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HETEROSIS AND COMBINING ABILITY FOR YIELD AND ITS CONTRIBUTING TRAITS OF KHARIF MAIZE (*ZEA MAYS* L.)

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ABSTRACT

36 crosses were made using line x tester involving 9 lines and 4 testers which were evaluated along with two checks, namely DHM-117 and BIO-9637. Analysis of variance exhibited highly significant differences among themselves for all the traits under study. SCA was more pronounced than variance due to GCA for all the characters under study except leaf rolling. Some of the crosses found good for yield on the basis of morphological data were P_6 x P_{11}(5319.66 Kg ha^{-1}), P_8 x P_{11}(5000.33 Kg ha^{-1}), P_1 x P_{13}(4906.33 Kg ha^{-1}), P_7 x P_{12} (4891 Kg ha^{-1}) and P_9 x P_{12} (4804 Kg ha^{-1}). On the basis of mean performance, heterosis and SCA for grain yield total five crosses were selected and recommended for further use in our conditions

INTRODUCTION

Maize is one of the third most important crop grown throughout the world and having highest production and productivity among food cereals. Having a wide range of adaptability to diverse climatic conditions and immense potential in meeting day to day increasing population demand. Heterosis acts as an important tool for enhancing hybrid vigour for growth and yield traits (Soni and Khanorkar, 2013). The Line x Tester analysis provides information on the type of gene action and general combining ability and specific combining ability (SCA) of genotypes (Iqbal *et al.*, 2014; Kumar *et al.,* 2014; Rajesh *et al.,* 2014). Selection of parents is most important criteria for developing hybrids. Combining ability which is widely used in the breeding of cross-pollinated crop provides information regarding the selection of lines for hybrid combination (Khan and Dubey, 2015). The reason behind carrying out the present research work is during *kharif* season maize suffers from various constraints like irregular rainfall, water logging, high water table, less pollen shedding due to which it causes severe impact on the yield of plant or sometimes leading to complete failure of crop. Keeping these problems in mind there is a strong need for carrying out research for *kharif* season. Hence, by considering the above points the present investigation was therefore carried out to determine the heterosis and combining ability for yield and its contributing traits of *kharif* maize.

MATERIALS AND METHODS

The experimental material consisted of 9 lines and 4 tester (Table 1) and total 36 crosses (Table 2) which was obtained using line x tester design and was evaluated along with two checks DHM-117 (C_1) and BIO-9637 (C_2) in randomized block design with three replications in *kharif* 2014 at maize section of Bihar Agricultural University, Sabour, Bhagalpur. Observations recorded were days to 50 % tasseling, days to 50 % silking, days to 75 % brown husk, pollen shedding duration, plant height, ear height, leaf firing (1-5 scale)as per Seetharama *et al.*,1980, leaf rolling (1-5 scale)as per Zaidi *et al.,* 2008, tassel blast (1-5 scale) as per Smith *et al.,* 1997, post flowering stalk rot (1-5 scale) as per Mughogho and Pande 1983, cob length, cob diameter, number of kernel rows per cob,number of kernels per row, 100-seed weight, grain yield, harvest index and shelling percentage.The replication wise mean values of experimental materials were subjected to statistical analysis using INDOSTAT software

RESULTS AND DISCUSSION

Estimates of components of variance

From table-3 it was clearly obtained that there was greater contribution of female in hybrid interaction with respect to male which showed that female is more predominating in expressing its character in their hybrids which is one of the major characteristics of line x tester design as obtained by Iqbal *et al,* 2014. The analysis of variance due to SCA was more than GCA variance for all the characters exhibiting preponderance of non-additive gene effect except leaf rolling. Dominance of SCA indicates the preponderance of non-additive gene action. Here breeding method like heterosis breeding should be used (Singh and Narayanan, 2013). Several workers have reported the greater importance of SCA

Table 1: Pedigree of lines, testers and their codes

Sl.No.	Pedigree	Codes
	Lines	
1	(CML427-3-B/[Ent 320:92 SEW2-77/{DMRSER-W} Early Sel.-#-1-2-4-BCML386]–B–11-3–B–2–#-B*4–1-B)–B-361	P_1
2	(CML474/[Ent 320:92 SEW2-77/{DMRESR – W} Early Sel. #1-2-4-B/CML386]-B-11-3-B-2-#-B*4-1-B)B-366	P_2
3	DTPYC$_9$-F$_{38}$-5-2-1-1-2-2-1-B$_4$	P_3
4	CL-RCY08-(CL-03618*CML287)B-13-1-1-B*B	P_4
5	EC-672848	P_5
6	CML-161	P_6
7	EC-611064	P_7
8	P$_{62}$C$_6$-BBB-21-BBB	P_8
9	CL-RCY08-(CL-03618*CML287)-B-B-1-1-B*	P_9
	Tester	
10	BML-7	P_{10}
11	CLO-2450	P_{11}
12	CML-451	P_{12}
13	SUWAN	P_{13}

Table 2: Pedigree of crosses and their codes

Sl.No.	Pedigree of crosses	Code
1	(CML427-3-B/[Ent 320:92 SEW2-77/{DMRSER-W} Early Sel.-#-1-2-4-BCML386] –B–11-3–B–2–#-B*4–1-B)–B-361 x BML-7	$P_1 \times P_{10}$
2	(CML427-3-B/[Ent 320:92 SEW2-77/{DMRSER-W} Early Sel.-#-1-2-4-BCML386]–B–11-3– B–2–#-B*4–1-B)–B-361 x CLO-2450	$P_1 \times P_{11}$
3	(CML427-3-B/[Ent 320:92 SEW2-77/{DMRSER-W} Early Sel.-#-1-2-4-BCML386]–B– 11-3–B–2–#-B*4–1-B)–B-361 x CML-451	$P_1 \times P_{12}$
4	(CML427-3-B/[Ent 320:92 SEW2-77/{DMRSER-W} Early Sel.-#-1-2-4-BCML386]–B– 11-3–B–2–#-B*4–1-B)–B-361 x SUWAN	$P_1 \times P_{13}$
5	(CML474/[Ent 320:92 SEW2-77/{DMRESR – W} Early Sel. #1-2-4-B/CML386]-B-11- 3-B-2-#-B*4-1-B)B-366 x BML-7	$P_2 \times P_{10}$
6	(CML474/[Ent 320:92 SEW2-77/{DMRESR – W} Early Sel. #1-2-4-B/CML386]-B- 11-3-B-2-#-B*4-1-B)B-366 x CLO-2450	$P_2 \times P_{11}$
7	(CML474/[Ent 320:92 SEW2-77/{DMRESR – W} Early Sel. #1-2-4-B/CML386]-B- 11-3-B-2-#-B*4-1-B)B-366 x CML-451	$P_2 \times P_{12}$
8	(CML474/[Ent 320:92 SEW2-77/{DMRESR – W} Early Sel. #1-2-4-B/CML386]-B-11- 3-B-2-#-B*4-1-B)B-366 x SUWAN	$P_2 \times P_{13}$
9	DTPYC$_9$-F$_{38}$-5-2-1-1-2-2-1-B$_4$ x BML-7	$P_3 \times P_{10}$
10	DTPYC$_9$-F$_{38}$-5-2-1-1-2-2-1-B$_4$ x CLO-2450	$P_3 \times P_{11}$
11	DTPYC$_9$-F$_{38}$-5-2-1-1-2-2-1-B$_4$ x CML-451	$P_3 \times P_{12}$
12	DTPYC$_9$-F$_{38}$-5-2-1-1-2-2-1-B$_4$ x SUWAN	$P_3 \times P_{13}$
13	CL-RCY08-(CL-03618*CML287)B-13-1-1-B*B x BML-7	$P_4 \times P_{10}$
14	CL-RCY08-(CL-03618*CML287)B-13-1-1-B*B x CLO-2450	$P_4 \times P_{11}$
15	CL-RCY08-(CL-03618*CML287)B-13-1-1-B*B x CML-451	$P_4 \times P_{12}$
16	CL-RCY08-(CL-03618*CML287)B-13-1-1-B*B x SUWAN	$P_4 \times P_{13}$
17	EC-672848 x BML-7	$P_5 \times P_{10}$
18	EC-672848 x CLO-2450	$P_5 \times P_{11}$
19	EC-672848 x CML-451	$P_5 \times P_{12}$
20	EC-672848 x SUWAN	$P_5 \times P_{13}$
21	CML-161 x BML-7	$P_6 \times P_{10}$
22	CML-161 x CLO-2450	$P_6 \times P_{11}$
23	CML-161 x CML-451	$P_6 \times P_{12}$
24	CML-161 x SUWAN	$P_6 \times P_{13}$
25	EC-611064 x BML-7	$P_7 \times P_{10}$
26	EC-611064 x CLO-2450	$P_7 \times P_{11}$
27	EC-611064 x CML-451	$P_7 \times P_{12}$
28	EC-611064 x SUWAN	$P_7 \times P_{13}$
29	P$_{62}$C$_6$-BBB-21-BBB x BML-7	$P_8 \times P_{10}$
30	P$_{62}$C$_6$-BBB-21-BBB x CLO-2450	$P_8 \times P_{11}$
31	P$_{62}$C$_6$-BBB-21-BBB x CML-451	$P_8 \times P_{12}$
32	P$_{62}$C$_6$-BBB-21-BBB x SUWAN	$P_8 \times P_{13}$
33	CL-RCY08-(CL-03618*CML287)-B-B-1-1-B* x BML-7	$P_9 \times P_{10}$
34	CL-RCY08-(CL-03618*CML287)-B-B-1-1-B* x CLO-2450	$P_9 \times P_{11}$
35	CL-RCY08-(CL-03618*CML287)-B-B-1-1-B* x CML-451	$P_9 \times P_{12}$
36	CL-RCY08-(CL-03618*CML287)-B-B-1-1-B* x SUWAN	$P_9 \times P_{13}$

Table 3: Proportional contribution of lines, testers and their interaction

Sl. No	Characters	Contribution of females (%)	Contribution of males (%)	Contribution of females x males (%)	GCA	SCA	GCA / SCA
1.	Days 50% tasseling	23.96	10.18	66.45	0.17	0.53	0.32
2.	Days 50% silking	26.32	9.65	64.02	0.28	1.98	0.14
3.	Pollen shedding duration	43.67	3.70	53.61	0.08	0.64	0.12
4.	Days to 75 % brown husk	31.55	4.05	64.38	0.24	1.21	0.19
5.	Plant height	51.06	6.88	42.04	27.01	88.19	0.30
6.	Ear height	41.75	2.53	55.70	3.01	16.60	0.18
7.	Leaf firing	20.54	1.40	78.04	0.14	0.22	0.63
8.	Leaf rolling	28.78	9.84	61.36	0.17	0.17	1.00
9.	Tassel blast	43.11	7.74	49.14	0.13	0.22	0.59
10.	Post flowering stalk rot	31.88	0.45	67.65	0.20	0.30	0.66
11.	Cob length	24.22	10.50	65.26	0.49	2.08	0.23
12.	Cob diameter	48.56	3.98	47.44	0.10	0.23	0.43
13.	Number of kernel rows per cob	41.27	0.53	58.18	0.15	0.26	0.57
14.	Number of kernels per row	39.47	16.21	44.31	3.01	14.54	0.20
15.	100 Seed weight	46.05	0.54	53.39	1.84	4.09	0.44
16.	Grain yield	39.17	0.41	60.40	454712.06	622717.06	0.73
17.	Harvest index	48.20	0.19	51.59	1.81	3.23	0.56
18.	Shelling percentage	42.61	3.02	54.35	19.72	26.18	0.75

Table 4: Estimates of general combining ability (GCA) effect of parents

	Daysto 50% tasseling	Daysto 50% silking	Pollen shedding duration	Days to 75 % brown husk	Plant height	Ear height	Leaf firing	Leaf rolling	Tassel blast	Post flowering stalkrot
P_1	0.602	1.222*	0.620**	1.944*	13.611**	0.796	-0.509**	-0.185	-0.472**	-0.574**
P_2	-0.565	-0.861	-0.296	0.528	-0.306	-0.620	-0.176	-0.519**	-0.306**	-0.407**
P_3	-0.981*	-0.528	0.454**	-1.472	1.694*	5.130**	0.574**	0.731**	0.861**	0.676**
P_4	-0.148	0.472	0.620**	-0.389	5.028**	2.380**	-0.176	-0.102	-0.139	0.176
P_5	0.185	-0.361	-0.546**	0.861	-0.972	-3.204**	-0.093	-0.602**	-0.556**	-0.324**
P_6	0.769	0.639	-0.130	0.611	-2.222**	1.713*	0.241*	0.065	0.528**	-0.157
P_7	-0.065	-0.278	-0.213	-0.639	3.944**	0.713	0.324**	-0.185	0.278**	-0.074
P_8	-0.565	-1.111*	-0.546**	-2.389*	-12.389**	-2.537**	-0.009	0.398**	-0.222*	-0.157
P_9	0.769	0.806	0.037	0.944	-8.389**	-4.370**	-0.176	0.398**	0.028	0.843**
P_{10}	-0.185	-0.148	0.037	-0.194	4.380**	-0.259	0.509**	0.315**	0.407**	0.269**
P_{11}	-0.037	0.185	0.222*	-0.602	-1.139*	-0.556	-0.491**	-0.574**	-0.333**	0.620**
P_{12}	-0.444	-0.667*	-0.222*	0.139	1.269*	1.556**	0.028	-0.019	-0.074	0.009
P_{13}	0.667*	0.630*	-0.037	0.657	-4.509**	-0.741	-0.046	0.278**	0.000	0.343**

Table 4: Cont.....

	Cob length	Cob diameter	Number of kernel rows per cob	Number of kernels per row	100 Seed weight	Grain yield	Harvest index	Shelling percentage
P_1	1.317*	0.406**	-0.074	2.954**	1.213	658.787**	1.287	5.596**
P_2	0.625	0.297**	-1.407**	0.537	-0.620	550.870**	1.634*	3.816**
P_3	-0.742	-0.453**	0.926**	-3.130**	0.713	-1198.046**	-3.308**	-4.898**
P_4	0.250	0.181**	-0.074	1.537*	-0.787	-174.213*	0.683	-0.122
P_5	-0.033	0.331**	0.759*	-0.630	2.463**	570.037**	2.391**	3.969**
P_6	-0.583	-0.019	-0.407	-2.213**	-1.287*	-9.546	-0.135	-1.196**
P_7	-0.133	-0.011	-0.074	-1.296*	-0.454	542.454**	0.299	1.561**
P_8	-0.758	-0.328**	0.093	0.954	-0.037	-292.463**	-0.791	-2.991**
P_9	0.058	-0.403**	0.259	1.287*	-1.204	-647.880**	-2.061**	-5.736**
P_{10}	0.359	-0.286**	-0.019	-0.259	-0.157	-717.167**	-1.907**	-3.666**
P_{11}	0.048	0.440**	-0.093	0.926*	2.139**	1222.278**	2.544**	6.610**
P_{12}	0.800*	-0.179**	0.426*	1.630**	-0.565	-355.685**	-0.813	-2.618**
P_{13}	-1.270**	0.025	-0.315	-2.296**	-1.417**	-149.426**	0.176	-0.327

variance than the GCA variance for grain field and other yield contributing characters Aminu *et al.,* 2014; Gowda *et al.,* 2013; Khodarahmpour 2011; Jebraj *et al.,* 2010; Vijayabharathi *et al.,* 2009; Atanaw *et al.,* 2003; Dodiya and Joshi, 2003; Konak *et al.,* 2001. For leaf rolling both GCA and SCA were equally important hence reciprocal recurrent selection for population improvement is taken into consideration (Singh and Narayanan, 2013). Some workers

Table 5: Estimates of specific combining ability (SCA) effect of crosses

Crosses	Daysto 50% tasseling	Daysto 50% silking	Pollen shedding duration	Days to75 % brown husk	Plant height	Ear height	Leaf firing	Leaf rolling	Tassel blast	Post flowering stalk rot
$P_1 \times P_{10}$	-0.898	-1.852	-0.954**	-3.389	-7.463**	0.093	-0.676**	0.185	-0.157	-0.019
$P_1 \times P_{11}$	-0.380	-0.852	-0.472	0.352	3.722*	1.056	0.991**	0.074	0.250	0.537*
$P_1 \times P_{12}$	-0.360	0.333	0.639*	0.611	6.315**	-4.056*	-0.194	0.519*	-0.009	-0.093
$P_1 \times P_{13}$	1.583	2.370*	0.787*	2.426	-2.574	2.907	-0.120	-0.778**	-0.083	-0.426*
$P_2 \times P_{10}$	-1.065	-0.102	0.963**	4.028*	9.787**	1.176	-0.009	-0.148	0.343	-0.519*
$P_2 \times P_{11}$	0.120	-0.769	-0.889**	-3.898*	5.306*	0.861	-0.009	0.407*	0.083	0.370
$P_2 \times P_{12}$	1.528	1.417	-0.111	1.028	-6.435**	-2.972	0.472*	0.185	-0.176	-0.259
$P_2 \times P_{13}$	-0.583	-0.546	0.037	-1.157	-8.657**	2.657	-0.454*	-0.444*	-0.250	0.407
$P_3 \times P_{10}$	-0.315	0.231	0.546	1.361	-2.213	-4.574**	0.241	-0.065	-0.824**	0.065
$P_3 \times P_{11}$	-0.463	-0.435	0.028	0.435	2.972	3.389*	-0.759**	0.157	-0.083	-0.380
$P_3 \times P_{12}$	0.611	0.417	-0.194	-1.639	0.231	3.278*	0.722**	0.269	0.324	0.991**
$P_3 \times P_{13}$	0.167	-0.213	-0.380	-0.157	-0.991	-2.093	-0.204	-0.361	0.583**	-0.676**
$P_4 \times P_{10}$	1.519	3.231**	1.713**	0.611	1.787	1.176	0.324	0.435*	0.176	-0.435*
$P_4 \times P_{11}$	-0.630	-0.102	0.528	-0.315	-3.028	-0.528	0.324	-0.009	-0.083	-0.213
$P_4 \times P_{12}$	0.444	0.083	-0.361	2.278	10.231**	1.361	-0.528*	-0.565**	0.324	-0.176
$P_4 \times P_{13}$	-1.333	-3.213**	-1.880**	-2.574	-8.991**	-1.009	-0.120	0.139	-0.417*	0.824**
$P_5 \times P_{10}$	-0.481	-0.935	-0.454	-0.639	0.454	2.426	-0.093	-0.398	-0.407*	-0.602**
$P_5 \times P_{11}$	-0.630	1.269	-0.639*	-2.231	-7.694**	4.722**	-0.093	0.491*	0.333	0.287
$P_5 \times P_{12}$	-0.222	-0.083	0.139	1.361	12.898**	-1.389	0.389	-0.065	0.074	-0.343
$P_5 \times P_{13}$	1.333	2.287*	0.954**	1.509	-5.657**	-5.759**	-0.204	-0.028	0.000	0.657**
$P_6 \times P_{10}$	-1.065	-1.269	-0.204	-0.056	-0.630	-0.157	0.426*	0.269	0.509**	0.565**
$P_6 \times P_{11}$	2.120*	3.398**	1.278**	2.352	7.22**	1.139	-0.426*	-0.176	-0.750**	0.120
$P_6 \times P_{12}$	-0.472	-0.750	0.278	-1.389	-9.852**	0.028	0.056	-0.398	-0.009	-0.509*
$P_6 \times P_{13}$	-0.583	-1.380	-0.796*	-0.907	3.259	-1.009	0.796**	0.306	0.250	-0.176
$P_7 \times P_{10}$	0.435	-0.352	-0.787*	-1.139	-7.130**	-2.824	0.157	0.185	-0.574**	0.148
$P_7 \times P_{11}$	0.954	1.315	0.361	2.935	-14.278**	-5.528**	0.157	0.074	0.500**	0.037
$P_7 \times P_{12}$	-0.639	-0.833	-0.194	-1.139	5.981**	8.028**	-0.361	-0.481	-0.759**	-0.593**
$P_7 \times P_{13}$	-0.750	-0.130	0.620*	-0.657	15.426**	0.324	0.046	0.222	0.833**	0.407
$P_8 \times P_{10}$	-0.065	-0.852	-0.787*	1.278	11.870**	-5.574**	0.824**	-0.065	0.593**	0.231
$P_8 \times P_{11}$	-0.546	-0.858	-0.306	-0.981	-7.944**	1.056	-0.176	-0.509*	0.000	0.120
$P_8 \times P_{12}$	-0.139	0.333	0.472	-0.722	-7.352**	3.944*	-0.694**	0.602**	-0.259	0.491*
$P_8 \times P_{13}$	0.750	1.370	0.620*	0.426	3.426*	0.574	0.046	-0.028	-0.333	-0.843**
$P_9 \times P_{10}$	1.935*	1.898*	-0.037	-2.056	-6.463**	8.259**	-0.343	-0.398	0.343	0.565**
$P_9 \times P_{11}$	-0.546	-0.435	0.111	1.352	13.722**	-4.44**	-0.009	-0.509*	-0.250	-0.880**
$P_9 \times P_{12}$	-0.806	-0.917	-0.111	-0.389	-12.019**	-7.22**	0.139	-0.065	0.491**	0.491*
$P_9 \times P_{13}$	0.583	-0.546	0.037	1.093	4.759**	3.407*	0.213	0.972**	-0.583**	-0.176

Table 5: Cont.....

Crosses	Cob length	Cob diameter	Number of kernel rows per cob	Number of kernels per row	100 Seed weight	Grain yield	Harvest index	Shelling percentage
$P_1 \times P_{10}$	-0.609	0.294**	0.519	3.676**	4.157**	487.250**	1.407	2.466**
$P_1 \times P_{11}$	-3.298**	-0.465**	-0.074	-4.843**	-0.139	-1094.194**	-3.551*	-5.274**
$P_1 \times P_{12}$	4.917**	0.087	-0.593	3.454**	-0.769	-413.898**	1.530	0.911
$P_1 \times P_{13}$	-1.009	0.083	0.148	-2.287	-3.250*	1020.843**	0.614	1.897*
$P_2 \times P_{10}$	2.682*	0.136*	-0.148	0.759	-2.009	-38.500	1.800	0.796
$P_2 \times P_{11}$	-0.873	-0.190**	-0.074	-0.426	1.028	-113.278	0.016	0.073
$P_2 \times P_{12}$	-1.458	-0.038	-0.593	-2.463*	-0.935	-341.648*	-1.267	-3.149**
$P_2 \times P_{13}$	-0.351	0.092	0.815	2.130	1.917	493.426**	-0.549	2.280*
$P_3 \times P_{10}$	-0.384	0.653**	-0.481	0.093	-4.676**	638.417**	1.132	12.742**
$P_3 \times P_{11}$	-0.340	0.127*	0.259	-4.426**	1.694	-323.695*	0.767	-2.260*
$P_3 \times P_{12}$	-0.492	-0.455**	0.407	1.204	0.398	-226.398	-1.945	-6.855**
$P_3 \times P_{13}$	1.216	-0.325**	-0.185	3.130*	2.583	-88.324	0.046	-3.627**
$P_4 \times P_{10}$	-0.676	0.053	-0.148	-1.574	0.824	190.250	-0.856	-1.940*
$P_4 \times P_{11}$	2.702*	-0.473**	1.259	4.574**	-1.139	-1034.861**	-1.634	-5.016**
$P_4 \times P_{12}$	-0.717	0.245**	-0.593	0.537	-0.102	689.102**	0.124	2.399**
$P_4 \times P_{13}$	-1.309	0.175**	-0.519	-3.537**	0.417	155.509	2.365	4.558**
$P_5 \times P_{10}$	0.007	0.103	-0.315	-0.407	1.241	57.000	0.069	0.196
$P_5 \times P_{11}$	1.452	-0.190**	0.426	2.741*	3.944**	213.556	-1.699	-1.067
$P_5 \times P_{12}$	-2.067*	0.129*	-0.093	-4.963**	-1.352	-5.815	1.903	2.278*

Table 5: Cont.....

Crosses	Cob length	Cob diameter	Number of kernel rows per cob	Number of kernels per row	100 Seed weight	Grain yield	Harvest index	Shelling percentage
$P_5 x P_{13}$	0.607	-0.042	-0.019	2.630*	-3.833**	-264.741	-0.273	-1.407
$P_6 x P_{10}$	0.157	-0.614**	0.185	0.509	-0.676	-506.083**	-0.187	-2.349*
$P_6 x P_{11}$	0.335	0.260**	0.926	-1.343	-0.306	730.806**	1.768	2.705**
$P_6 x P_{12}$	-1.250	0.245**	-0.259	-2.046	0.731	39.435	0.046	1.756
$P_6 x P_{13}$	0.757	0.108	-0.852	2.880*	0.250	-264.157	-1.627	-2.112*
$P_7 x P_{10}$	-0.959	0.278**	0.519	-4.741**	1.157	-320.750*	0.192	-1.899*
$P_7 x P_{11}$	-0.781	0.119	-1.407*	-1.593	-3.139*	69.806	0.204	0.588
$P_7 x P_{12}$	1.433	0.704**	0.741	7.370**	0.231	1328.102**	2.328	8.173**
$P_7 x P_{13}$	0.307	-1.100**	0.148	-1.037	1.750	-1077.157**	-2.724*	-6.862**
$P_8 x P_{10}$	-0.034	-0.472**	0.352	-4.324**	0.074	-338.167*	-2.488	-6.238**
$P_8 x P_{11}$	1.477	0.369**	0.426	3.824**	0.444	694.389**	1.807	3.860**
$P_8 x P_{12}$	-0.775	-0.480**	-0.093	2.454*	1.148	-685.982**	-1.612	-3.725**
$P_8 x P_{13}$	-0.668	0.583**	-0.685	-1.954	-1.667	329.759*	2.293	6.130**
$P_9 x P_{10}$	-0.184	-0.431**	-0.481	6.009**	-0.093	-169.417	-1.068	-3.773**
$P_9 x P_{11}$	-0.673	0.444**	-1.741**	1.491	-2.389	857.472**	2.321	6.391**
$P_9 x P_{12}$	0.408	-0.438**	1.074	-5.546**	0.648	-382.898**	-1.108	-1.787
$P_9 x P_{13}$	0.449	0.425**	1.148	-1.954	1.833	-305.157*	-0.144	-0.832

Table 6: Estimates of standard heterosis

Crosses	Days to 50% tasseling	Days to 50% silking	Pollen shedding duration	Days to 75%brown husk	Plant height	Ear height	Leaf firing	Leaf rolling	Tassel blast
$P_1 x P_{10}$	-4.10*	-6.10**	-27.78**	-4.11	5.08**	-9.29*	0.00	100.00**	33.33
$P_1 x P_{11}$	-3.08	-4.23*	-16.67*	-0.68	9.01**	-8.20*	66.67*	0.00	0.00
$P_1 x P_{12}$	-3.59	-3.76*	-5.56	0.34	12.47**	-13.11**	0.00	100.00**	0.00
$P_1 x P_{13}$	1.03	0.94	0.00	2.74	2.31	-5.46	0.00	0.00	0.00
$P_2 x P_{10}$	-6.15**	-6.57**	-11.11	2.05	7.39**	-9.84*	100.00**	33.33	100.00**
$P_2 x P_{11}$	-4.10*	-7.04**	-38.89**	-6.51*	0.46	-13.66**	0.00	0.00	0.00
$P_2 x P_{12}$	-2.56	-5.16**	-33.33**	-0.68	-6.00**	-13.66**	100.00**	33.33	0.00
$P_2 x P_{13}$	-4.10*	-6.10**	-27.78**	-2.40	-11.55**	-8.20*	0.00	0.00	0.00
$P_3 x P_{10}$	-5.64**	-5.63**	-5.56	-2.74	0.46	-9.84*	200.00**	166.67**	100.00**
$P_3 x P_{11}$	-5.64**	-6.10**	-11.11	-4.11	0.23	2.73	0.00	100.00**	100.00**
$P_3 x P_{12}$	-4.62*	-6.10**	-22.22**	-5.48*	0.00	6.01	200.00**	166.67**	166.67**
$P_3 x P_{13}$	-3.59	-5.16**	-22.22**	-3.42	-4.85**	-6.56	100.00**	133.33**	200.00**
$P_4 x P_{10}$	-1.54	0.00	16.67*	-2.40	5.54**	-4.92	133.33**	133.33**	100.00**
$P_4 x P_{11}$	-4.62*	-4.23*	0.00	-3.77	-1.62	-8.20*	33.33	0.00	0.00
$P_4 x P_{12}$	-3.59	-5.16**	-22.22**	-0.34	9.24**	-3.28	0.00	0.00	66.67*
$P_4 x P_{13}$	-4.62*	-7.98**	-44.44**	-4.79	-8.08**	-9.29*	33.33	100.00**	0.00
$P_5 x P_{10}$	-4.10*	-7.04**	-38.89**	-2.40	0.46	-12.02**	100.00**	0.00	0.00
$P_5 x P_{11}$	-4.10*	-7.04**	-38.89**	-4.45	-9.01**	-8.74*	0.00	0.00	0.00
$P_5 x P_{12}$	-4.10*	-6.57**	-33.33**	0.00	6.93**	-15.30**	100.00**	0.00	0.00
$P_5 x P_{13}$	0.00	-1.41	-16.67**	0.68	-9.93**	-26.23**	33.33	33.33	0.00
$P_6 x P_{10}$	-4.10*	-6.10**	-27.78**	-2.05	-1.15	-8.20*	100.00**	133.33**	200.00**
$P_6 x P_{11}$	1.03	0.94	0.00	0.00	0.46	-6.56	0.00	0.00	0.00
$P_6 x P_{12}$	-3.59	-6.10**	-33.33**	-3.08	-9.70**	-4.92	100.00**	33.33	100.00**
$P_6 x P_{13}$	-2.05	-5.16**	-38.89**	-2.05	-4.62**	-10.38**	166.67**	133.33**	133.33**
$P_7 x P_{10}$	-3.08	-6.10**	-38.89**	-4.45	-1.39	-14.21**	166.67**	100.00**	66.67*
$P_7 x P_{11}$	-2.05	-3.29	-16.67*	-0.68	10.16**	-19.13**	66.67*	0.00	100.00**
$P_7 x P_{12}$	-5.13**	-7.51**	-33.33**	-4.11	5.54**	6.56	66.67*	0.00	0.00
$P_7 x P_{13}$	-3.59	-4.69*	-16.67*	-3.08	8.08**	-9.84*	100.00**	100.00**	166.67**
$P_8 x P_{10}$	-4.62*	-7.98**	-44.44**	-3.77	0.46	-24.04**	200.00**	133.33**	133.33**
$P_8 x P_{11}$	-5.13**	-7.51**	-33.33**	-6.51	-17.09**	-13.66**	0.00	0.00	0.00
$P_8 x P_{12}$	-5.13**	-7.04**	-27.78**	-5.48	-15.01**	-5.46	0.00	166.67**	0.00
$P_8 x P_{13}$	-2.05	-3.76*	-22.22**	-3.77	-11.55**	-14.75**	66.67*	133.33**	0.00
$P_9 x P_{10}$	0.51	-1.41	-22.22**	-3.77	-9.47**	-4.37	66.67*	100.00**	133.33**
$P_9 x P_{11}$	-3.08	-4.23*	-16.67*	-0.68	0.69	-25.68**	0.00	0.00	0.00
$P_9 x P_{12}$	-4.10*	-6.10**	-27.78**	-1.71	-15.47**	-26.78**	66.67*	100.00**	100.00**
$P_9 x P_{13}$	-2.05	-3.76*	-22.22**	0.34	-7.85**	-13.11**	66.67*	233.33**	0.00

Table 6: Cont....

Crosses	Post flowering stalk rot	Cob length	Cob Diameter	Number of kernel rows per cob	Number of kernels per row	100 Seed weight	Grain yield	Harvest index	Shelling percentage
P_1 x P_{10}	33.33	1.67	14.96**	5.00	61.19**	22.86**	-8.72	7.22	1.00
P_1 x P_{11}	0.00	-17.12	14.17**	0.00	28.36**	14.29	-0.14	5.72	4.36*
P_1 x P_{12}	0.00	39.04**	12.60**	0.00	68.66**	0.00	-21.67**	10.83	0.33
P_1 x P_{13}	0.00	-10.65	17.32**	0.00	25.37**	-14.29	17.70**	11.05	4.66**
P_2 x P_{10}	0.00	17.95	8.66**	-10.00	37.31**	-11.43	-23.92**	9.42	-3.55*
P_2 x P_{11}	0.00	-6.26	18.11**	-10.00	37.31**	11.43	20.81**	17.33**	9.07**
P_2 x P_{12}	0.00	-5.22	7.09**	-10.00	31.34**	-8.57	-22.53**	3.56	-7.38**
P_2 x P_{13}	100.00**	-10.86	14.96**	-5.00	34.33**	0.00	2.45	8.63	2.82
P_3 x P_{10}	166.67**	-9.81	3.15	5.00	17.91*	-17.14*	-49.64**	-7.23	0.72
P_3 x P_{11}	33.33	-11.48	7.87**	10.00	2.99	20.00**	-26.20**	4.90	-5.53**
P_3 x P_{12}	233.33**	-7.72	-20.47**	15.00*	31.34**	2.86	-61.71**	-13.12*	-23.80**
P_3 x P_{13}	100.00**	-9.60	-12.60**	5.00	22.39**	8.57	-53.45**	-4.27	-16.50**
P_4 x P_{10}	66.67*	-5.43	3.94	0.00	31.34**	0.00	-35.83**	-1.29	-12.37**
P_4 x P_{11}	0.00	13.78	8.66**	10.00	64.18**	1.43	-18.70**	9.62	-2.86
P_4 x P_{12}	66.67*	-2.92	11.02**	0.00	49.25**	-5.71	-15.19**	4.87	-5.26**
P_4 x P_{13}	200.00**	-19.21*	14.17**	-5.00	13.43	-7.14	-23.04**	14.45*	0.63
P_5 x P_{10}	0.00	-2.92	8.66**	5.00	26.87**	15.71*	-21.17**	6.53	-4.15*
P_5 x P_{11}	0.00	4.18	18.90**	10.00	46.27**	37.14**	29.11**	14.49*	7.77*
P_5 x P_{12}	0.00	-13.15	11.81**	10.00	14.93	2.86	-14.01**	15.21**	-0.01
P_5 x P_{13}	133.33**	-8.98	12.60**	5.00	31.34**	-11.43	-15.27**	11.69*	-1.85
P_6 x P_{10}	133.33**	-5.43	-16.54**	0.00	23.88**	-8.57	-48.58**	-1.73	-14.33**
P_6 x P_{11}	0.00	-6.26	21.26**	5.00	20.90**	2.86	27.61**	17.28**	5.92**
P_6 x P_{12}	0.00	-11.48	6.30**	0.00	20.90**	-4.29	-26.83**	2.21	-7.52**
P_6 x P_{13}	66.67*	-11.48	7.87**	-10.00	25.37**	-10.00	-29.16**	0.18	-9.61**
P_7 x P_{10}	100.00**	-9.60	4.72*	5.00	4.48	2.86	-30.90**	0.68	-10.10**
P_7 x P_{11}	0.00	-10.44	18.11**	-10.00	23.88**	-5.71	25.00**	13.93*	6.77**
P_7 x P_{12}	0.00	8.14	17.32**	10.00	67.16**	-2.86	17.33**	10.27	4.60**
P_7 x P_{13}	166.67**	-9.39	6.30**	10.00	19.40*	-2.86	-45.46**	-1.14	-13.92**
P_8 x P_{10}	133.33**	-11.48	-20.47**	0.00	11.94	0.00	-35.42**	-1.79	-12.24**
P_8 x P_{11}	100.00**	-7.72	-20.47**	5.00	16.420	0.00	-51.34**	-10.51	-21.84**
P_8 x P_{12}	0.00	-0.21	16.54**	5.00	58.21**	11.43	19.95**	15.45**	5.08**
P_8 x P_{13}	100.00**	-9.60	-18.11**	5.00	55.22**	2.86	-51.02**	-4.66	-17.14**
P_9 x P_{10}	0.00	-21.50*	11.81**	-5.00	17.91*	-12.86	-21.70**	9.86	-1.12
P_9 x P_{11}	233.33**	-3.55	-21.26**	0.00	64.18**	-5.71	-55.82**	-10.06	-22.21**
P_9 x P_{12}	0.00	-8.56	16.54**	-10.00	49.25**	-5.71	15.34**	13.21*	4.80**
P_9 x P_{13}	200.00**	2.92	-18.90**	15.00*	20.90**	-4.29	-52.27**	-6.93	-18.21**

have shown equal importance of both GCA and SCA component of genetic variance Amiruzza man *et al.,* 2013; Debnath and Sarkar 1990; Sharma *et al.,* 1982.

General combining ability (GCA) effect

Estimation of gca effect (Table 4) revealed that P_3 (-0.981) showed earlier for days to 50% tasseling.P_8 (-1.111) and P_{12}(-0.667) were earlier for days to 50% silking. P_1(0.620), P_3(0.454), P_4(0.620) and P_{11}(0.222) were good combiner for pollen shedding duration.P_8(-2.389) was earlier for days to 75% brown husk.P_8(-12.389),P_9(-8.389), P_6 (-2.222), P_{13}(-4.509) and P_{11} (-1.139) were good combiner for short plant height. P_9 (-4.370),P_5(-3.204) and P_8(-2.537) were good combiner for ear height.P_1(-0.509) and P_{11}(-0.491) showed good combiner for leaf firing.P_5(-0.602), P_2(-0.519) and P_{11}(-0.574) were good combiner for leaf rolling.P_5(-0.556), P_1 (-0.472), P_2 (-0.306),P_8(-0.222) and P_{11}(-0.333) expressed as good combiner for tassel blast. P_1 (-0.574), P_2(-0.407) and P_5(-0.324) showed good combiner for post flowering stalk rot.P_1(1.317) and P_{12}(0.800) were identified as good combiner for cob length. P_1 (0.406), P_5 (0.331), P_2 (0.297), P_4(0.181) and P_{11}(0.440) were identified as good combiner for cob diameter. P_3 (0.926), P_5(0.759) and P_{12}(0.426) were good combiner for number of kernel rows per cob. P_1(2.954), P_4 (1.537), P_9(1.287), P_{12}(1.630) andP_{11}(0.926) identified as good combiner for number of kernels per row. P_5(2.463) and P_{11} (2.139)identified as good combiner for 100 seed weight. P_1(658.787), P_5 (570.037), P_2 (550.870), P_7(542.454) and P_{11}(1222.278) identified as good combiner for grain yield and shelling percentage. P_5(2.391), P_2(1.634) and P_{11}(2.544) identified as good combiner for harvest index. Hence by considering above, parents P_1, P_2, P_5, P_8 and P_{11} were considered good for most of the characters under study.So these parents could be used in hybrid breeding programme aimed for increasing grain yield. The high significant positive gca effects for different characters could be helpful in identifying outstanding parents with favourable alleles for yield and other desirable components. The high gca effects were due to additive effects and additive × additive gene effects (Griffing 1956; Sprague 1966). Locatelli *et al.* 2001 reported that general combining ability was good indicator of inbred line performance at hybrid combinations. Paul and Duara (1991) reported that parents with high gca always produce with high estimates of SCA.

Specific combining ability (SCA) effect

Estimation of SCA effect (Table-5) revealed that there was no desirable significant crosses obtained for earlier tasseling, number of kernel rows per cob and harvest index. However, $P_4 \times P_{13}$(-3.213) showed earlier silking. For pollen shedding duration some of the good crosses obtained were $P_1 \times P_{12}$ (0.639), $P_1 \times P_{13}$ (0.787) $P_2 \times P_{10}$ (0.963) $P_4 \times P_{10}$ (1.713) $P_5 \times P_{13}$ (0.954), $P_6 \times P_{11}$ (1.278) $P_7 \times P_{13}$(0.620) and $P_8 \times P_{13}$ (0.620). Similarly, best combination for plant height was $P_1 \times P_{10}$ (-7.463) $P_2 \times P_{12}$ (-6.435) $P_2 \times P_{13}$ (-8.657) $P_4 \times P_{13}$ (-8.991), $P_5 \times P_{11}$ (-7.694) $P_5 \times P_{13}$ (-5.657) $P_6 \times P_{12}$ (-9.852) $P_7 \times P_{10}$ (-7.130), $P_7 \times P_{11}$ (-14.278) $P_8 \times P_{11}$ (-7.944) $P_8 \times P_{12}$ (-7.352) $P_9 \times P_{10}$ (-6.463) and $P_9 \times P_{12}$ (-12.019). Related to the ear height crosses with good sca were $P_9 \times P_{12}$ (-7.22),$P_5 \times P_{13}$(-5.759), $P_8 \times P_{10}$ (-5.574), $P_7 \times P_{11}$ (-5.528), $P_3 \times P_{10}$ (-4.574), $P_9 \times P_{11}$(-4.44) and $P_1 \times P_{12}$(-4.056). With respect to leaf firing better crosses were $P_3 \times P_{11}$ (-0.759), $P_8 \times P_{12}$ (-0.694), $P_1 \times P_{10}$ (-0.676), $P_4 \times P_{12}$ (-0.528), $P_2 \times P_{13}$ (-0.454) and $P_6 \times P_{11}$ (-0.426). Some of the crosses related to leaf rolling were $P_1 \times P_{13}$(-0.778),$P_4 \times P_{12}$ (-0.565), $P_8 \times P_{11}$ (-0.509), $P_9 \times P_{11}$(-0.509) and $P_2 \times P_{13}$(-0.444) exhibited the best combination. Related to the tassel blast some of the crosses which showed good combination were $P_3 \times P_{10}$(-0.824), $P_7 \times P_{12}$ (-0.759), $P_6 \times P_{11}$ (-0.750), $P_9 \times P_{13}$ (-0.583), $P_7 \times P_{10}$ (-0.574), $P_4 \times P_{13}$(-0.417) and $P_5 \times P_{10}$ (-0.407). Some of the crosses which showed resistant against post flowering stalk rot were $P_9 \times P_{11}$ (-0.880),$P_8 \times P_{13}$ (-0.843), $P_3 \times P_{13}$ (-0.676), $P_5 \times P_{10}$ (-0.602), $P_7 \times P_{12}$ (-0.593), $P_6 \times P_{12}$ (-0.509), $P_2 \times P_{10}$ (-0.519), $P_4 \times P_{10}$(-0.435) and $P_1 \times P_{13}$ (-0.426). For cob length better combination were$P_1 \times P_{12}$ (4.917), $P_4 \times P_{11}$(2.702) and $P_2 \times P_{10}$ (2.682). However, most of the crosses obtained good for cob diameter which were $P_7 \times P_{12}$ (0.704), $P_3 \times P_{10}$ (0.653), $P_8 \times P_{13}$ (0.583), $P_9 \times P_{11}$ (0.444), $P_9 \times P_{13}$ (0.425), $P_8 \times P_{11}$ (0.369), $P_1 \times P_{10}$(0.294), $P_7 \times P_{10}$ (0.278), $P_6 \times P_{11}$ (0.260), $P_6 \times P_{12}$ (0.245), $P_4 \times P_{12}$ (0.245), $P_4 \times P_{13}$(0.175), $P_3 \times P_{11}$ (0.127), $P_2 \times P_{10}$(0.136) and $P_5 \times P_{12}$ (0.129). For number of kernels per row good cross combinations were$P_7 \times P_{12}$ (7.370), $P_9 \times P_{10}$(6.009), $P_4 \times P_{11}$ (4.574), $P_8 \times P_{11}$ (3.824), $P_1 \times P_{10}$ (3.676), $P_1 \times P_{12}$ (3.454), $P_3 \times P_{13}$ (3.130), $P_6 \times P_{13}$ (2.880), $P_5 \times P_{11}$ (2.741), $P_5 \times P_{13}$(2.630) and $P_8 \times P_{12}$ (2.454). For 100 seed weight $P_1 \times P_{10}$(4.157) and $P_5 \times P_{11}$(3.944) showed good combination. For grain yield $P_7 \times P_{12}$ (1328.102), $P_1 \times P_{13}$ (1020.843), $P_9 \times P_{11}$ (857.472), $P_6 \times P_{11}$ (730.806), $P_8 \times P_{11}$ (694.389), $P_4 \times P_{12}$ (689.102) $P_3 \times P_{10}$ (638.417), $P_2 \times P_{13}$ (493.426), $P_1 \times P_{10}$(487.250) and $P_8 \times P_{13}$ (329.759). Positive sca effects usually represent dominance and epistatic component of variation.In most of the cases, positive SCA effects for grain yield was reported by Lal and Kumar 2012; Jebaraj *et al.,* 2010; Dhillon and Singh 1976. Ivy and Hawlader 2000 reported that good general combining parents does not always show high sca effects in their hybrid combination.With respect to shelling percentage good cross combination were $P_3 \times P_{10}$ (12.742), $P_7 \times P_{12}$ (8.173), $P_9 \times P_{11}$ (6.391), $P_8 \times P_{13}$ (6.130), $P_4 \times P_{13}$ (4.558), $P_8 \times P_{11}$ (3.860), $P_6 \times P_{11}$ (2.705), $P_1 \times P_{10}$ (2.466), $P_2 \times P_{13}$ (2.280), $P_4 \times P_{12}$ (2.399), $P_5 \times P_{12}$(2.278) and $P_1 \times P_{13}$ (1.897).For best cross selection Izhar and Chakraborty 2013; Lal and Kumar 2012 also reported similar result.

Heterosis

Percentage of heterosis over the check C_2 given in table 6**.** For pollen shedding duration only cross$P_4 \times P_{10}$(16.67) showed significant positive heterosis. For brown husk $P_2 \times P_{11}$(-6.51) and $P_3 \times P_{12}$(-5.48) showed significant negative heterosis. For leaf firing, leaf rolling, tassel blast and post flowering stalk rot none of the crosses showed significant negative heterosis. With respect to cob length $P_1 \times P_{12}$ (39.04), for number of kernel rows per cob $P_3 \times P_{12}$(15.00) and $P_9 \times P_{12}$(15.00) showed significant positive heterosis. However, for tasseling 18 crosses, silking 30 crosses, plant height 14 crosses and ear height 25 crosses showed significant negative heterosis. Significant positive heterosis was showed by cob diameter for 26 crosses, number of kernels per row for 30 crosses,100 seed weight for 4 crosses, grain yield for 8 crosses,harvest index and shelling percentage for 9 crosses. Approximately, similar types of range of result was obtained by Kumar *et al.,* 2014 and Rajesh *et al.,* 2014.The wide range and significant heterosis for grain yield and other characters was also recorded by the Amiruzza man *et al.,* 2010; Dubey *et al.*, 2009; Chattopadhyay and Dhiman 2006.

Overall results on the basis of mean performance, heterosis and combining ability, revealed that five crosses $P_6 \times P_{11}$, $P_8 \times P_{11}$, $P_1 \times P_{13}$, $P_7 \times P_{12}$ and $P_9 \times P_{12}$showed better combination with respect to most of the traits under taken by considering the problems faced during *kharif* season.

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