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Estimation of Heterosis for Grain Yield and its related Traits over the Environments in Maize (*Zea mays* L.)

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ABSTRACT: The study of standard heterosis among maize germplasm is essential to maximize the effectiveness of cultivars selection. The present investigation was carried out to estimate the heterosis in maize hybrids developed through crossing eight elite inbred lines in half diallel mating design. The experimental material consisted of 8 parental genotypes, their 28 crosses and two checks *viz.*, Palam Sankar Makka-2 and Bio-9544. The experimental material was evaluated in RBD with two replications during *Kharif*, 2019 at two different environments representing different agroclimatic and ecological conditions of North-Western Himalayas *i.e.* SAREC, Kangra (E1) and HAREC, Bajaura (E2). Data was recorded on various agro-morphological traits. Bartlett's test revealed that error variance was homogeneous for days to 50% pollen shed, days to 50% silking, days to 75% brown husk, ear circumference, 1000-grain weight and grain yield. Standard heterosis (%) for grain yield ranged from -52.34 ($P_4 \times P_7$) to 16.05 ($P_1 \times P_4$) in E1, -53.12 ($P_4 \times P_7$) to 13.14 ($P_2 \times P_4$) in E2 and -51.91 ($P_4 \times P_7$) to 16.15 ($P_1 \times P_4$) in pooled over environment. Two hybrids *viz.*, $P_1 \times P_4$ and $P_2 \times P_4$ were found to be consistently superior and had significant standard heterosis for grain yield in individual as well as in pooled analysis. In addition, significant standard heterosis (%) for ear circumference was also observed for these hybrids over pooled environment. These identified crosses seem to be potential hybrids and can be used in further breeding programmes or can be used directly as cultivar after multi-location evaluation.

Keywords: Heterosis, Pooled Environment, Half Diallel Analysis, *Zea mays* L.

INTRODUCTION

Maize (*Zea mays* L., 2n=20) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. It possesses a genome size of 2.3 gigabase and more than 32,000 genes (Schnable *et al.*, 2009). It is a member of the grass family *Poaceae*, tribe *Maydeae* and one of the oldest cultivated crops (Sleper and Poehlman 2006). Globally, maize is known as "Queen of cereals" because it has the highest genetic yield potential among the cereals. Being a C_4 plant, it is physiologically more efficient and resilient to changing climatic conditions with wider genetic variability and also able to grow successfully throughout the world over wide range of environmental conditions covering tropical, subtropical and temperate agro-climatic conditions. Maize is a strategically important crop for the millions of resource-poor farmers because of its multiple uses as food, feed and raw material for industry.

Heterosis is an important in breeding program especially for cross pollinated crop and is a great achievement to meet the world's food needs (Duvick, 1999). It is a well-known fact that one of the top breakthroughs in modern agriculture came with the discovery of heterosis. Heterosis is a base breeding programmes especially for cross pollinated crops like maize. It is an important tool to increase the crop production in the form of hybrids (Singh, 2015). The heterotic studies can offer the possibilities to exploit the valuable hybrid combinations in the future plant breeding programmes and commercial utilization. Therefore, the heterosis is widely exploited and used by plant breeders to enhance the yield of many crops. Standard heterosis is estimated over standard commercial hybrid. The study of standard heterosis among maize germplasm is essential in maximizing the effectiveness of cultivars selection especially in cross pollinated crops. It has practical importance in plant breeding. It is also referred as useful or economic heterosis. Therefore, the present study was carried out

with the objective to determine extent and magnitude of heterosis for various yield and yield contributing traits in maize over the environments that could ultimately be utilized to develop maize hybrids with high yielding potential.

MATERIALS AND METHODS

The experimental material consisted of 8 parental genotypes, their 28 crosses and two checks *viz.*, Palam Sankar Makka-2 and Bio-9544 were evaluated in Randomized complete Block Design (RBD) with two replications in a plot size of 3.0 × 1.2m (3.6 m^2) at a spacing of 60 × 20 cm during *Kharif*, 2019 (Table 1). This material was evaluated at two environments representing different agroclimatic and ecological conditions *i.e.* SAREC, Kangra (E1) and HAREC, Bajaura (E2). The data was recorded for plant height (cm), ear height (cm), number of kernel rows per ear, number of kernels per row, ear length (cm), ear circumference (cm), 1000-grain weight (g), shelling (%), grain yield (q/ha) on 10 randomly chosen competitive plants and the average was worked out. However, days to 50 per cent pollen shed, days to 50 per cent silking and days to 75 per cent brown husk data was recorded on the plot basis for both the environments (E1 and E2). Heterosis over mid parent (MPH), better parent (BPH) and standard check (SH) was calculated as per Liang *et al*., (1971) for individual as well as over the environments. The test for homogeneity of error variance for pooled analysis of variance was carried out as procedure suggested by Bartlett, (1937).

Table 1: Details of inbred lines used as parents along with checks used in the study.

Symbol/Code	Inbred line	Pedigree/Source
P_1	B73	PI 550473 (USDA)
P_2	BAJIM-1522	HKI488/HKI295-x-20-3-2-1-2-4-b-8- (HAREC, Bajaura)
P_3	BAJIM-2010	V336×3083-05-1 (HAREC, Bajaura)
P_4	BAJIM-1811	B52-x-1-1-5-4-b-x-x (HAREC, Bajaura)
P_5	LM16	PAU, Ludhiana
P_6	LM14	CA00310xbxb-1-1-1-1 (PAU, Ludhiana)
P_7	40318	DMR-155 (EC 447158) (IIMR, Winter Maize Nursery)
P_8	CML141	Pob62c3HC24-5-3-2-1-B-B-2-B-B-#
Symbol/Code	**Checks**	**Source**
Check 1	Palam Sankar Makka-2	CSKHPKV, Palampur (Himachal Pradesh)
Check 2	Bio-9544	Shriram Bioseed Genetics India Limited

RESULTS AND DISCUSSION

Results from Bartlett's test revealed that error variance was homogeneous for days to 50% pollen shed, days to 50% silking, days to 75% brown husk, ear circumference, 1000-grain weight and grain yield therefore, pooled analysis was carried out for these characters only. The results of Bartlett's test are comparable with the findings of Kumar *et al.*, (2017) . The standard heterosis was estimated over the best check Palam Sankar Makka-2 in E1, whereas, Bio-9544 in E2 and pooled over environment. The range of mid, better and standard parent for 12 traits are presented in Table 2.

For days to 50% pollen shed, 16 crosses over Palam Sankar Makka-2 in E1, whereas, 24 crosses and 25 crosses over Bio-9544 in E2 and pooled over environment, repectively had significant negative standard heterosis. 28 crosses in E1, 26 crosses in E2 and 27 crosses in pooled over environment had significant negative relative heterosis. All the crosses (28) in E1 and in pooled over environment, whereas, 27 crosses in E2 had significant negative heterobeltiosis. For days to 50% silking, 20 crosses in E1, 24 crosses in E2, whereas, 26 crosses in pooled over environment had significant negative standard heterosis. All the crosses (28) in E1, 26 crosses in E2 and 27 crosses in pooled over environment had significant negative relative heterosis. All the crosses (28) in E1, whereas, 27 crosses in E2 and in pooled over environment had significant negative heterobeltiosis (Table 3).

Among 28 crosses, 4 crosses in E1, 20 crosses in E2 and 12 crosses in pooled over environment had significant negative relative heterosis for days to 75 per cent brown husk. 12 crosses in E1, 25 crosses in E2 and 21 crosses in pooled over environment had significant negative heterobeltiosis. 7 crosses in E1, 25 crosses in E2 and 13 crosses in pooled over environment had significant negative standard heterosis (Table 4). Hence, these hybrids can be utilized in rainfed conditions to avoid drought stress.

Best crosses with maximum MPH (%) were, $P_1 \times P_5$ for days to 50% pollen shed and days to 50% silking, $P_3 \times P_8$ for days to 75% brown husk, $P_3 \times P_5$ for plant height and ear height, $P_2 \times P_4$ for number of kernel rows per ear, $P_4 \times P_6$ for 1000-grain weight and $P_1 \times P_4$ for number of kernels per row, ear length, ear circumference and grain yield in E1; $P_1 \times P_5$ for days to

50% pollen shed and days to 50% silking, $P_2 \times P_3$ for days to 75% brown husk, $P_4 \times P_5$ for plant height and number of kernels per row, $P_3 \times P_5$ for ear height, $P_1 \times P_6$ for number of kernel rows per ear and 1000-grain weight, $P_5 \times P_6$ ear length, $P_4 \times P_6$ for ear circumference, $P_2 \times P_5$ for shelling (%) and $P_1 \times P_3$ for grain yield in E2 and $P_1 \times P_5$ for days to 50% pollen shed and days to 50% silking, $P_5 \times P_6$ for days to 75% brown husk, $P_1 \times P_6$ for 1000-grain weight and $P_1 \times P_4$ for ear circumference and grain yield in pooled analysis (Table 5-8).

Among BPH (%), the most promising crosses were $P_1 \times P_8$ for days to 50% pollen shed and days to 75% brown husk, $P_1 \times P_5$ for days to 50% silking, $P_3 \times P_5$ for plant height and ear height, $P_2 \times P_4$ for number of kernel rows per ear, $P_3 \times P_5$ for 1000-grain weight and $P_1 \times P_4$ for number of kernels per row, ear length, ear circumference and grain yield in E1; $P_1 \times P_5$ for days to 50% pollen shed and days to 50% silking, $P_1 \times P_3$ for days to 75% brown husk, $P_3 \times P_5$ for plant height and ear height, $P_1 \times P_6$ for number of kernel rows per ear and 1000-grain weight, $P_3 \times P_6$ for number of kernels per row, $P_4 \times P_5$ ear length, $P_4 \times P_6$ for ear circumference, $P_2 \times P_5$ for shelling (%) and $P_1 \times P_3$ for grain yield in E2 and $P_1 \times P_5$ for days to 50% pollen shed and days to 50% silking, $P_1 \times P_3$ for days to 75% brown husk and grain yield, $P_4 \times P_5$ for ear circumference and $P_1 \times P_6$ for 1000-grain weight in pooled analysis (Table 5-8).

$P_1 \times P_5$ for days to 50% pollen shed and days to 50% silking, $P_1 \times P_6$ for days to 75% brown husk, $P_1 \times P_7$ for plant height and ear height, $P_1 \times P_4$ for number of kernel rows per ear, ear circumference and grain yield, $P_4 \times P_8$ for 1000-grain weight and in E1; $P_1 \times P_5$ for days to 50% pollen shed and days to 50% silking, $P_6 \times P_7$ for days to 75% brown husk, $P_2 \times P_4$ for number of kernel rows per ear, ear circumference and 1000-grain weight, $P_4 \times P_5$ for number of kernels per row, ear length, $P_2 \times P_5$ for shelling (%) and $P_2 \times P_4$ for grain yield in E2 and $P_1 \times P_5$ for days to 50% pollen shed and days to 50% silking, $P_5 \times P_6$ for days to 75% brown husk, $P_2 \times P_4$ for ear circumference, $P_4 \times P_8$ for 1000-grain weight and $P_1 \times P_4$ for grain yield in pooled analysis were most promising crosses for SH (%) (Table 5-8). These results are in agreement with those of Netaji *et al*., (2000); Malik *et al.,* (2004); Sharma *et al.,* (2017); Kumar *et al.,* (2019); Patel *et al.,* (2019); Chandel *et al.,* (2020).

The crosses, $P_1 \times P_4$ (16.05), $P_2 \times P_4$ (13.40), $P_4 \times P_6$ (11.57) and $P_3 \times P_6$ (8.54) in E1, $P_2 \times P_4$ (13.14), $P_1 \times P_4$ (12.65), $P_1 \times P_3$ (7.08) in E2 and $P_1 \times P_4$ (16.15), $P_2 \times P_4$ (15.45) in pooled over environment, showed significant positive heterosis over check hybrid Palam Sankar Makka-2 in E1, Bio-9544 in E2 and pooled over environment, respectively. Two hybrids *viz.*, $P_1 \times P_4$ and $P_2 \times P_4$ were found to be early and had significant standard heterosis (%) for number of kernel rows per ear, ear circumference and grain yield in individual as well as over the environments. These crosses were identified as most promising and require further testing for its superiority and stability across the locations over years for enhancing the yield of maize in the North-Western Himalayas.

Table 2: Range of heterosis for 12 yield and yield related traits in maize.

Characters	Mid parent heterosis			Better parent heterosis			Standard heterosis		
	E1	E2	P	E1	E2	P	E1	E2	P
Days to 50% pollen shed	-12.65 to -3.17	-20.62 to -0.39	-16.73 to -1.96	-13.18 to -5.43	-20.93 to -2.29	-17.06 to -1.96	-9.32 to 3.39	-19.69 to 0.79	-16.40 to 0.00
Days to 50% silking	-13.62 to -3.37	-21.77 to -1.12	-17.80 to -2.25	-15.27 to -4.44	-22.06 to -2.22	-18.42 to -3.33	-11.20 to 3.20	-19.08 to 0.76	-16.86 to 0.00
Days to 75% brown husk	-3.24 to 2.06	-4.62 to 1.31	-2.96 to 0.90	-4.48 to 1.54	-5.61 to 1.05	-4.55 to 0.26	-2.54 to 1.52	-5.15 to -0.52	-3.58 to 0.26
Plant height (cm)	24.3 to 86.97	24.53 to 75.96	-	7.52 to 75.54	3.92 to 69.50	-	-5.80 to 14.73	-32.38 to 2.44	-
Ear height (cm)	24.62 to 90.55	24.45 to 81.82	-	7.28 to 83.33	2.70 to 79.08	-	-6.22 to 14.67	-31.01 to 4.94	-
Number of kernel rows per ear	14.17 to 117.14	-9.36 to 40.89	-	5.38 to 68.89	-14.79 to 38.1	-	-10.0 to 18.57	-14.79 to 23.94	-
Number of kernels per row	69.11 to 395.65	2.39 to 78.41	-	56.0 to 276.42	-2.48 to 67.81	-	-19.51 to 9.62	-35.34 to 20.0	-
Ear length (cm)	44.12 to 190.95	-9.98 to 53.66	-	38.67 to 167.55	-16.09 to 49.25	-	-16.23 to 10.90	-19.09 to 29.45	-
Ear circumference (cm)	18.44 to 87.27	-15.38 to 31.73	5.82 to 50.61	15.22 to 65.78	-20.62 to 29.74	3.46 to 42.36	-11.11 to 11.83	-6.85 to 29.44	-7.25 to 18.36
1000-grain weight (g)	-4.08 to 76.38	-14.88 to 85.91	2.09 to 70.45	-19.88 to 59.17	-19.68 to 77.38	-7.23 to 57.32	-17.30 to 35.01	0.45 to 50.34	-0.64 to 36.41
Shelling (%)	-14.22 to 3.64	-5.61 to 11.46	-	-15.49 to 2.37	-6.57 to 8.34	-	-14.09 to 2.89	-3.86 to 7.12	-
Grain Yield (q/ha)	204.56 to 1485.20	172.49 to 687.58	183.82 to 865.89	96.16 to 1419.08	156.08 to 647.23	129.50 to 835.52	-52.34 to 16.05	53.12 to 13.14	-51.91 to 16.15

Table 3: Estimation of heterosis (%) over mid, better and check parent across the environments and pooled over environment for days to 50% pollen shed and days to 50% silking.

Cross	Days to 50% pollen shed									Days to 50% silking								
	E1			E2			Pooled			E1			E2			Pooled		
	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)
$P_1 \times P_2$	-6.50 **	-7.26 **	-2.54	-13.39 **	-14.06 **	-13.39 **	-10.00 **	-10.00 **	-10.00 **	-5.43 **	-7.58 **	-2.40	-14.93 **	-16.18 **	-12.98 **	-10.27**	-10.61 **	-9.58 **
$P_1 \times P_3$	-11.48 **	-11.48 **	-8.47 **	-19.53 **	-19.53 **	-18.90 **	-15.60 **	-15.60 **	-15.60 **	-9.02 **	-10.08 **	-7.20 **	-20.74 **	-21.32 **	-18.32 **	-15.05 **	-15.21 **	-14.56 **
$P_1 \times P_4$	-10.48 **	-11.90 **	-5.93 **	-17.69 **	-18.94 **	-15.75 **	-14.17 **	-15.50 **	-12.80 **	-10.77 **	-13.43 **	-7.20 **	-18.38 **	-18.38 **	-15.27 **	-14.66 **	-15.93 **	-13.03 **
$P_1 \times P_5$	-12.65 **	-13.01 **	-9.32 **	-20.62 **	-20.93 **	-19.69 **	-16.73 **	-17.06 **	-16.40 **	-13.62 **	-15.27 **	-11.20 **	-21.77 **	-22.06 **	-19.08 **	-17.80 **	-18.42 **	-16.86 **
$P_1 \times P_6$	-10.46 **	-12.30 **	-9.32 **	-15.75 **	-16.41 **	-15.75 **	-13.18 **	-14.40 **	-14.40 **	-10.76 **	-11.11 **	-10.40 **	-16.85 **	-18.38 **	-15.27 **	-13.90 **	-14.89 **	-14.56 **
$P_1 \times P_7$	-9.39 **	-9.76 **	-5.93 **	-11.72 **	-11.72 **	-11.02 **	-10.58 **	-10.76 **	-10.40 **	-9.73 **	-11.45 **	-7.20 **	-12.69 **	-13.97 **	-10.69 **	-11.24 **	-11.41 **	-10.73 **
$P_1 \times P_8$	-10.76 **	-13.18 **	-5.08 *	-11.97 **	-12.98 **	-10.24 **	-11.37 **	-13.08 **	-9.60 **	-9.58 **	-12.59 **	-5.60 **	-12.92 **	-13.24 **	-9.92 **	-11.28 **	-12.59 **	-9.58 **
$P_2 \times P_3$	-8.94 **	-9.68 **	-5.08 *	-9.45 **	-10.16 **	-9.45 **	-9.20 **	-9.20 **	-9.20 **	-11.11 **	-12.12 **	-7.20 **	-10.53 **	-11.19 **	-9.16 **	-10.82 **	-10.98 **	-9.96 **
$P_2 \times P_4$	-8.80 **	-9.52 **	-3.39	-14.73 **	-16.67 **	-13.39 **	-11.81 **	-13.18 **	-10.40 **	-9.02 **	-9.70 **	-3.20	-14.93 **	-16.18 **	-12.98 **	-11.99 **	-12.96 **	-9.96 **
$P_2 \times P_5$	-6.88 **	-7.26 **	-2.54	-13.73 **	-14.73 **	-13.39 **	-10.36 **	-10.71 **	-10.00 **	-10.27 **	-10.61 **	-5.60 **	-14.61 **	-15.56 **	-12.98 **	-12.45 **	-12.78 **	-11.11 **
$P_2 \times P_6$	-7.05 **	-9.68 **	-5.08 *	-13.49 **	-13.49 **	-14.17 **	-10.34 **	-11.60 **	-11.60 **	-8.95 **	-11.36 **	-6.40 **	-13.31 **	-13.64 **	-12.98 **	-11.15 **	-12.50 **	-11.49 **
$P_2 \times P_7$	-6.07 **	-6.45 **	-1.69	-9.45 **	-10.16 **	-9.45 **	-7.78 **	-7.97 **	-7.60 **	-6.46 **	-6.82 **	-1.60	-9.85 **	-9.85 **	-9.16 **	-8.16 **	-8.33 **	-7.28 **
$P_2 \times P_8$	-3.56 *	-5.43 **	3.39	-0.39	-2.29	0.79	-1.96	-3.85 *	0.00	-3.37 *	-4.44 *	3.20	-1.12	-2.22	0.76	-2.25	-3.33	0.00
$P_3 \times P_4$	-8.06 **	-9.52 **	-3.39	-7.69 **	-9.09 **	-5.51 **	-7.87 **	-9.30 **	-6.40 **	-9.51 **	-11.19 **	-4.80 *	-8.15 **	-8.82 **	-5.34 **	-8.82 **	-10.00 **	-6.90 **
$P_3 \times P_5$	-9.39 **	-9.76 **	-5.93 **	-12.84 **	-13.18 **	-11.81 **	-11.16 **	-11.51 **	-10.80 **	-11.54 **	-12.21 **	-8.00 **	-13.75 **	-14.07 **	-11.45 **	-12.67 **	-13.16 **	-11.49 **
$P_3 \times P_6$	-7.11 **	-9.02 **	-5.93 **	-6.30 **	-7.03 **	-6.30 **	-6.69 **	-8.00 **	-8.00 **	-9.45 **	-10.85 **	-8.00 **	-5.66 **	-6.72 **	-4.58 *	-7.51 **	-8.75 **	-8.05 **
$P_3 \times P_7$	-7.76 **	-8.13 **	-4.24 *	-8.59 **	-8.59 **	-7.87 **	-8.18 **	-8.37 **	-8.00 **	-10.00 **	-10.69 **	-6.40 **	-9.02 **	-9.70 **	-7.63 **	-9.51 **	-9.51 **	-8.81 **
$P_3 \times P_8$	-5.18 **	-7.75 **	0.85	-3.47 *	-4.58 **	-1.57	-4.31 **	-6.15 **	-2.40	-7.58 **	-9.63 **	-2.40	-4.09 *	-4.44 *	-1.53	-5.82 **	-7.04 **	-3.83 *
$P_4 \times P_5$	-9.24 **	-10.32 **	-4.24 *	-15.71 **	-16.67 **	-13.39 **	-12.55 **	-13.57 **	-10.80 **	-13.21 **	-14.18 **	-8.00 **	-15.87 **	-16.18 **	-12.98 **	-14.55 **	-15.19 **	-12.26 **
$P_4 \times P_6$	-9.47 **	-12.70 **	-6.78 **	-14.73 **	-16.67 **	-13.39 **	-12.18 **	-14.73 **	-12.00 **	-11.97 **	-14.93 **	-8.80 **	-14.61 **	-16.18 **	-12.98 **	-13.31 **	-15.56 **	-12.64 **
$P_4 \times P_7$	-6.83 **	-7.94 **	-1.69	-7.69 **	-9.09 **	-5.51 **	-7.27 **	-8.53 **	-5.60 **	-7.92 **	-8.96 **	-2.40	-7.46 **	-8.82 **	-5.34 **	-7.69 **	-8.89 **	-5.75 **
$P_4 \times P_8$	-7.45 **	-8.53 **	0.00	-6.46 **	-6.82 **	-3.15	-6.95 **	-7.31 **	-3.60 *	-10.04 **	-10.37 **	-3.20	-5.54 **	-5.88 **	-2.29	-7.78 **	-7.78 **	-4.60 **
$P_5 \times P_6$	-8.33 **	-10.57 **	-6.78 **	-12.16 **	-13.18 **	-11.81 **	-10.30 **	-11.90 **	-11.20 **	-10.94 **	-12.98 **	-8.80 **	-12.78 **	-14.07 **	-11.45 **	-11.88 **	-13.53 **	-11.88 **
$P_5 \times P_7$	-7.32 **	-7.32 **	-3.39	-14.40 **	-14.73 **	-13.39 **	-10.93 **	-11.11 **	-10.40 **	-9.16 **	-9.16 **	-4.80 *	-14.61 **	-15.56 **	-12.98 **	-11.91 **	-12.41 **	-10.73 **
$P_5 \times P_8$	-7.94 **	-10.08 **	-1.69	-12.31 **	-12.98 **	-10.24 **	-10.16 **	-11.54 **	-8.00 **	-10.53 **	-11.85 **	-4.80 *	-12.59 **	-12.59 **	-9.92 **	-11.57 **	-12.22 **	-9.20 **
$P_6 \times P_7$	-7.50 **	-9.76 **	-5.93 **	-11.81 **	-12.50 **	-11.81 **	-9.72 **	-11.16 **	-10.80 **	-9.38 **	-11.45 **	-7.20 **	-11.79 **	-12.12 **	-11.45 **	-10.60 **	-11.79 **	-11.11 **
$P_6 \times P_8$	-8.13 **	-12.40 **	-4.24 *	-9.73 **	-11.45 **	-8.66 **	-8.95 **	-11.92 **	-8.40 **	-8.46 **	-11.85 **	-4.80 *	-9.77 **	-11.11 **	-8.40 **	-9.13 **	-11.48 **	-8.43 **
$P_7 \times P_8$	-3.17 *	-5.43 **	3.39	-2.70	-3.82 *	-0.79	-2.94 *	-4.62 **	-0.80	-3.76 *	-5.19 **	2.40	-2.62	-3.70 *	-0.76	-3.19 *	-4.44 *	-1.15

E1 = Kangra, E2 = Bajaura, P = Pooled
*, ** Significant at 5% and 1% probability level, respectively

Table 4: Estimation of heterosis (%) over mid, better and check parent across the environments and pooled over environment for days to 75% brown husk and plant height (cm).

Cross	Days to 75% brown husk									Plant height (cm)								
	E1			E2			Pooled			E1			E2			Pooled		
	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)
$P_1 \times P_2$	0.00	0.00	-2.03 *	-2.62 **	-4.12 **	-4.12 **	-1.30	-2.07 *	-3.07 **	32.28 **	11.89 **	2.90	32.05 **	13.62 **	-26.22 **	-	-	-
$P_1 \times P_3$	-1.78 *	-3.50 **	-2.03 *	-3.65 **	-5.61 **	-4.64 **	-2.70 **	-4.55 **	-3.32 **	35.06 **	7.52 **	-1.12	49.41 **	26.59 **	-17.80 **	-	-	-
$P_1 \times P_4$	0.00	-1.99 *	0.00	-1.04	-3.06 **	-2.06 *	-0.51	-2.52 **	-1.02	44.87 **	19.90 **	10.27 **	48.82 **	31.83 **	-14.40 **	-	-	-
$P_1 \times P_5$	-0.77	-1.53	-2.03 *	-2.37 *	-3.14 **	-4.64 **	-1.56 *	-2.33 **	-3.32 **	31.01 **	9.71 **	0.89	50.91 **	27.69 **	-17.08 **	-	-	-
$P_1 \times P_6$	-1.29	-2.04 *	-2.54 **	-2.62 **	-4.12 **	-4.12 **	-1.95 **	-3.08 **	-3.32 **	31.45 **	13.11 **	4.02	35.54 **	21.07 **	-21.38 **	-	-	-
$P_1 \times P_7$	1.03	0.51	-0.51	0.53	0.00	-2.06 *	0.78	0.26	-1.28	28.50 **	24.76 **	14.73 **	27.59 **	20.41 **	-11.89 **	-	-	-
$P_1 \times P_8$	-2.54 **	-4.48 **	-2.54 **	-1.32	-2.09 *	-3.61 **	-1.94 **	-3.32 **	-3.07 **	24.30 **	17.96 **	8.48 **	24.53 **	14.29 **	-11.17 **	-	-	-
$P_2 \times P_3$	-1.27	-3.00 **	-1.52	-4.62 **	-5.10 **	-4.12 **	-2.94 **	-4.04 **	-2.81 **	67.86 **	55.79 **	-0.89	59.39 **	56.47 **	-26.76 **	-	-	-
$P_2 \times P_4$	0.51	-1.49	0.51	-2.56 **	-3.06 **	-2.06 *	-1.02	-2.27 **	-0.77	65.41 **	61.05 **	2.46	62.75 **	57.40 **	-21.13 **	-	-	-
$P_2 \times P_5$	0.77	0.00	-0.51	-2.34 *	-3.09 **	-3.09 **	-0.78	-0.78	-1.79 *	71.23 **	69.12 **	7.59 **	61.98 **	58.76 **	-25.68 **	-	-	-
$P_2 \times P_6$	-0.77	-1.53	-2.03 *	-3.09 **	-3.09 **	-3.09 **	-1.93 **	-2.31 **	-2.56 **	45.02 **	42.09 **	-5.80 **	38.16 **	32.40 **	-32.38 **	-	-	-
$P_2 \times P_7$	2.06 *	1.54	0.51	-1.56	-2.58 *	-2.58 *	0.26	0.00	-1.02	39.08 **	20.62 **	4.46 *	29.07 **	5.82	-22.56 **	-	-	-
$P_2 \times P_8$	0.00	-1.99 *	0.00	-1.30	-2.06 *	-2.06 *	-0.64	-1.28	-1.02	53.59 **	35.95 **	12.28 **	64.51 **	31.80 **	2.44	-	-	-
$P_3 \times P_4$	-0.25	-0.50	1.52	-2.04 *	-2.04 *	-1.03	-1.13	-1.26	0.26	68.09 **	60.00 **	-3.57	54.70 **	46.96 **	-26.36 **	-	-	-
$P_3 \times P_5$	-0.51	-1.50	0.00	-2.33 *	-3.57 **	-2.58 *	-1.40 *	-2.53 **	-1.28	86.97 **	75.54 **	8.93 **	69.77 **	69.50 **	-23.57 **	-	-	-
$P_3 \times P_6$	0.51	-0.50	1.02	-2.56 **	-3.06 **	-2.06 *	-1.02	-1.77 *	-0.51	59.33 **	45.12 **	-3.79	62.23 **	52.73 **	-21.99 **	-	-	-
$P_3 \times P_7$	0.25	-1.00	0.51	-2.59 **	-4.08 **	-3.09 **	-1.15	-2.53 **	-1.28	47.15 **	19.85 **	3.79	39.61 **	12.82 **	-17.44 **	-	-	-
$P_3 \times P_8$	-3.24 **	-3.48 **	-1.52	-2.33 *	-3.57 **	-2.58 *	-2.79 **	-3.28 **	-2.05 *	60.26 **	32.97 **	9.82 **	51.94 **	20.05 **	-6.70 *	-	-	-
$P_4 \times P_5$	-0.76	-1.99 *	0.00	-2.84 **	-4.08 **	-3.09 **	-1.79 **	-3.02 **	-1.53	66.42 **	64.03 **	1.79	75.96 **	66.90 **	-16.37 **	-	-	-
$P_4 \times P_6$	0.25	-1.00	1.02	-2.56 **	-3.06 **	-2.06 *	-1.14	-2.02 *	-0.51	58.73 **	51.52 **	0.45	47.96 **	46.56 **	-25.14 **	-	-	-
$P_4 \times P_7$	-0.51	-1.99 *	0.00	-1.04	-2.55 *	-1.55	-0.77	-2.27 **	-0.77	41.03 **	19.59 **	3.57	38.29 **	16.50 **	-14.76 **	-	-	-
$P_4 \times P_8$	-0.50	-0.50	1.52	-1.81 *	-3.06 **	-2.06 *	-1.14	-1.76 *	-0.26	55.63 **	34.59 **	11.16 **	33.93 **	10.14 *	-14.40 **	-	-	-
$P_5 \times P_6$	-2.04 *	-2.04 *	-2.54 **	-3.90 **	-4.64 **	-4.64 **	-2.96 **	-3.33 **	-3.58 **	51.30 **	46.46 **	-2.90	47.03 **	38.22 **	-29.41 **	-	-	-
$P_5 \times P_7$	1.28	1.02	0.51	-1.31	-1.57	-3.09 **	0.00	-0.26	-1.28	42.04 **	21.91 **	5.58 **	39.48 **	12.58 **	-17.62 **	-	-	-
$P_5 \times P_8$	-0.76	-1.99 *	0.00	-2.09 *	-2.09 *	-3.61 **	-1.41 *	-2.04 *	-1.79 *	51.85 **	32.97 **	9.82 **	54.16 **	21.66 **	-5.44	-	-	-
$P_6 \times P_7$	1.79 *	1.53	1.02	-4.17 **	-5.15 **	-5.15 **	-1.16	-1.79 *	-2.05 *	31.39 **	15.98 **	0.45	53.82 **	30.59 **	-4.44	-	-	-
$P_6 \times P_8$	-1.26	-2.49 **	-0.51	-2.34 *	-3.09 **	-3.09 **	-1.79 **	-2.04 *	-1.79 *	40.63 **	26.76 **	4.69 *	25.42 **	3.92	-19.23 **	-	-	-
$P_7 \times P_8$	0.51	-1.00	1.02	1.31	1.05	-0.52	0.90	0.00	0.26	31.66 **	28.61 **	11.38 **	28.84 **	25.07 **	-2.79	-	-	-

E1 = Kangra, E2 = Bajaura
*, ** Significant at 5% and 1% probability level, respectively
- Not calculated (Bartlett's Test)

Table 5: Estimation of heterosis (%) over mid, better and check parent across the environments for ear height (cm) and number of kernel rows per ear.

Cross	Ear height (cm)									Number of kernel rows per ear								
	E1			E2			Pooled			E1			E2			Pooled		
	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)
$P_1 \times P_2$	32.37 **	11.17 **	1.78	29.14 **	9.94	-27.74 **	-	-	-	56.00 **	41.82 **	11.43	27.76 **	18.31 **	18.31 **	-	-	-
$P_1 \times P_3$	34.76 **	7.28 **	-1.78	50.96 **	26.52 **	-16.85 **	-	-	-	54.00 **	40.00 **	10.00	20.31 **	14.07 **	8.45 **	-	-	-
$P_1 \times P_4$	44.97 **	18.93 **	8.89 **	53.56 **	34.81 **	-11.40 **	-	-	-	107.50 **	50.91 **	18.57 *	25.98 **	20.30 **	12.68 **	-	-	-
$P_1 \times P_5$	31.36 **	7.77 **	-1.33	48.44 **	25.97 **	-17.21 **	-	-	-	27.27 **	27.27 **	0.00	16.05 **	15.57 **	-0.70	-	-	-
$P_1 \times P_6$	33.33 **	13.59 **	4.00	37.68 **	23.76 **	-18.66 **	-	-	-	18.33 *	9.23	1.43	40.89 **	38.10 **	22.54 **	-	-	-
$P_1 \times P_7$	29.00 **	25.24 **	14.67 **	29.03 **	21.93 **	-9.95 *	-	-	-	32.73 **	32.73 **	4.29	13.94 **	10.00 **	0.70	-	-	-
$P_1 \times P_8$	24.62 **	17.96 **	8.00 **	27.05 **	15.32 **	-7.04	-	-	-	42.57 **	30.91 **	2.86	5.69	4.00	-8.45 **	-	-	-
$P_2 \times P_3$	69.47 **	58.57 **	-1.33	61.86 **	58.81 **	-26.65 **	-	-	-	64.44 **	64.44 **	5.71	8.30 **	5.63	5.63	-	-	-
$P_2 \times P_4$	69.12 **	64.29 **	2.22	60.61 **	54.97 **	-23.02 **	-	-	-	117.14 **	68.89 **	8.57	28.00 **	23.94 **	23.94 **	-	-	-
$P_2 \times P_5$	77.21 **	72.14 **	7.11 **	63.38 **	62.74 **	-24.84 **	-	-	-	44.00 **	30.91 **	2.86	16.67 **	8.45 **	8.45 **	-	-	-
$P_2 \times P_6$	48.07 **	45.52 **	-6.22 **	39.91 **	31.58 **	-31.01 **	-	-	-	40.00 **	18.46 *	10.00	23.88 **	16.90 **	16.90 **	-	-	-
$P_2 \times P_7$	40.72 **	21.13 **	4.44	28.25 **	4.23	-23.02 **	-	-	-	54.00 **	40.00 **	10.00	11.76 **	7.04 *	7.04 *	-	-	-
$P_2 \times P_8$	56.79 **	38.04 **	12.89 **	65.52 **	30.18 **	4.94	-	-	-	42.86 **	41.30 **	-7.14	-9.36 **	-14.79 **	-14.79 **	-	-	-
$P_3 \times P_4$	70.87 **	64.39 **	-3.56	60.49 **	52.05 **	-24.47 **	-	-	-	94.29 **	51.11 **	-2.86	0.75	0.00	-4.93	-	-	-
$P_3 \times P_5$	90.55 **	83.33 **	7.56 **	81.82 **	79.08 **	-17.94 **	-	-	-	50.00 **	36.36 **	7.14	1.17	-3.70	-8.45 **	-	-	-
$P_3 \times P_6$	60.30 **	47.59 **	-4.89 *	65.67 **	53.05 **	-19.75 **	-	-	-	40.00 **	18.46 *	10.00	24.14 **	20.00 **	14.08 **	-	-	-
$P_3 \times P_7$	46.84 **	19.59 **	3.11	45.49 **	16.52 **	-13.94 **	-	-	-	42.00 **	29.09 **	1.43	4.91	2.96	-2.11	-	-	-
$P_3 \times P_8$	61.44 **	34.24 **	9.78 **	53.31 **	18.92 **	-4.14	-	-	-	47.25 **	45.65 **	-4.29	9.23 **	5.19	0.00	-	-	-
$P_4 \times P_5$	74.24 **	74.24 **	2.22	80.99 **	73.98 **	-13.58 **	-	-	-	70.00 **	23.64 *	-2.86	23.14 **	18.05 **	10.56 **	-	-	-
$P_4 \times P_6$	63.90 **	56.55 **	0.89	52.20 **	48.20 **	-22.29 **	-	-	-	68.89 **	16.92	8.57	21.62 **	18.42 **	10.92 **	-	-	-
$P_4 \times P_7$	43.56 **	20.62 **	4.00	38.74 **	16.03 **	-14.31 **	-	-	-	75.00 **	27.27 **	0.00	9.51 **	8.27 *	1.41	-	-	-
$P_4 \times P_8$	58.23 **	35.87 **	11.11 **	39.91 **	13.06 **	-8.86 *	-	-	-	97.18 **	52.17 **	0.00	0.78	-2.26	-8.45 **	-	-	-
$P_5 \times P_6$	59.57 **	52.41 **	-1.78	44.86 **	35.73 **	-28.83 **	-	-	-	14.17	5.38	-2.14	14.52 **	12.70 **	0.00	-	-	-
$P_5 \times P_7$	43.56 **	20.62 **	4.00	42.96 **	15.83 **	-14.45 **	-	-	-	21.82 *	21.82 *	-4.29	14.29 **	10.77 **	1.41	-	-	-
$P_5 \times P_8$	56.96 **	34.78 **	10.22 **	48.77 **	16.67 **	-5.95	-	-	-	24.75 *	14.55	-10.00	-1.21	-2.40	-14.08 **	-	-	-
$P_6 \times P_7$	34.51 **	17.53 **	1.33	55.26 **	32.74 **	-1.96	-	-	-	18.33 *	9.23	1.43	22.66 **	20.77 **	10.56 **	-	-	-
$P_6 \times P_8$	43.47 **	28.26 **	4.89 *	24.45 **	2.70	-17.21 **	-	-	-	29.73 **	10.77	2.86	19.52 **	19.05 **	5.63	-	-	-
$P_7 \times P_8$	32.28 **	28.87 **	11.11 **	26.94 **	21.62 **	-1.96	-	-	-	28.71 **	18.18	-7.14	1.96	0.00	-8.45 **	-	-	-

E1 = Kangra, E2 = Bajaura
*, ** Significant at 5% and 1% probability level, respectively
- Not calculated (Bartlett's Test)

Table 6: Estimation of heterosis (%) over mid, better and check parent across the environments for number of kernels per row and ear length (cm).

Cross	Number of kernels per row									Ear Length (cm)								
	E1			E2			Pooled			E1			E2			Pooled		
	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)
$P_1 \times P_2$	168.19 **	160.44 **	-19.51 *	25.68 **	15.77 **	-17.53 **	-	-	-	74.12 **	50.25 **	-14.20	14.56 **	9.12	-3.24	-	-	-
$P_1 \times P_3$	175.00 **	134.67 **	-3.30	54.97 **	46.92 **	4.66	-	-	-	115.23 **	104.40 **	-5.80	42.22 **	41.94 **	13.92 **	-	-	-
$P_1 \times P_4$	395.65 **	276.42 **	9.62	69.58 **	56.54 **	11.51 **	-	-	-	190.95 **	167.55 **	10.90	49.61 **	44.03 **	24.92 **	-	-	-
$P_1 \times P_5$	248.79 **	240.57 **	-0.82	31.83 **	29.15 **	-4.11	-	-	-	128.66 **	114.02 **	1.74	42.07 **	38.02 **	17.48 **	-	-	-
$P_1 \times P_6$	130.07 **	76.00 **	-3.30	43.79 **	35.77 **	-3.29	-	-	-	81.92 **	52.61 **	-6.67	35.85 **	30.65 **	4.85	-	-	-
$P_1 \times P_7$	156.73 **	108.88 **	-3.02	49.03 **	32.69 **	-5.48	-	-	-	85.33 **	51.56 **	-1.16	42.58 **	38.26 **	18.12 **	-	-	-
$P_1 \times P_8$	191.07 **	176.27 **	-10.44	36.25 **	31.54 **	-6.30	-	-	-	103.10 **	82.22 **	-4.93	34.16 **	19.56 **	22.65 **	-	-	-
$P_2 \times P_3$	161.33 **	128.67 **	-5.77	44.25 **	39.91 **	-10.68 **	-	-	-	74.16 **	57.36 **	-10.14	21.69 **	15.69 **	2.59	-	-	-
$P_2 \times P_4$	254.63 **	164.00 **	-18.41 *	35.31 **	35.00 **	-18.63 **	-	-	-	96.97 **	58.48 **	-9.51	18.82 **	17.52 **	4.21	-	-	-
$P_2 \times P_5$	186.65 **	172.00 **	-15.93 *	44.49 **	30.63 **	-3.01	-	-	-	60.11 **	46.70 **	-16.23	30.73 **	28.10 **	13.59 **	-	-	-
$P_2 \times P_6$	102.24 **	58.00 **	-13.19	6.67	3.90	-34.25 **	-	-	-	44.12 **	39.34 **	-14.78	4.17	-4.38	-15.21 **	-	-	-
$P_2 \times P_7$	137.30 **	97.63 **	-8.24	17.54 **	13.24 *	-32.05 **	-	-	-	60.19 **	50.22 **	-2.03	17.10 **	14.96 **	1.94	-	-	-
$P_2 \times P_8$	181.13 **	174.58 **	-10.99	2.39	-2.48	-35.34 **	-	-	-	85.68 **	77.66 **	1.45	-9.98 *	-16.09 **	-13.92 **	-	-	-
$P_3 \times P_4$	235.61 **	129.33 **	-5.49	50.99 **	46.78 **	-6.30	-	-	-	133.55 **	104.91 **	-5.57	30.87 **	25.75 **	9.06	-	-	-
$P_3 \times P_5$	190.04 **	142.67 **	0.00	30.95 **	21.77 **	-9.59 *	-	-	-	117.96 **	114.63 **	2.03	24.31 **	20.53 **	2.59	-	-	-
$P_3 \times P_6$	117.71 **	90.50 **	4.67	68.53 **	67.81 **	7.12	-	-	-	87.24 **	64.17 **	0.41	49.58 **	44.13 **	15.21 **	-	-	-
$P_3 \times P_7$	97.49 **	86.39 **	-13.46	50.92 **	41.20 **	-9.86 *	-	-	-	62.50 **	38.67 **	-9.57	20.55 **	16.67 **	-0.32	-	-	-
$P_3 \times P_8$	147.76 **	121.33 **	-8.79	56.21 **	53.31 **	1.64	-	-	-	120.41 **	107.56 **	8.29	12.06 *	-0.32	2.27	-	-	-
$P_4 \times P_5$	342.31 **	241.58 **	-5.22	78.41 **	61.62 **	20.00 **	-	-	-	141.97 **	109.51 **	-0.41	50.66 **	49.25 **	29.45 **	-	-	-
$P_4 \times P_6$	177.65 **	77.00 **	-2.75	63.19 **	59.31 **	0.82	-	-	-	110.51 **	65.12 **	0.99	30.38 **	20.90 **	4.85	-	-	-
$P_4 \times P_7$	183.93 **	88.17 **	-12.64	23.88 **	19.09 **	-28.22 **	-	-	-	102.09 **	54.93 **	1.04	-6.02	-6.72	-19.09 **	-	-	-
$P_4 \times P_8$	275.72 **	175.42 **	-10.71	55.41 **	48.35 **	-1.64	-	-	-	151.20 **	109.33 **	9.22	20.00 **	10.73 *	13.59 **	-	-	-
$P_5 \times P_6$	107.97 **	56.50 **	-14.01	49.80 **	38.75 **	3.01	-	-	-	71.63 **	52.51 **	-6.72	53.66 **	43.73 **	22.33 **	-	-	-
$P_5 \times P_7$	138.52 **	90.53 **	-11.54	40.93 **	23.25 **	-8.49 *	-	-	-	65.55 **	43.11 **	-6.67	36.62 **	36.36 **	16.50 **	-	-	-
$P_5 \times P_8$	176.71 **	156.78 **	-16.76 *	18.52 **	12.18 *	-16.71 **	-	-	-	93.72 **	85.11 **	-3.42	13.45 **	3.79	6.47	-	-	-
$P_6 \times P_7$	69.11 **	56.00 **	-14.29	58.06 **	48.48 **	-6.03	-	-	-	52.29 **	47.56 **	-3.77	36.31 **	27.27 **	8.74	-	-	-
$P_6 \times P_8$	101.89 **	60.50 **	-11.81	46.72 **	43.39 **	-4.93	-	-	-	70.33 **	57.82 **	-3.48	39.93 **	20.50 **	23.62 **	-	-	-
$P_7 \times P_8$	107.67 **	76.33 **	-18.13 *	50.11 **	38.02 **	-8.49 *	-	-	-	68.40 **	51.56 **	-1.16	25.99 **	15.46 **	18.45 **	-	-	-

E1 = Kangra, E2 = Bajaura
*, ** Significant at 5% and 1% probability level, respectively
- Not calculated (Bartlett's Test)

Table 7: Estimation of heterosis (%) over mid, better and check parent across the environments and pooled over environment for ear circumference (cm) and 1000-grain weight (gm).

Cross	Ear Circumference (cm)									1000-grain weight (gm)								
	E1			E2			Pooled			E1			E2			Pooled		
	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)
$P_1 \times P_2$	49.54 **	44.78 **	4.30	14.77 **	7.08	25.65 **	29.29 **	22.48 **	13.14 *	-4.08	-19.88 **	-17.30 **	31.09 **	5.85	17.45 **	12.91 *	-7.23	-0.64
$P_1 \times P_3$	58.74 **	57.81 **	6.45	21.79 **	18.65 **	20.56 **	37.77 **	35.39 **	11.90 *	38.07 **	35.00 **	-2.21	58.40 **	40.05 **	24.38 **	48.22 **	37.65 **	10.62
$P_1 \times P_4$	87.27 **	65.78 **	11.83 **	25.37 **	20.40 **	22.34 **	50.61 **	39.80 **	15.55 **	42.74 **	30.68 **	8.85 *	77.28 **	48.45 **	50.11 **	60.00 **	39.95 **	28.66 **
$P_1 \times P_5$	54.70 **	51.33 **	2.08	21.09 **	15.08 *	16.94 **	35.69 **	30.58 **	7.92	54.26 **	50.83 **	9.26 **	64.61 **	39.23 **	37.36 **	59.59 **	44.44 **	22.82 **
$P_1 \times P_6$	39.38 **	30.70 **	0.72	22.01 **	15.48 *	17.34 **	29.97 **	29.94 **	7.40	55.84 **	39.53 **	-3.42	85.91 **	77.38 **	21.03 **	70.45 **	57.32 **	8.39
$P_1 \times P_7$	41.48 **	29.29 **	5.38	17.94 **	13.49 *	15.32 *	28.80 **	25.98 **	8.90	32.58 **	8.06 *	18.71 **	56.09 **	23.47 **	44.74 **	43.92 **	15.61 **	31.32 **
$P_1 \times P_8$	38.89 **	30.23 **	0.36	4.93	4.31	7.26	19.97 **	16.17 **	2.52	34.13 **	14.05 **	12.68 **	45.14 **	12.16 **	40.27 **	39.73 **	13.05 *	26.01 **
$P_2 \times P_3$	56.59 **	50.75 **	8.60	10.57 *	0.69	18.15 **	29.99 **	21.14 **	11.90 *	18.44 **	0.78	4.02	29.00 **	16.13 **	28.86 **	23.78 **	8.33	16.03 **
$P_2 \times P_4$	78.84 **	53.93 **	10.90 *	22.75 **	10.31	29.44 **	45.09 **	28.13 **	18.36 **	20.82 **	9.16 **	12.68 **	41.77 **	35.48 **	50.34 **	31.41 **	22.10 **	30.79 **
$P_2 \times P_5$	49.61 **	41.79 **	2.15	10.42	-1.72	15.32 *	27.03 **	16.06 **	7.21	22.57 **	4.29	7.65 *	32.98 **	25.60 **	39.37 **	27.96 **	14.77 **	22.93 **
$P_2 \times P_6$	41.83 **	37.21 **	5.73	10.85 *	-1.72	15.32 *	24.68 **	18.09 **	9.09	27.39 **	-2.53	0.60	29.88 **	1.21	12.30 **	28.63 **	-0.69	6.37
$P_2 \times P_7$	43.32 **	35.00 **	10.04 *	19.85 **	7.90	26.61 **	30.41 **	26.22 **	16.60 **	18.04 **	14.47 **	25.75 **	18.82 **	15.65 **	35.57 **	18.42 **	15.05 **	30.68 **
$P_2 \times P_8$	33.65 **	29.30 **	-0.36	-15.38 **	-20.62 **	-6.85	5.82	3.46	-4.43	19.92 **	17.35 **	21.13 **	-14.88 **	-19.68 **	0.45	2.09	0.10	11.57 *
$P_3 \times P_4$	71.84 **	52.90 **	1.94	24.42 **	22.59 **	18.15 **	43.99 **	35.86 **	8.41	30.49 **	21.98 **	1.61	20.61 **	13.27 **	14.54 **	25.32 **	17.44 **	7.96
$P_3 \times P_5$	55.63 **	53.12 **	2.08	11.67 *	8.87	4.92	31.01 **	28.24 **	2.33	59.17 **	59.17 **	15.29 **	29.12 **	22.68 **	21.03 **	43.00 **	39.08 **	18.26 **
$P_3 \times P_6$	48.23 **	38.23 **	6.52	28.45 **	24.69 **	20.16 **	37.62 **	35.27 **	11.75 *	69.94 **	49.17 **	8.05 *	51.34 **	28.46 **	14.09 **	60.34 **	38.31 **	11.15
$P_3 \times P_7$	30.14 **	18.29 **	-3.58	17.37 **	15.90 *	11.69	23.33 **	18.59 **	2.52	21.19 **	0.55	10.46 **	21.17 **	6.49 *	24.83 **	21.18 **	3.46	17.52 **
$P_3 \times P_8$	38.95 **	29.58 **	-0.14	13.36 *	9.80	12.90 *	24.83 **	18.85 **	4.88	25.50 **	8.76 *	7.44 *	15.27 **	-1.43	23.27 **	20.09 **	3.33	15.18 *
$P_4 \times P_5$	75.63 **	58.56 **	2.29	28.10 **	26.72 **	18.55 **	47.81 **	42.36 **	8.79	47.29 **	37.68 **	14.69 **	28.78 **	27.21 **	28.64 **	37.37 **	32.22 **	21.55 **
$P_4 \times P_6$	65.22 **	38.33 **	6.59	31.73 **	29.74 **	21.37 **	46.49 **	36.00 **	12.35 *	76.38 **	46.14 **	21.73 **	30.04 **	4.87	6.04	52.51 **	24.60 **	14.54 *
$P_4 \times P_7$	51.45 **	24.01 **	1.08	10.54	10.30	3.63	28.73 **	17.07 **	1.20	24.38 **	9.34 **	20.12 **	10.66 **	3.05	20.81 **	17.46 **	6.26	20.70 **
$P_4 \times P_8$	62.00 **	35.63 **	4.52	12.11 *	7.06	10.08	33.32 **	20.13 **	6.01	48.29 **	36.66 **	35.01 **	21.46 **	9.84 **	37.36 **	34.13 **	22.38 **	36.41 **
$P_5 \times P_6$	25.57 **	15.35 **	-11.11 *	8.85	8.37	-0.81	16.65 **	12.27	-7.25	40.82 **	23.61 **	-10.46 **	40.39 **	14.29 **	12.75 **	40.59 **	18.48 **	0.74
$P_5 \times P_7$	39.91 **	25.33 **	2.15	18.26 **	16.74 *	9.68	28.43 **	20.98 **	4.58	26.27 **	4.76	15.09 **	24.97 **	15.08 **	34.90 **	25.60 **	9.81	24.73 **
$P_5 \times P_8$	32.35 **	21.58 **	-6.31	-1.24	-6.67	-4.03	13.89 *	6.26	-6.23	43.36 **	24.24 **	22.74 **	16.60 **	4.29	30.43 **	28.90 **	13.62 **	26.65 **
$P_6 \times P_7$	26.58 **	23.13 **	0.36	14.85 *	12.88	6.05	20.61 **	17.94 **	1.95	33.99 **	0.37	10.26 **	34.83 **	3.05	20.81 **	34.40 **	1.68	15.50 **
$P_6 \times P_8$	29.30 **	29.30 **	-0.36	12.08 *	5.49	8.47	20.22 **	16.38 **	2.70	45.48 **	13.03 **	11.67 **	23.44 **	-7.69 **	15.44 **	33.96 **	2.00	13.69 *
$P_7 \times P_8$	18.44 **	15.22 **	-6.09	3.69	-0.78	2.02	10.71 *	9.57	-3.30	16.30 **	10.44 **	21.33 **	3.79	0.54	25.73 **	9.91 *	8.88	23.67 **

E1 = Kangra, E2 = Bajaura, P = Pooled
*, ** Significant at 5% and 1% probability level, respectively

Table 8: Estimation of heterosis (%) over mid, better and check parent across the environments and pooled over environment for shelling(%) and grain yield (q/ha).

Cross	Shelling (%)									Grain Yield (q/ha)								
	E1			E2			Pooled			E1			E2			Pooled		
	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)	MPH (%)	BPH (%)	SH (%)
$P_1 \times P_2$	-5.75	-7.32	-3.86	6.67 **	4.62 *	1.56	-	-	-	500.80 **	478.74 **	-52.28 **	499.02 **	448.55 **	-15.14 **	499.47 **	455.87 **	-27.69 **
$P_1 \times P_3$	-4.39	-5.35	-1.81	8.25 **	7.11 **	6.22 **	-	-	-	1390.40 **	1259.85 **	3.89	687.58 **	647.23 **	7.08 **	853.01 **	835.52 **	7.95
$P_1 \times P_4$	-4.54	-6.88	-3.39	7.74 **	6.79 **	5.51 **	-	-	-	1485.20 **	1419.08 **	16.05 **	677.90 **	599.67 **	12.65 **	865.89 **	797.97 **	16.15 *
$P_1 \times P_5$	-5.75	-7.96 *	-4.52	6.68 **	5.71 **	4.52 *	-	-	-	459.16 **	357.26 **	-45.03 **	481.97 **	460.43 **	-27.92 **	474.60 **	449.39 **	-33.06 **
$P_1 \times P_6$	-4.08	-4.46	-0.11	3.14	-1.43	4.99 *	-	-	-	791.36 **	585.26 **	-2.61	472.10 **	418.92 **	-18.01 **	572.35 **	477.26 **	-10.52
$P_1 \times P_7$	1.17	-2.38	1.27	5.64 **	1.96	6.39 **	-	-	-	467.97 **	273.28 **	-9.30 *	422.19 **	344.55 **	-18.62 **	439.63 **	312.94 **	-13.47
$P_1 \times P_8$	-3.09	-4.40	-0.83	6.99 **	4.98 *	1.91	-	-	-	949.46 **	817.56 **	-6.37	598.24 **	512.31 **	4.47	690.84 **	592.97 **	2.37
$P_2 \times P_3$	-5.83	-6.48	-4.93	7.30 **	4.15 *	3.29	-	-	-	960.46 **	835.46 **	-22.87 **	504.08 **	481.85 **	-9.99 **	607.52 **	567.58 **	-13.16
$P_2 \times P_4$	-1.89	-2.68	-2.42	6.44 **	3.50	2.26	-	-	-	1387.46 **	1275.36 **	13.40 **	616.79 **	602.73 **	13.14 **	790.04 **	787.54 **	15.45 *
$P_2 \times P_5$	-0.59	-1.27	-1.01	11.46 **	8.34 **	7.12 **	-	-	-	687.26 **	563.62 **	-20.23 **	502.83 **	433.49 **	-17.47 **	559.58 **	538.72 **	-16.91 *
$P_2 \times P_6$	-2.03	-4.04	0.33	2.37	-3.95 *	2.30	-	-	-	723.98 **	551.01 **	-7.48	361.19 **	356.37 **	-27.90 **	470.50 **	424.63 **	-18.68 *
$P_2 \times P_7$	-1.23	-3.11	-2.85	2.89	-2.53	1.71	-	-	-	460.83 **	275.57 **	-8.75 *	378.35 **	341.29 **	-19.22 **	408.58 **	312.14 **	-13.64
$P_2 \times P_8$	-2.57	-2.90	-1.98	2.95	2.91	-3.86	-	-	-	949.74 **	848.95 **	-3.16	358.14 **	336.75 **	-25.48 **	508.42 **	472.09 **	-15.49 *
$P_3 \times P_4$	-14.22 **	-15.49 **	-14.09 **	-1.75	-1.94	-2.75	-	-	-	945.75 **	893.40 **	-30.44 **	418.89 **	390.37 **	-21.05 **	528.44 **	494.53 **	-23.10 **
$P_3 \times P_5$	-1.67	-3.01	-1.40	2.79	2.64	1.79	-	-	-	976.17 **	720.15 **	-1.41	495.92 **	445.59 **	-21.81 **	637.79 **	618.23 **	-12.48
$P_3 \times P_6$	-2.36	-3.71	0.67	0.11	-3.33	2.96	-	-	-	958.25 **	663.73 **	8.54 *	461.93 **	435.82 **	-15.34 **	605.95 **	515.75 **	-4.56
$P_3 \times P_7$	0.97	-1.61	0.02	1.07	-1.43	2.85	-	-	-	462.77 **	254.36 **	-13.90 **	263.18 **	223.75 **	-40.73 **	335.07 **	237.33 **	-29.31 **
$P_3 \times P_8$	-5.94	-6.27	-4.72	9.08 **	5.91 **	5.04 *	-	-	-	1075.19 **	850.43 **	-3.01	415.13 **	373.90 **	-19.14 **	573.51 **	499.81 **	-11.39
$P_4 \times P_5$	-5.65	-5.76	-6.81	4.25 *	4.21 *	3.04	-	-	-	699.50 **	532.60 **	-23.95 **	528.79 **	446.97 **	-11.93 **	578.24 **	558.59 **	-14.81
$P_4 \times P_6$	-2.58	-5.32	-1.01	0.30	-3.33	2.96	-	-	-	951.90 **	685.09 **	11.57 **	466.41 **	461.11 **	-9.66 **	604.95 **	546.61 **	0.23
$P_4 \times P_7$	0.86	-0.27	-1.61	-2.91	-5.49 **	-1.38	-	-	-	204.56 **	96.16 **	-52.34 **	172.49 **	156.08 **	-53.12 **	183.82 **	129.50 **	-51.91 **
$P_4 \times P_8$	-1.78	-2.89	-1.98	6.17 **	3.29	2.05	-	-	-	839.17 **	691.80 **	-19.20 **	380.77 **	367.23 **	-20.28 **	489.66 **	452.99 **	-18.31 *
$P_5 \times P_6$	-1.93	-4.58	-0.24	2.01	-1.65	4.76 *	-	-	-	444.97 **	402.97 **	-28.52 **	442.34 **	375.60 **	-24.86 **	443.30 **	385.20 **	-24.79 **
$P_5 \times P_7$	3.64	2.37	1.22	0.68	-1.96	2.30	-	-	-	340.27 **	229.05 **	-20.05 **	362.09 **	281.37 **	-30.19 **	352.94 **	258.16 **	-24.95 **
$P_5 \times P_8$	0.68	-0.35	0.59	4.36 *	1.49	0.34	-	-	-	820.22 **	750.70 **	2.26	417.91 **	339.73 **	-24.97 **	544.78 **	488.33 **	-13.09
$P_6 \times P_7$	1.03	-2.88	1.54	-5.61 **	-6.57 **	-0.48	-	-	-	412.25 **	305.93 **	-1.37	309.40 **	281.37 **	-30.19 **	350.95 **	292.26 **	-17.80 *
$P_6 \times P_8$	0.14	-1.59	2.89	4.60 *	-1.83	4.56 *	-	-	-	683.95 **	573.43 **	-4.29	342.10 **	325.74 **	-27.36 **	447.56 **	434.70 **	-17.12 *
$P_7 \times P_8$	0.39	-1.84	-0.92	0.08	-5.16 *	-1.04	-	-	-	427.64 **	274.62 **	-8.98 *	327.56 **	313.04 **	-24.39 **	364.53 **	296.00 **	-17.02 *

E1 = Kangra, E2 = Bajaura
*, ** Significant at 5% and 1% probability level, respectively
- Not calculated (Bartlett's Test)

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