last four decades of the 20th century the global wheat production is doubled from 3 to 6 billion mark and it is estimated that by the year 2012, it will reach the 8 billion mark[12]. Globally, demand for wheat by the year 2020 is forecasted around 950 million tons to meet future demands imposed by population and prosperity growth. This target may be achieved only, if global wheat production is increased by 2.5% per annum. This must be achieved under reduced water availability, a scenario of global warming, stricter end-use quality characteristics, and evolving pathogen and pest populations. Most of the production growth must occur in developing countries where wheat will be consumed. Breeding wheat cultivars with increased grain yield potential, enhanced water–use efficiency, heat tolerance, end-use quality, and durable resistance to important diseases and pests can contribute to meet at least half of the desired production increases. The remaining half must come through better agronomic and soil management practices and incentive policies.

Wheat is the second most important crop in India after rice, providing more than 50% of the calories to the people who mainly depend on it. Large number of end – use products such as chapatti, bread, biscuit and pasta products are made from wheat. It contains about 8-15% protein, and its unique gluten content makes it very essential for bakery industries. Besides staple food for human beings; its stover is used for large population of cattle in India. This golden grain winter cereal is a major contributor to the food security system and the economy of India. It occupying nearly 30.23 million hectares and producing around 93.53 million tons yield[1]. Around 95% of the wheat area is sown under *Triticum aestivum*, which is grown throughout the country, while durum and dicoccum wheat occupy nearly 5% area. The major wheat growing states of India are UP, MP, Punjab, Haryana, Rajasthan, Bihar, Gujarat and Maharastra.

MATERIALS AND METHODS

The present investigation aimed to gather information on the genetic basis of yield and its contributing traits in ten diverse genotypes of bread wheat (*Triticum aestivum* L. em. Thell.) viz. Raj 4083, Raj 4037, Raj 4079, Raj 4120, Raj 4238, PBW 343, DBW 17, DBW 621, HD 2967 and WH1021 selected from the germplasm maintained at Rajasthan Agriculture Research Institute, Durgapura, Jaipur, on the basis of a broad range of genetic diversity for major yield components. These selected genotypes were planted at Rajasthan Agriculture Research Institute, Durgapura, Jaipur, for hybridization in diallel fashion excluding reciprocals. The experiment was laid out in a randomized block design with three replications. The experiment plot comprised two rows each of parent and F_1 and six row of F_2 of 3-meter length. Row to row and plant to plant spacing was maintained at 30 cm and 10 cm. Recommended uniform agronomical practices were followed for raising the crop in all the three environments. Observations were recorded on twenty randomly selected competitive plants of each parent and F_1's and sixty plants in F_2's in every replication for following traits viz., days to heading, days to maturity, plant height (cm), tillers per plant, flag leaf area, spike area (cm^2), spikelets per spike, grains per spike, grain yield per spike,1000-grain weight (g), harvest index (%) and grain yield per plant (g). In case of maturity traits (days to heading & days to maturity), the data was recorded on the whole plot basis. The mean of each plot used for statistical analysis. The data were first subjected to the usual analysis followed for a randomized block design for individual environment as suggested by Panse and Sukhatme.

RESULTS AND DISCUSSION

The possibility of exploitation of hybrid vigour depends on the magnitude of heterosis and feasibility of hybrid seed production at commercial scale. The development of new superior varieties is an important goal of practically all breeding programmes irrespective of their use as varieties *per se* and/or as parents of a hybrid. Wheat is a self-pollinated crop and a suitable mechanism to produce hybrid seed at commercial scale is not yet available. Therefore, the heterosis *per se* may not be of economic value in this crop at present. Investigation on the degree of heterosis is however, important in deciding the direction of future breeding programmes. Furthermore, this study may also help to identify the cross combinations, which are promising in conventional breeding programme. In the present study almost all the characters in all the three environments showed the presence of heterosis. Mackey[9] (1976) described genetic principles of expression of heterosis superior to the better parent may result from one or more of the given situations like (i) the accumulated action of favorable dominant or semi- dominant genes dispersed between two parents *i.e.* dominance, (ii) the complementary interaction of additive-dominant on recessive genes at different loci *i.e.* non-allelic interaction or epistasis and (iii) favorable interaction between two alleles at the same locus *i.e.* intra locus or intra-allelic interactions referred to as over dominance. Several theories have been put forward to explain the genetic basis of heterosis in crop plants but the dominant linked gene hypothesi) has found favorable in self-pollinated crops to explain the phenomenon. Both additive and non-additive gene effects have been suggested to explain heterosis. If heterosis is due to epistatic gene action, particularly of additive x additive type or due to repulsion phase linked loci, exhibiting partial or complete dominance, it should be possible to fix the alleles at interacting loci to preserve the heterotic effects in the pure lines. In addition, the heterotic hybrid can also produce desirable transgressive segregants in their advance generations). Under such situation, it will be useful to observe the genetic effects in crosses involving them, which may throw desirable recombinants in later generations. However, dispersion of alleles, as one of the major causes of heterosis, cannot be ruled out as enough evidence now supports dispersion of complementary genes as the major cause of heterosis[1]).

The superiority of hybrids particularly over better parent (heterobeltiosis) is more important and useful in determining the feasibility of commercial exploitation of heterosis and also indicating the parental combinations capable of producing the highest level of transgressive segregants.

A comparative study of three best heterotic crosses in different environments for different traits in Table 1 showed that the crosses involving the parents Raj 4083, HD 2967 and Raj 4238 in E_1; WH 1021, Raj 4120 and DBW 621 in E_2 and WH 1021, Raj 4079 and PBW 343 in E_3 environments were found to be heterotic for a number of characters over the environments. Along with SCA effects and *per se* performance, Perusal of table 2 indicated that the crosses DBW 17 x WH 1021, DBW 17 x DBW 621 in E_1; PBW 343 x DBW 17 and DBW 17 x WH 1021 in E_2 and PBW 343 x WH 1021 and PBW 343 x DBW 17 in E_3 emerged as good heterotic as well as heterobeltiotic crosses for grain yield per plant. Five crosses viz., DBW 17 x WH 1021, DBW 17 x DBW 621; PBW 343 x DBW 17, DBW 621 x WH 1021 and PBW 343 x WH 1021 showed desirable heterosis and heterobeltiosis in all the environments for grain yield per plant. The crosses showing heterotic expression for grain yield per plant were not heterotic for all the characters. It was also noted that the expression of heterosis and heterobeltiosis was influenced by the environments for almost all the characters. This was because of significant F_1 x environment interaction.

Perusal of Table 3 revealed that heterosis for grain yield per plant was mainly contributed by flag leaf area, grain yield per spike, tillers per plant, spike area, plant height and grains per spike in all the three environments and 1000grain weight in E_1 & E_2, by harvest index in E_2 and E_3 in addition to the characters mentioned above in this paragraph. Heterobeltiosis for grain yield per plant was mainly contributed by flag leaf area, spike area, tillers per plant, grains per spike in all the three environments and by grain yield per spike in E_1; by harvest index in E_3 and by days to maturity, plant height in E_1 & E_3, and harvest index in E_3 in besides other characters mentioned above in this paragraph. The results of the present findings are in agreement with the results of Prasad *et al*[11]., Deshpande and Nayeem[3], Munir *et al*[10]., Subhani *et al*[20]., Dubey *et al*[4]., Salgotra *et al*[14]., Joshi *et al*[6]., Punia[13], Verma *et al*[21].), Singh *et al*[19]., Kumar and Kerkhi[8] and Kumar *et al*[7].

It is of considerable interest to know the cause of heterosis for grain yield. Grafius[5] suggested that there could be no separate gene system for yield *per se* as yield is an end product of multiplicative interaction between its various components. Thus, heterosis for yield could be determined by finding the effect of heterosis for individual yield components or alternatively by multiplicative effect of partial dominance of component characters.

In general, mechanism for the expression of heterosis and heterobeltiosis for grain yield was mainly dependent upon biological yield per plant, grain yield per spike, 1000-grain weight and number of grains per spike. On the basis of heterosis, heterobeltiosis, SCA effects and *per se* performance the crosses DBW 621 x WH 1021 in E_1; PBW 343 x DBW 17 in E_2 and PBW 343 x WH 1021 in E_2 and E_3 and DBW 17 x WH 1021 in all the environments emerged as good crosses for grain yield per plant (Table 3).

The heterotic expression normally declines in F_2 generation as the dominance or dominance interaction effects dissipate in this generation due to reduced heterozygosity, there by resulting into inbreeding depression. Significant inbreeding depression in present investigation was observed for different characters in all the three environments with some exceptions where significant negative inbreeding depression was exhibited *i.e.* a significant increase in F_2 over F_1. For e.g., Raj 4238 x PBW 343 for days to heading, Raj 4037 x Raj 4079 for plant height, Raj 4120 x WH 1021 for tillers par plant, Raj 4120 x HD 2967 for flag leaf area, Raj 4083 x PBW 343 for spikelets per spike, Raj 4238 x WH 1021 for grains per spike, Raj 4120x WH 1021 for grain yield per spike, Raj 4238 x DBW 621 for harvest index and DBW 17 x DBW 621 for grain yield per plant. Similar results were also obtained by Sharma and Menon[15], Joshi *et al*[6]., Sharma *et al*[16]., Singh *et al*[17]., Singh *et al*[19]., Kumar and Kerkhi[8], Kumar *et al*[7].

The negative inbreeding depression may result from the advantage of population buffering, which may occur in F_2 generation due to the segregation of genes or sometimes because of formation of superior gene combinations, such a situation is valuable in conventional breeding programme.

Table 1: Best three crosses based on heterosis, heterobeltiosis and inbreeding depression for different traits under different environments

Characters	Env.	Heterosis	Heterobeltiosis	Inbreeding depression
Days to heading	**E_1**	Raj 4083 x Raj 4037	Raj 4083 x Raj 4037	Raj 4083 x Raj 4037
		Raj 4120 x Raj 4238	-	Raj 4083 x Raj 4079
		Raj 4037 x HD 2967	-	Raj 4083 x Raj 4238
	E_2		Raj 4083 x Raj 4037	Raj 4083 x Raj 4238
			-	Raj 4120 x PBW 343
		HD 2967 x WH 1021	-	PBW 343 x WH 1021
	E_3	PBW 343 x HD 2967	Raj 4120 x PBW 343	HD 2967 x WH 1021
		DBW 17 x HD 2967	Raj 4120 x Raj 4238	Raj 4083 x Raj 4037
			Raj 4120 x WH 1021	Raj 4083 x WH 1021
Days to maturity	**E_1**	DBW 17 x HD 2967	Raj 4238 x DBW 17	Raj 4238 x WH 1021
		Raj 4083 x HD 2967	PBW 343 x DBW 621	Raj 4083 x Raj 4037

		PBW 343 x DBW 621	DBW 621 x HD 2967	Raj 4083 x Raj 4079
	E_2	Raj 4083 x HD 2967	-	Raj 4083 x Raj 4120
		DBW 17 x HD 2967	-	Raj 4083 x Raj 4037
		Raj 4120 x DBW 621	-	Raj 4083 x Raj 4079
	E_3		PBW 343 x DBW 621	Raj 4083 x Raj 4120
			DBW 17 x HD 2967	Raj 4083 x Raj 4037
			-	Raj 4083 x Raj 4079
Plant height	**E_1**	DBW 621 x WH 1021	DBW 621 x WH 1021	Raj 4037 x WH 1021
		HD 2967 x WH 1021	Raj 4238 x DBW 621	DBW 621 x HD 2967
		Raj 4120 x HD 2967	Raj 4120 x WH 1021	HD 2967 x WH 1021
	E_2	DBW 621 x HD 2967	DBW 621 x WH 1021	Raj 4238 x WH 1021
		HD 2967 x WH 1021	PBW 343 x DBW 17	DBW 621 x HD 2967
		Raj 4238 x WH 1021	DBW 621 x HD 2967	HD 2967 x WH 1021
	E_3	DBW 621 x HD 2967	DBW 621 x WH 1021	Raj 4079 x Raj 4120
		Raj 4079 x HD 2967	Raj 4238 x HD 2967	Raj 4079 x PBW 343
		Raj 4238 x DBW 621	Raj 4079 x DBW 17	Raj 4079 x WH 1021
Tillers per plant	**E_1**	DBW 17 x WH 1021	DBW 17 x WH 1021	Raj 4083 x Raj 4238
		Raj 4120 x HD 2967	Raj 4079 x WH 1021	Raj 4238 x PBW 343
		Raj 4238 x PBW 343	Raj 4083 x Raj 4238	DBW 621 x HD 2967
	E_2	Raj 4120 x Raj 4238	DBW 17 x WH 1021	Raj 4083 x Raj 4238
		DBW 17 x WH 1021	Raj 4120 x WH 1021	Raj 4120 x HD 2967
		Raj 4120 x HD 2967	Raj 4079 x WH 1021	DBW 621 x HD 2967
	E_3	Raj 4079 x WH 1021	PBW 343 x DBW 17	Raj 4083 x Raj 4238
		PBW 343 x DBW 17	Raj 4120 x PBW 343	Raj 4120 x HD 2967
		Raj 4079 x HD 2967		DBW 621 x HD 2967

Contd..

Characters	Env.	Heterosis	Heterobeltiosis	Inbreeding depression
Flag Leaf Area	**E_1**	PBW 343 x WH 1021	PBW 343 x WH 1021	PBW 343 x HD 2967
		Raj 4037 x WH 1021	PBW 343 x DBW 17	PBW 343 x WH 1021
		DBW 17 x WH 1021	DBW 17 x WH 1021	DBW 621 x WH 1021
	E_2	PBW 343 x WH 1021	PBW 343 x WH 1021	Raj 4083 x Raj 4238
		Raj 4037 x WH 1021	PBW 343 x DBW 17	Raj 4037 x Raj 4079
		DBW 17 x WH 1021	DBW 17 x WH 1021	PBW 343 x WH 1021
	E_3	PBW 343 x DBW 621	PBW 343 x DBW 621	Raj 4120 x DBW 621
		Raj 4120 x DBW 621	Raj 4120 x DBW 621	Raj 4120 x HD 2967
		PBW 343 x DBW 17	DBW 17 x DBW 621	PBW 343 x DBW 621
Spike area	**E_1**	PBW 343 x HD 2967	Raj 4037 x HD 2967	PBW 343 x HD 2967
		Raj 4037 x HD 2967	PBW 343 x HD 2967	PBW 343 x WH 1021
		DBW 17 x DBW 621	DBW17 x DBW 621	DBW17 x DBW 621
	E_2	PBW 343 x HD 2967	PBW 343 x HD 2967	PBW 343 x DBW 17
		Raj 4037 x HD 2967	Raj 4037 x HD 2967	PBW 343 x HD 2967
		HD 2967 x WH 1021	HD 2967 x WH 1021	DBW 17 x DBW 621
	E_3	PBW 343 x HD 2967	PBW 343 x HD 2967	PBW 343 x DBW 17
		Raj 4120 x PBW 343	Raj 4120 x PBW 343	PBW 343 x HD 2967

		Raj 4083 x HD 2967	Raj 4083 x HD 2967	DBW 17 x DBW 621
Spikelets per spike	**E$_1$**	Raj 4037 x Raj 4120 Raj 4083 x HD 2967 Raj 4120 x Raj 4238	Raj 4037 x Raj 4120 Raj 4037 x HD 2967 Raj 4120 x Raj 4238	Raj 4083 x Raj 4120 Raj 4037 x Raj 4120 Raj 4120 x Raj 4238
	E$_2$	Raj 4120 x Raj 4238 Raj 4083 x WH 1021 Raj 4083 x PBW 343		Raj 4083 x WH 1021 Raj 4120 x Raj 4238 Raj 4120 x HD 2967
	E$_3$	Raj 4083 x DBW 621 Raj 4083 x PBW 343 Raj 4120 x Raj 4238		Raj 4083 x WH 1021 Raj 4120 x Raj 4238 Raj 4120 x HD 2967
Grains per spike	**E$_1$**	HD 2967 x WH 1021 DBW 621 x HD 2967 Raj 4120 x HD 2967	HD 2967 x WH 1021 Raj 4120 x HD 2967 DBW 621 x HD 2967	Raj 4120 x HD 2967 Raj 4120 x WH 1021 HD 2967 x WH 1021
	E$_2$	HD 2967 x WH 1021 Raj 4120 x HD 2967 Raj 4120 x WH 1021	HD 2967 x WH 1021 Raj 4120 x HD 2967 Raj 4120 x WH 1021	Raj 4120 x HD 2967 Raj 4120 x WH 1021 HD 2967 x WH 1021
	E$_3$	Raj 4083 x WH 1021 DBW 621 x HD 2967 DBW 17 x DBW 621	Raj 4120 x HD 2967 DBW 621 x HD 2967 HD 2967 x WH 1021	Raj 4120 x HD 2967 Raj 4120 x WH 1021 HD 2967 x WH 1021

Contd..

Characters	**Env.**	**Heterosis**	**Heterobeltiosis**	**Inbreeding depression**
Grain yield per spike	**E$_1$**	DBW 17 x WH 1021 DBW 17 x DBW 621 PBW 343 x DBW 17	DBW 17 x WH 1021 DBW 17 x DBW 621 PBW 343 x DBW 17	Raj 4083 x HD 2967 DBW 17 x DBW 621 DBW 17 x WH 1021
	E$_2$	Raj 4083 x DBW 621 PBW 343 x DBW 17 Raj 4083 x Raj 4079	Raj 4083 x DBW 621 PBW 343 x DBW 17 Raj 4083 x PBW 343	Raj 4083 x Raj 4079 Raj 4120 x WH 1021 PBW 343 x DBW 17
	E$_3$			Raj 4083 x Raj 4037 Raj 4083 x Raj 4120 Raj 4083 x Raj 4238
1000 Grain weight	**E$_1$**	Raj 4037 x DBW 17 Raj 4079 x DBW 17 Raj 4238 x PBW 343	Raj 4037 x DBW 17 Raj 4037 x WH 1021 Raj 4037 x Raj 4079	Raj 4083 x HD 2967 Raj 4120 x Raj 4238 Raj 4238 x PBW 343
	E$_2$	Raj 4037 x DBW 17 Raj 4120 x Raj 4238 Raj 4238 x PBW 343	Raj 4037 x DBW 17 Raj 4238 x PBW 343 Raj 4120 x Raj 4238	Raj 4120 x Raj 4238 Raj 4238 x PBW 343 Raj 4238 x HD 2967
	E$_3$	Raj 4037 x Raj 4238 Raj 4083 x Raj 4037 Raj 4083 x PBW 343	Raj 4083 x PBW 343 Raj 4083 x Raj 4238 Raj 4037 x Raj 4238	Raj 4083 x PBW 343 Raj 4037 x HD 2967 Raj 4079 x Raj 4238
Harvest index	**E$_1$**	Raj 4083 x DBW 621 Raj 4238 x DBW 621 Raj 4238 x HD 2967	Raj 4238 x HD 2967 Raj 4238 x DBW 621 Raj 4083 x DBW 621	Raj 4120 x WH 1021 Raj 4238 x DBW 621 PBW343 x DBW 621
	E$_2$	Raj 4238 x HD 2967 Raj 4083 x DBW 621 Raj 4238 x DBW 621	Raj 4238 x HD 2967 Raj 4238 x DBW 621	Raj 4238 x DBW 621 Raj 4238 x HD 2967 PBW 343 x DBW 17

	E_3	Raj 4238 x HD 2967	Raj 4238 x HD 2967	Raj 4079 x DBW 621
		Raj 4083 x DBW 621	Raj 4079 x DBW 621	Raj 4238 x DBW 17
		Raj 4079 x DBW 621	Raj 4238 x DBW 621	Raj 4238 x DBW 621
Grain yield per plant	**E_1**	DBW 17 x WH 1021	DBW 17 x WH 1021	DBW 621 x HD 2967
		DBW 17 x DBW 621	DBW 17 x DBW 621	Raj 4238 x PBW 343
		DBW 621 x WH 1021	DBW 621 x WH 1021	HD 2967 x WH 1021
	E_2	PBW 343 x WH 1021	PBW 343 x WH 1021	Raj 4083 x Raj 4238
		PBW 343 x DBW 17	PBW 343 x DBW 17	Raj 4083 x HD 2967
		DBW 17 x WH 1021	DBW 17 x WH 1021	Raj 4238 x PBW 343
	E_3	DBW 17 x WH 1021	DBW 17 x WH 1021	Raj 4083 x Raj 4238
		PBW 343 x DBW 17	PBW 343 x DBW 17	Raj 4083 x HD 2967
		PBW 343 x WH 1021	PBW 343 x WH 1021	Raj 4238 x WH 1021

Table 2: Best three heterotic and heterobeltiotic crosses (F_1) for grain yield/plant along with their SCA effects and per se performance in different environments

Environments	**Heterotic crosses**	**Heterosis**	**SCA effect**	***per se* performance (g)**	**Heterobeltiotic crosses**	**Heterobeltiosis**	**SCA effect**	***per se* performance (g)**
E_1	DBW 17 x WH 1021	47.15	3.21**	23.13	DBW 17 x WH 1021	47.02	3.21**	23.13
	DBW 17 x DBW 621	32.58	3.51**	24.17	DBW 17 x DBW 621	32.78	3.51**	24.17
	DBW 621 x WH 1021	32.44	3.54**	25.67	DBW 621 x WH 1021	32.78	3.54**	25.67
E_2	PBW 343 x WH 1021	68.25	3.69**	23.67	PBW 343 x WH 1021	59.91	3.69**	23.67
	PBW 343 x DBW 17	59.16	3.21**	22.87	PBW 343 x DBW 17	54.5	3.21**	22.87
	DBW 17 x WH 1021	57.46	2.06**	21.47	DBW 17 x WH 1021	54.03	2.06**	21.47
E_3	DBW 17 x WH 1021	41.89	1.94**	14.73	DBW 17 x WH 1021	38.56	1.94**	14.73
	PBW 343 x DBW 17	32.08	1.29**	14.00	PBW 343 x DBW 17	26.51	1.29**	14.00
	PBW 343 x WH 1021	29.03	1.29**	14.00	PBW 343 x WH 1021	26.51	1.29**	14.00

Table 3: Crosses possessing high heterosis and heterobeltiosis for grain yield/plant along with desirable (+) heterotic expression for other characters in different environments

Particulars	**Environments**	**Crosses**	**Magnitude of SCA effect for grain yield per plant**	***Per se* performance for grain yield per plant**	**Magnitude of heterosis or Heterbeltiosis in per cent**	**Days to heading**	**Days to maturity**	**Plant height**	**Tillers per plant**	**Flag leaf area**	**Spike larea**	**Spikelets per spike**	**Grains per spike**	**Grain yield per spike**	**1000-grain weight**	**Harvest index**
Heterosis	E_1	DBW 17 x WH 1021	3.21	23.13	47.15	-	+	+	+	+	+	-	+	+	+	-
		DBW 17 x DBW 621	3.51	24.17	32.58	-	+	+	+	+	+	-	+	+	+	-
		DBW 621 x WH 1021	3.54	25.67	32.44	-	+	+	+	+	+	-	+	+	+	-
	E_2	PBW 343 x WH 1021	3.69	23.67	68.25	-	-	-	+	+	+	-	+	-	-	-
		PBW 343 x DBW 17	3.21	22.87	59.16	-	-	-	+	+	+	-	-	+	+	+
		DBW 17 x WH 1021	2.06	21.47	57.46	-	-	+	+	+	+	-	+	-	-	-
	E_3	DBW 17 x WH 1021	1.94	14.73	41.89	-	-	+	+	+	-	-	+	-	-	-
		PBW 343 x DBW 17	1.29	14.00	32.08	-	-	+	+	+	+	-	+	-	-	+
		PBW 343 x WH 1021	1.29	14.00	29.03	-	-	-	+	+	+	-	+	-	-	-
Heterobeltiosis	E_1	DBW 17 x WH 1021	3.21	23.13	47.02	-	+	+	+	+	+	-	+	+	+	-
		DBW 17 x DBW 621	3.51	24.17	32.78	-	+	+	-	+	+	-	+	+	-	-
		DBW 621 x WH 1021	3.54	25.67	32.78	-	+	+	-	+	-	-	+	+	-	-
	E_2	PBW 343 x WH 1021	3.69	23.67	59.91	-	-	-	-	+	+	-	+	-	-	-
		PBW 343 x DBW 17	3.21	22.87	54.5	-	-	-	-	+	+	-	-	-	-	-
		DBW 17 x WH 1021	2.29	21.47	54.03	-	-	+	+	+	+	-	+	-	-	-
	E_3	DBW 17 x WH 1021	1.94	14.73	38.56	-	-	+	-	+	-	-	-	-	-	-
		PBW 343 x DBW 17	1.29	14.00	26.51	-	+	+	+	+	+	-	-	-	-	+
		PBW 343 x WH 1021	1.29	14.00	26.51	-	+	-	-	-	+	-	-	-	-	-

REFERENCES

1. Anonymous, United States Department of Agriculture Rajasthan, India (2016).
2. Arunachalam, V., Evaluation of diallel crosses by graphical and combining ability methods. Indian *J. Genet.*, **36:** 358-366 (1976).
3. Deshpande, D.P. and Nayeem, K.A., Heterosis of heat tolerance, protein content, yield components in bread wheat (*Triticum aestivum* L.). *Indian J. Genet.*, **59:** 13-22 (1999).
4. Dubey, L.K., Sastry, E.V.D. and Sinha, K., Heterosis for yield and yield components in wheat (*Triticum aestivum* L.) under saline and normal environments. *Ann. Arid Zone*, **40:** 57-60 (2001).
5. Grafius, J.E., Heterosis in barley. *Agron. J.*, **51:** 551-554 (1959).
6. Joshi, S.K., Sharma, S.N., Singhania, D.L. and Sain, R.S., Hybrid vigour over environments in a ten parent diallel cross in common wheat. SABRAO.*J. Breeding &Genetics*., **35:** 81-91 (2003b).
7. Kumar, A., Harshwardhan Kumar, A. and Prasad, B., Heterotic performance of diallel F1 crosses over parents for yield and its contributing traits in bread wheat. *J. Hill Agriculture*, **6(1):** 237-245 (2015).
8. Kumar, D. and Kerkhi, S.A., Heterosis studies for yield component traits and quality in spring wheat (*Triticum aestivum* L.). *Supplement on Genetics and Plant Breeding*, **9(4):** 1725-1731 (2014).
9. Mackey, I., Genetic and evolutionary principles of heterosis. In: Janossy, A. and Lupton, F.G.H. (eds), Heterosis in plantbreeding. Proc. VIII Congr.

EUCARPIA Elsevier Scientific Pub. Co., Amsterdam. 17-33 (1976).

10. Munir, I., Swati, M.S., Muhammad, F., Ahmad, R. and Imtiaz, M., Heterosis in different crosses of wheat (*Triticum aestivum* L.).*Sarh. J. Agric*., **15:** 299-303 (1999).
11. Prasad, K.D., Haque, M.F. and Ganguli, D.K., Heterosis studies for yield and its components in bread wheat (*T. aestivum* L.). *Indian J. Genet*., **58:** 97-100 (1998).
12. Prasad, R. and Nagarajan, S., Rice wheat cropping system- Food Security and Sustainability. *Cur. Sci*., **87:** 1334-1335 (2004).
13. Punia, S.S., Combining ability and stability analysis for high temperature tolerance and yield contributing characters in wheat (*Triticum aestivum* L.). Unpubl. Ph.D. Thesis, MPUAT, Udaipur (Raj.) (2003).
14. Salgotra, R.K., Thakur, K.S., Sethi, G.S. and Sharma, J.K., Heterosis in winter x spring wheat crosses. *Indian J. Genet*., **62:** 104-106 (2002).
15. Sharma, S.N. and Menon, Uma, Heterosis over environments in bread wheat. *Crop Improv*., **23:** 225-228 (1996).
16. Sharma, S.N., Mann, M.S. and Sain, R.S., Heterosis in durum wheat (*Triticum turgidum* var. durum). SABRAO – *Journal of Breading and Genetics*, **36:** 127-130 (2004).
17. Singh H., Sharma, S.N., Sain R.S. and Sastry, E.V.D., Heterosis studies for yield and its components in bread wheat under normal and late sowing conditions. SABRAO. *Journal of Breading and Genetics*, **36:** 1-11 (2004).
18. Singh, R.K. and Singh, M., Concepts of heterosis and exploitation of hybrid vigour in pulse crops.In : Proc. Natl. Seminar on Pulse Research and Development, 21 May, 1984. Jabalpur (1984).
19. Singh, V., Krishna, R., Singh, S. and Vikram, P., Combining ability and heterosis analysis for yield traits in bread wheat (*T. aestivum* L.). *Indian J. Agric. Sci*., **82:** 11 (2012).
20. Subhani, G.M. and Chowdhary, M.A., Genetic studies in bread wheat under irrigated and drought stress conditions. *Pak. J. Biol. Sci.,* **3:** 1793-1798 (2000).
21. Verma, R.K., Singh, B.N., Singh, P.K. and Vishwakarma, S.R., Heterosis studies in wheat (*Triticum aestivum* L. em. Thell). *J. Wheat Res*., **1:** 38-43 (2007).