Exploitation of combining ability and heterosis for development of maize hybrids for tarai region of Uttarakhand

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Abstract: The present investigation was carried out with fifty six genotypes involving 10 parents, their 45 F_{1s} hybrids and one check hybrid in tarai region of Uttarakhand. The presence of more amount of variance due to SCA effects than GCA effects in our experimental material indicated that heterosis breeding is better choice. The good general combiners were P_1, P_3 and P_4 for ear length; P_8 for ear diameter; P_5 and P_8 for number of kernel rows per ear; P_1 and P_4 for number of kernels per row, P_8 and P_9 for100-kernel weight and P_5 for grain yield, which can be utilized directly or indirectly in breeding programme. The best eight specific combiners for grain yield were P_1xP_8, P_4xP_{10}, P_7xP_8, P_5xP_8, P_5xP_9, P_4xP_9, P_1xP_2 and P_5xP_{10} involving average x average, good x average, good x poor and average x poor parental combinations of generalcombining ability indicating the presence of non-additive gene action. The nine crosses, P_1xP_2, P_1xP_5, P_1xP_8, P_4xP_9, P_4xP_{10}, P_5xP_8, P_5xP_9, P_5xP_{10} and P_7xP_8 had positive significant per cent heterosis for grain yield, and crosses namely P_1xP_4, P_1xP_5 and P_1xP_8 for ear length; P_1xP_3 and P_1xP_5 for number of kernels per row and P_1xP_8 and $P_9x P_{10}$ for 100-kernel weight were having positive significant per cent heterosis at 1% and/or 5% level of significance for respective traits. The crosses, P_1xP_2, P_1xP_8, P_4xP_9 andP_7xP_8 manifested high SCA effects along with excellent standard heterosis and per se performance for grain yield and also for most of the studied characters, therefore, classified as potential hybrids.

Keywords: Combining ability, Maize, *Per se* performance, Standard heterosis

INTRODUCTION

Maize (*Zea mays* L.) has emerged as world's leading crop among the cereals with highest production and productivity (Kumar *et al.*, 2015). In India, maize is third important food crop after wheat and rice and its production has been recorded about 24.35 MT from 9.4 mha area with average productivity of 2.5 t ha^{-1} in 2013-14, which is almost half to the world average (AICRP on Maize, 2015).Due to maize being allogamous crop species, maintenance of heterozygosity is utmost important to suppress the undesirable effect of recessive alleles, therefore, grain productivity enhancement needs better exploitation of heterosis utilizing additive and non-additive gene actions. To develop good economically viable maize hybrid, information on the heterotic patterns and combining ability among maize germplasm is essential to maximize the effectiveness of hybrid development (Amiruzzaman *et al.,* 2010). Combining ability analysis elucidates the combining ability of parents and their crosses and also nature and magnitude of various types of gene actions involved in the expression of quantitative characters. Therefore, it is a powerful tool in the identification of best combiners and breeding strategies to be adopted either heterosis breeding or recombinant breeding for the accumulation of desirable genes. Thus study was performed with the ob-

jective of identification of desirable parents, crosses and breeding strategies to be adopted on the basis of various types of gene actions and combining ability of parents and crosses.

MATERIALS AND METHODS

The present investigation was undertaken with ten parental lines namely CML 226 (P_1), POP31 (P_2), YHP-B (P_3), POP 31 (P_4), Pob 446 (P_5), POB 45 (P_6), Tarun (P_7), POB 45 (P_8), PHPA (P_9)**,** Pob 445 (P_{10}), which were crossed in half diallel fashion(excluding reciprocals) to develop forty five F_1s hybrids during *rabi* 2012-13, at N. E. Borlaug Crop Research Center, Pantnagar, Uttarakhand. These parental lines along with 45 F_1s hybrids and one commercial check hybrid, (PSM 1) were evaluated in randomized block design with three replications in plot size of 6.00 m^2 in the following kharif 2013, at same research farm. The data was recorded on grain yield (YH) and important yield attributing traits namely ear length (EL), ear diameter (ED), number of kernel rows/ear (NKR/E), number of kernels/row (NK/R) and 100-kernel weight (100-SW). Standard heterosis against the commercial check hybrid was calculated and tested as per methods given by Singh and Singh (1994), and significance of heterosis was tested using t- test at 1% and 5% level of significance. The combining ability analysis was per-

formed with method 2 and Model I of Griffing (1956) using AGD-R software, CIMMYT.

RESULTS AND DISCUSSION

The analysis of variance for combining ability revealed that variance due to GCA and SCA were significant for all above mentioned characters indicating that both type of gene actions namely additive and non- additive gene actions are important for expression of characters (Table 1). In which GCA can be exploited for the improvement of parental inbred lines through fixation of deesirable genes acting in additive fashion, while SCA based on non-additive gene actions through development of effective hybrids. Rokadia and Kaushik (2005); Amiruzzaman *et al.*(2010) and Aminu *et al.* (2014) also observed the significant values of both GCA and SCA effects showing the presence of addi-

tive and non-additive gene actions for yield and yield attributing traits. The present experimental material is also having the significant levels of both types of gene action which might be utilized for crop improvement programme. The ratio σ^2GCA to σ^2SCA lesser than unity for all the studied characters were recorded which indicated the presence of more amount of non-additive than additive type of gene action (Table 1). Therefore, idea of opting for maintaining heterozygosity i.e. heterosis breeding for grain yield and yield contributing characters is recommended. Alamine *et al.* (2003); Kambe *et al.* (2013) and Aminu *et al.* (2014) also observed the less than unity ratio between σ^2GCA to σ^2SCA for yield and yield attributing traits, and also recommended the heterosis breeding for crop improvement programme, but Alam *et al.* (2008) reported the significant role of additive gene action for number of

Table 1. Analysis of variance for combining ability and variance effects with respect to yield and yield attributing traits of maize .

Source of variation	df	EL	ED	NKR/E	NK/R	100-SW	YH
Due to GCA	9	9.77**	0.27**	3.73**	39.15**	14.83**	321.43**
Due to SCA	45	13.03**	0.33**	2.28**	76.80**	20.21**	727.13**
Error	108	0.96	0.09	0.49	8.50	2.25	82.09
σ^2**GCA**		0.240	0.010	0.090	0.851	0.350	6.648
σ^2**SCA**		4.020	0.080	0.595	22.767	5.985	215.014
σ^2**GCA/**σ^2**SCA**		0.060	0.060	0.151	0.037	0.058	0.031

*, ** Significant at 5% and 1% probability levels, respectively; GCA- General combining ability; SCA- Specific combining ability; σ^2GCA- variance due to GCA; σ^2SCA- variance due to SCA; EL-Ear Length; ED-Ear Diameter; NKR/E- No. of Kernel Rows per Ear; NK/R- No. of Kernels per Ror; 100-SW-100 Seed Weight; YH- Yield per Hectare

Table 2. General combining ability effects (GCA) and *per se* performance of parental lines with respect to yield and yield attributing traits of maize.

S. N.	Genotype	EL		ED		NKR/E		NK/R		100-SW		YH	
		GCA	*Per se* performance	GCA	*Per se* performance	GCA	*Per se* performance	GCA	*Per se* performance	GCA	*Per se* performance	GCA	*Per se* performance
1.	P_1	0.95 **	13.25	0.02	3.47	-0.10	12.56	1.81 **	25.89	0.24	18.52	2.55	23.34
2.	P_2	-0.66 **	10.08	-0.12 *	3.43	-0.22 *	11.47	-0.38	25.80	-0.69 **	21.72	-0.50	27.49
3.	P_3	0.41 **	11.67	-0.05	3.51	-0.33 **	11.27	0.41	22.43	-0.10	25.07	-2.80	23.31
4.	P_4	0.59 **	15.73	0.04	3.97	0.15	13.90	1.82 **	35.73	-0.88 **	23.09	-0.69	34.22
5.	P_5	0.01	12.47	-0.03	3.65	0.34 **	12.30	-0.21	25.22	-0.25	23.02	6.03 **	23.77
6.	P_6	-0.44 **	10.23	-0.07	3.67	-0.37 **	12.29	-0.87	20.22	-0.31	22.46	-2.27	26.89
7.	P_7	-0.46 **	12.63	0.06	3.93	0.13	12.50	-0.43	30.67	-0.33	21.96	-2.16	23.95
8.	P_8	0.17	13.07	0.19 **	3.67	0.61 **	13.60	-0.24	28.97	0.86 **	23.13	2.05	30.61
9.	P_9	-0.31 *	11.43	0.01	3.27	0.10	12.67	-1.06 *	21.97	1.13 **	26.72	1.38	27.44
10.	P_{10}	-0.27	8.43	-0.06	3.07	-0.31 **	10.20	-0.85	17.90	0.32	20.64	-3.60 *	16.60
11.	S.E.(g_i)	0.16	13.25	0.05	3.47	0.11	12.56	0.46	25.89	0.24	18.52	1.43	23.34
12.	SE(g_i-g_j)	0.23	10.08	0.07	3.43	0.17	11.47	0.69	25.80	0.35	21.72	2.14	27.49

*, ** Significant at 5% and 1% probability levels, respectively; GCA- General combining ability; SCA- Specific combining ability; σ^2GCA- variance due to GCA; σ^2SCA- variance due to SCA; EL-Ear Length; ED-Ear Diameter; NKR/E- No. of Kernel

Table 3. Specific combining ability effects of half diallel hybrids with respect to yield and yield attributing traits of maize.

S.N.	Genotype	EL	ED	NKR/E	NK/R	100-SW	YH
1.	$P_1 \times P_2$	2.22 **	0.43 **	0.11	3.59 **	2.44 **	18.03 **
2.	$P_1 \times P_3$	-1.02 **	-0.20 **	0.98 **	4.98 **	-0.85 **	-1.07
3.	$P_1 \times P_4$	1.57 **	0.03	0.40 **	1.63 **	3.11 **	-2.98
4.	$P_1 \times P_5$	2.25 **	0.21 **	0.22	8.26 **	-0.15	14.88 **
5.	$P_1 \times P_6$	-0.33	-0.34 **	-0.67 **	-1.86 **	0.98 **	8.92 **
6.	$P_1 \times P_7$	-1.11 **	-0.31 **	0.16	-3.52 **	-0.73 *	1.54
7.	$P_1 \times P_8$	2.26 **	0.39 **	0.78 **	3.51 **	5.74 **	29.59 **
8.	$P_1 \times P_9$	0.09	0.35 **	-0.52 **	1.83 **	-0.33	1.62
9.	$P_1 \times P_{10}$	1.06 **	0.37 **	-0.54 **	1.86 **	1.00 **	-14.74 **
10.	$P_2 \times P_3$	0.92 **	0.17 **	0.07	3.39 **	1.54 **	16.05 **
11.	$P_2 \times P_4$	-1.74 **	0.28 **	-0.14	-4.39 **	-1.11 **	-3.90 *
12.	$P_2 \times P_5$	0.65 **	-0.22 **	1.67 **	0.61	0.13	11.06 **
13.	$P_2 \times P_6$	1.99 **	0.08	-0.45 **	5.47 **	2.04 **	4.92 *
14.	$P_2 \times P_7$	-1.23 **	-0.34 **	0.85 **	-2.61 **	-0.06	-5.78 **
15.	$P_2 \times P_8$	2.09 **	0.01	-0.10	0.80	2.52 **	-2.88
16.	$P_2 \times P_9$	0.63 **	0.14 *	-0.20	1.03	-3.60 **	5.34 **
17.	$P_2 \times P_{10}$	1.40 **	-0.08	0.82 **	3.81 **	-2.79 **	-7.55 **
18.	$P_3 \times P_4$	0.01	0.11	0.10	1.16	-6.20 **	-4.86 *
19.	$P_3 \times P_5$	1.29 **	-0.19 **	-0.29	3.36 **	2.20 **	5.81 **
20.	$P_3 \times P_6$	1.50 **	0.15 *	0.56 **	4.69 **	0.16	10.45 **
21.	$P_3 \times P_7$	0.76 **	0.49 **	0.69 **	-3.31 **	1.64 **	-3.37
22.	$P_3 \times P_8$	0.21	-0.02	-0.12	-1.11	-1.32 **	3.14
23.	$P_3 \times P_9$	1.91 **	0.01	-0.05	3.05 **	-0.37	-7.02 **
24.	$P_3 \times P_{10}$	2.46 **	0.07	0.66 **	5.38 **	-0.04	15.36 **
25.	$P_4 \times P_5$	-0.61 **	-0.34 **	0.07	-2.49 **	0.90 **	-10.32 **
26.	$P_4 \times P_6$	0.27	-0.13 *	-1.45 **	0.14	1.91 **	1.46
27.	$P_4 \times P_7$	0.25	-0.00	-0.20	-0.29	-2.97 **	1.38
28.	$P_4 \times P_8$	0.18	0.30 **	-0.07	3.19 **	-0.05	-2.80
29.	$P_4 \times P_9$	-0.25	-0.03	-0.13	0.83	-0.38	18.43 **
30.	$P_4 \times P_{10}$	0.92 **	-0.20 **	0.65 **	0.88	2.37 **	24.70 **
31.	$P_5 \times P_6$	-0.36	-0.13 *	0.16	0.23	-3.21 **	-5.07 **
32.	$P_5 \times P_7$	-1.83 **	-0.04	0.67 **	-1.27 *	-1.84 **	-5.12 **
33.	$P_5 \times P_8$	0.39	0.31 **	0.04	2.34 **	1.49 **	20.28 **
34.	$P_5 \times P_9$	1.94 **	0.49 **	0.05	2.59 **	0.66 *	19.67 **
35.	$P_5 \times P_{10}$	1.10 **	0.30 **	0.59 **	-0.06	0.05	17.69 **
36.	$P_6 \times P_7$	2.01 **	0.40 **	0.73 **	0.79	3.44 **	6.31 **
37.	$P_6 \times P_8$	0.14	-0.05	-0.68 **	1.10	-4.42 **	-4.88 *
38.	$P_6 \times P_9$	1.04 **	-0.39 **	0.42 **	4.94 **	-0.03	-4.16 *
39.	$P_6 \times P_{10}$	1.25 **	0.58 **	1.74 **	5.39 **	0.28	11.47 **
40.	$P_7 \times P_8$	1.83 **	-0.27 **	-0.55 **	2.89 **	1.20 **	23.16 **
41.	$P_7 \times P_9$	0.05	0.13 *	0.26	3.44 **	-2.68 **	9.91 **
42.	$P_7 \times P_{10}$	1.89 **	0.12	-0.66 **	5.66 **	4.06 **	7.71 **
43.	$P_8 \times P_9$	-2.18 **	0.45 **	1.25 **	-5.30 **	1.04 **	-8.62 **
44.	$P_8 \times P_{10}$	-0.66 **	0.11	1.09 **	-1.52 *	-1.71 **	-17.71 **
45.	$P_9 \times P_{10}$	2.37 **	0.14 *	0.43 **	4.23 **	4.06 **	7.75 **
46.	S.E.(S_{ij})	0.21	0.06	0.15	0.62	0.32	1.93
47.	SE($S_{ij} - S_{ik}$)	0.73	0.22	0.52	2.17	1.12	6.75

GCA- General combining ability; SCA- Specific combining ability; EL-Ear Length; ED-Ear Diameter; NKR/E- No. of Kernel Rows per Ear; NK/R- No. of Kernels per Row; 100-SW-100 Seed Weight; YH - Yield per Hectare **; ** Significant at 5% and 1% probability levels, respectively.

Table 4. Standard heterosis effects of half diallel hybrids with respect to yield and yield attributing traits of maize.

S.N.	Genotype	EL	ED	NKR/E	NK/R	100-SW	YH
1.	P₁ x P₂	8.09	0.2	-8.24*	13.09	-2.9	37.61*
2.	P₁ x P₃	-5.39	-13.04*	-2.82	19.64**	-13.14**	-6.85
3.	P₁ x P₄	11.83*	-5.53	-3.53	13.8	-1.07	-6.43
4.	P₁ x P₅	12.45*	-2.77	-3.53	27.69**	-11.04**	44.64**
5.	P₁ x P₆	-6.43	-17.00**	-14.82**	-4.88	-6.97	15
6.	P₁ x P₇	-11.41*	-13.04*	-5.41	-8.56	-13.52**	-0.1
7.	P₁ x P₈	13.49**	6.72	2.35	13.24	15.48**	66.93**
8.	P₁ x P₉	-3.01	1.19	-10.35*	5.69	-6.49	7.43
9.	P₁ x P₁₀	3.32	0	-13.41**	6.45	-4.56	-36.91*
10.	P₂ x P₃	-3.32	-7.51	-10.12*	8.26	-7.6	22.39
11.	P₂ x P₄	-18.78**	-2.77	-8.24*	-10.98	-20.59**	-14.68
12.	P₂ x P₅	-7.47	-16.21**	5.88	-2.01	-13.50**	30.35
13.	P₂ x P₆	-1.97	-10.08	-14.12**	10.67	-6.5	0.34
14.	P₂ x P₇	-22.10**	-17.00**	-1.41	-12.39	-14.53**	-21.65
15.	P₂ x P₈	2.49	-5.53	-4.71	-1.53	-0.25	-6.86
16.	P₂ x P₉	-9.65	-6.92	-8.94*	-3.32	-22.40**	8.82
17.	P₂ x P₁₀	-4.56	-13.83*	-4.71	5.74	-22.42**	-28.32
18.	P₃ x P₄	-1.24	-5.14	-7.29	8.16	-37.64**	-21.44
19.	P₃ x P₅	3.11	-13.83*	-8.71*	8.66	-3.46	14.68
20.	P₃ x P₆	1.66	-6.72	-7.76	10.67	-11.39*	7.08
21.	P₃ x P₇	-3.11	4.35	-3.29	-12.13	-5.85	-21.43
22.	P₃ x P₈	-2.59	-4.74	-5.65	-4.93	-12.58**	0.87
23.	P₃ x P₉	4.98	-8.3	-8.71*	5.14	-7.92	-21.62
24.	P₃ x P₁₀	8.71	-8.7	-6.59	12.84	-9.77*	14.51
25.	P₄ x P₅	-7.57	-15.42**	-2.82	-4.73	-11.31*	-14.45
26.	P₄ x P₆	-4.88	-11.26*	-18.59**	1.21	-7.73	-7.23
27.	P₄ x P₇	-5.19	-5.14	-6.2	1.28	-26.26**	-7.17
28.	P₄ x P₈	-1.66	5.14	-1.88	12.34	-10.72*	-7.09
29.	P₄ x P₉	-7.37	-7.11	-5.88	2.72	-10.93*	35.63*
30.	P₄ x P₁₀	0.21	-12.85*	-3.29	3.52	-3.62	38.31*
31.	P₅ x P₆	-12.45*	-13.04*	-5.88	-4.63	-24.72**	-6.84
32.	P₅ x P₇	-21.68**	-7.71	1.25	-7.82	-19.62**	-6.71
33.	P₅ x P₈	-3.94	3.56	0.24	3.63	-2.47	54.83**
34.	P₅ x P₉	2.7	3.36	-3.29	1.91	-4.6	52.17**
35.	P₅ x P₁₀	-2.28	-2.77	-2.35	-5.44	-10.01*	37.70*
36.	P₆ x P₇	-0.62	1.78	-3.29	-3.63	0.18	-0.22
37.	P₆ x P₈	-8.3	-5.93	-9.88*	-2.11	-25.08**	-14.71
38.	P₆ x P₉	-5.71	-18.38**	-5.65	7	-7.42	-14.61
39.	P₆ x P₁₀	-4.15	2.96	0.71	9.01	-9.36*	7.52
40.	P₇ x P₈	2.07	-8.1	-5.41	4.63	-3.89	43.78**
41.	P₇ x P₉	-12.03*	-2.96	-3.29	3.83	-17.55**	14.86
42.	P₇ x P₁₀	-0.31	-4.94	-12.71**	11.18	4.9	-0.06
43.	P₈ x P₉	-21.99**	7.71	7.06	-22.05**	1.04	-14.88
44.	P₈ x P₁₀	-12.24*	-1.98	3.06	-9.97	-12.46**	-44.12**
45.	P₉ x P₁₀	3.63	-5.73	-5.18	4.93	10.43*	7.39

EL–Ear Length; ED–Ear Diameter; NKR/E– No. of Kernel Rows per Ear; NK/R– No. of Kernels per Row; 100-SW–100 Seed Weight; YH– Yield per Hectare
*, ** Significant at 5% and 1% probability levels, respectively.

kernels per ear and 100-kernel weight. Therefore, additive gene action of both traits can be fixed through improvement of inbred lines.

General combining ability (GCA) effects: The GCA estimates and *per se* performance of parental lines are presented in Table 2. In present study, parents with significant positive GCA effects were classified as good general combiner; with non-significant GCA as average combiner and significant negative GCA effects were classified as poor general combiner. The good general combiners for yield attributing traits were P_1, P_3 and P_4 for ear length; P_8 for ear diameter; P_5 and P_8 for number of kernel rows per ear; P_1 and P_4 for number of kernels per row and P_8 and P_9 for 100-kernel weight. The parent, P_5 was good general combiner for yield along with good general combiner for number of kernel rows per ear and average general combiner for remaining yield attributing traits, but could not be qualified as having potential directly for hybrid breeding programme because of its low *per se* performance. Some yield attributing traits namely ear length, number of kernel rows per ear, number of kernels per row and 100-kernel weight had somewhat correlations between high per se performance and good GCA effects. Amiruzzaman *et al.* (2010) also identified the correlation of good general combining ability of grain yield and other yield attributing traits with *per se* performance of parental genotypes. Therefore, *per se* performance of parents could be used as useful index for general combining ability.

Specific combining ability (SCA) effects: The SCA estimates of crosses are presented in Table 3. The SCA effects ranged from -2.18 to 2.46 for ear length; -0.39 to 0.58 for ear diameter; -1.45 to 1.74 for number of kernel rows per ear; -5.30 to 8.26 for number of kernels per row; -6.20 to 5.74 for 100-kernel weight and -17.71 to 29.59 for grain yield. The number of crosses having significant positive SCA effects was 25 for ear length; 19 for ear diameter; 18 for number of kernel rows per ear; 23 for number of kernels per row; 20 for 100-kernel weight and 22 for grain yield. For grain yield best eight specific combiners were P_1 x P_8 (25.59), P_4 x P_{10} (24.70), P_7 x P_8 (23.16), P_5 x P_8 (20.28), P_5 x P_9 (19.67), P_4 x P_9 (18.43), P_1 x P_2 (18.03) and P_5 x P_{10} (17.69). The crosses namely P_1 x P_8 and P_7 x P_8 were also having the positive significant SCA effects for all studied yield attributing traits while other remaining crosses were having the positive significant SCA effects for most of the yield attributing traits in addition to good SCA effect. In contrast to GCA effect (additive gene action), SCA effect are the result of non-additive gene actions (dominance and epistatic interaction). Among these eight best significant positive crosses for grain yield, four (P_1 x P_2, P_1 x P_8, P_4 x P_9 and P_7 x P_8) were having parents with average x average general combiner; two (P_5 x P_8 and P_5 x P_9) with good x average general combiner parents; P_5 x P_{10} with good x

poor parents and P_4 x P_{10} with average x poor parents. These parental combinations show the clear role of non-additive gene action in SCA effects. The SCA effects of grain yield and yield attributing traits in maize were also reported by Amiruzzaman *et al.* (2010); Haddadi *et al.* (2012); Aminu *et al.* (2014) and Guerrero *et al.* (2014), also had given the emphasis on heterosis breeding for exploitation of non-additive gene action for maize improvement program.

Heterosis: The per cent standard heterosis of crosses is presented in Table 4. Per cent standard heterosis was ranged from -22.10 (P_2 x P_7) to 13.49 (P_1 x P_8) for ear length; -18.38 (P_6 x P_9) to 7.71 (P_8 x P_9) for ear diameter; -18.59 (P_4 x P_6) to 7.06 (P_8 x P_9) for number of kernel rows per ear; -22.05 (P_8 x P_9) to 27.69 (P_1 x P_5) for number of kernels per row; -37.64 (P_3 x P_4) to 15.48 (P_1 x P_8) for 100-kernel weight and -44.12 (P_8 x P_{10}) to 66.93 (P_1 x P_8) for grain yield. None of the crosses was having the positive significant per cent standard heterosis for ear diameter and number of kernel rows per ear. Elymyhum (2013) also reported the non-significant genetic difference ultimately significant standard heterosis for ear diameter and number of kernel rows per ear. While, three crosses (P_1 x P_4, P_1 x P_5 and P_1 x P_8) for ear length; two crosses (P_1 x P_3 and P_1 x P_5) for number of kernels per row; two crosses (P_1 x P_8 and P_9 x P_{10}) for 100-kernel weight and nine crosses (P_1 x P_2, P_1 x P_5, P_1 x P_8, P_4 x P_9, P_4 x P_{10}, P_5 x P_8, P_5 x P_9, P_5 x P_{10} and P_7 x P_8) for grain yield had positive significant per cent standard heterosis. The magnitude of per cent standard heterosis for grain yield of different crosses were P_1 x P_8 (66.93), P_5 x P_8 (54.83), P_5 x P_9 (52.17), P_1 x P_5 (44.64), P_7 x P_8 (43.78), P_4 x P_{10} (38.31), P_1 x P_2 (37.61) and P_4 x P_9 (35.63). Out of these, cross, P_1 x P_8 also showed the positive significant per cent heterosis for ear length and 100-kernel weight and good *per se* performance of other remaining traits, therefore, this cross, is classified as best from practical point of view. Vivek *et al.* (2009) and Snezana *et al.* (2012) also reported the significant standard heterosis for grain yield, while Shete *et al.* (2011) and Aminu *et al.* (2014) also reported the significant standard heterosis for grain yield along with ear length, no. of kernels per row and 100-kernel weight, and recommended the heterosis breeding for crop improvement programme

Conclusion

Heterosis breeding is suggested for the development of effective cultivars of maize crop because of the presence of more amount of variance due to SCA effects than GCA effects. Good general combiner parents along with high per se performance were P_1 and P_4 for ear length; P_8 for number of kernel rows per ear; P_4 for number of kernels per row and P_9 for 100-kernel weight, which, can be utilized as donor as yield attributing traits in crop improvement programme. However, P_8 for ear diameter and P_5 for grain yield were

having the good GCA effects along with low per se value, therefore, could not be classified as good parental lines. The crosses, P_1 x P_2, P_1 x P_8, P_4 x P_9 and P_7 x P_8 manifested high SCA effects along with excellent standard heterosis and per se performance for grain yield and also for most of the studied characters, therefore, classified as potential hybrids for commercial purpose.

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