General and specific combining ability studies in single cross hybrids of maize (*Zea mays* L.)

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ABSTRACT

Information about combining ability is important for working breeding strategies. A line x tester analysis in maize was carried out at All India Co-ordinated Maize Improvement Project (AICMIP), Agricultural Research station (ARS), Arabhavi with twenty nine newly developed lines from national yellow pool and three testers to estimate the combining ability effects and nature of gene action for twelve characters viz., Days to 50% tasseling, Days to 50% silking, plant height (cm), ear length (cm), ear circumference (cm), number of kernels per row, number of kernel rows per cob, 100-grain weight (g), grain yield per plant (g), fodder yield (t/ha) and grain yield (q/ha). Based on the gca effects, YP⊗4#07-20 among lines and CI-5 among testers were found to be good general combiner for grain yield. The cross combination, YP⊗4#07-20 x CI-5 (8.82) exhibited the maximum positive and significant sca effect for grain yield and hence recommended for heterosis breeding. Considering its negative gca and sca effects for days to 50% tasseling and days to 50% silking, material can be marked as a valuable source for inducing earliness. It also revealed that there is inconsistent relationship between gca and sca effects.

KEY WORDS: Combining ability, gca effects, maize, sca effects

INTRODUCTION

Maize is the world's most widely grown cereal and is the primary staple food in many developing countries (Morries *et al.,* 1999). The concept of general and specific combining ability was introduced by Sprague and Tatum (1942) and its mathematical modeling was set about by Griffing (1956) in his classical paper in conjunction with the diallel crosses. The value of any population depends on its potential *per se* and its combining ability in crosses (Vacaro *et al*., 2002). The usefulness of these concepts for the characterization of an inbred in crosses have been increasingly popular among the maize breeders since the last few decades. The variances of general and specific combining ability are related to the type of gene action involved. Variance for GCA includes additive portion of total variance arising largely from dominance and epistatic deviations (Rojas and Sprague, 1952).

Maize is a highly cross pollinated crop and there is a wide scope for exploitation of hybrid vigour. Already this phenomenon has been successfully exploited and still there is tremendous potential to exploit several high yielding hybrids and composites. An understanding of the genetic architecture of parent, their mode of inheritance will greatly aid the breeder to device appropriate breeding methodology to incorporate the traits in question. Line x Tester analysis is one of the methods employed by which the genetic architecture of a given character, the combing ability and heterosis could be understood.

The objective of this study was to evaluate the performance of 29 new inbred lines derived from national yellow pool. These promising lines were never appeared to be tested before for their breeding potential per se in specific combinations (sca) and their overall performance in crosses (gca). These lines would be a valuable source of germplasm to enhance hybrid grain yield in India.

MATERIALS AND METHODS

The experimental material used in the present investigation comprised of twenty nine promising inbred lines selected from National Yellow Pool based on their performance in S4 generation. These selected lines were used as female lines and were crossed with three testers *viz*., Prabha (composite with broad genetic base), KDMI-10 and CI-5 (Inbred lines with narrow genetic base) at Main Agricultural Research Station, Agricultural college, Dharwad during *kharif* 2007-08.

The 87 F_1 hybrids thus generated from the above line x tester crossing programme were evaluated in RCBD with two replications along with parental lines and five checks *viz*., DMH-2, EH-434042 (Arjun) (Public hybrids), Pinnacle, Bio-9681 and 900M (Private hybrids) at All India Co-ordinated Maize Improvement Project (AICMIP), Agricultural Research Station (ARS), Arabhavi during *rabi/summer* 2008-09. Each entry was raised in two rows with a row length of 4m and the spacing maintained was 75cm between the rows and 20cm between the plants. The recommended packages of practices were followed to raise a good crop. The observation on grain yield and its 11 important component traits were recorded from ten competitive plants which were selected randomly from each treatment to record observations on days to 50 percent tasseling, days to 50 percent silking, plant height (cm), ear length (cm), ear circumference (cm), number of kernel rows per ear, number of kernels per row, 100-grain weight (g), shelling percent, grain yield per plant, fodder yield (t/ha) and grain yield (q/ha). The mean values of these ten plants were used for combining ability analysis (line x tester) as per the method suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

In the present investigation, the analysis of variance for combining ability in respect of 12 quantitative characters under study is presented in table 1. Analysis of variance for parents revealed that all the parents chosen were highly significant for all the traits indicating sufficient variability. The variance among the lines was highly significant for all the traits where as variance among testers were significant for number of kernels per row, 100 grain weight, grain yield per plant and fodder yield. The variance due to line x testers interaction was highly significant for all traits except ear length, ear circumference, shelling percentage and fodder yield per hectare. However, the variance among testers for grain yield per plant was significantly higher (443.89) as compared to the female lines. This indicated that the female lines would contributed to the final yield indirectly through the yield contributing traits, while the male line directly contributed to yield by grain yield per plant in the hybrids.

The mean sum of squares for hybrids were highly significant for days to 50 percent teaseling, days to 50 percent silking, number of kernel rows per ear, number of kernels per row , 100-grain weight, shelling percentage and fodder yield per hectare. The variance due to the interaction effect of parents verses hybrids was also found highly significant for all traits indicates that the parents chosen were diverse and with a difference genetic background. The contribution to total hybrid variance was found to be higher from females than males for all characters under study as females were genetically diverse than males.

The SCA variance was higher than the GCA variance indicating predominance of dominance variance. Dominance variance was greater than additive variance for all the character indicating the predominance of non-additive gene action. These results are in confirmative with the findings of Sanghi *et al* (1982), Sedhom (1994), Dehghanapour *et al* (1997), Herbert and Gallis (1986), El-Hosary *et al* (1994a), Guo et al (1986), Pal et al (1986), Vasal et al (1992), Mohammad (1993), Pal and Prodhan (1994), Sinobas and Monteagudo (1994), Satyanarayana et al (1994), Paul and Duara (1991).

The gca effects calculated for each parent are presented in table 2. Among the 32 parents, the highest and significant gca effects for grain yield per plant was observed in YP⊗4#07-20 (5.95), YP⊗4#07-27 (4.21), YP⊗4#07-28 (3.85). The parent YP⊗4#07-20 (5.95) was found to be the best general combiner for the character for plant height and fodder yield per hectare, while YP⊗4#07-1 was the best general combiner for plant height, ear circumference, 100-grain weight and fodder yield per hectare. The parent YP⊗4#07-2 had highest negative gca effects for days to 50 per cent tasseling (-2.46) and days to 50 per cent silking (-2.07). These parents may therefore used in breeding programme for earliness. For plant height YP⊗4#07-19 (13.42), YP⊗4#07-29 (12.42), YP⊗4#07-1 (12.25) showed significant positive gca effects and two testers Prabha (2.74) and KDMI-10 (1.41) showed gca effects in the positive direction. Dhillon (1975) reported that combining ability of parents give useful information on the choice of parents in terms of expected performance of the hybrids and their progenies. A number of workers had advocated gca effects to critically analyze the parents for their ability to transmit superior performance to their progenies.

The gca effects is a value derived from the general mean of hybrid involving all parents. The gca effects of parents may be positive or negative. Simmonds (1979) pointed out that the gca values were relative and dependent upon the mean of the chosen material. It is better to choose parents possessing significant gca effects or merely based on mean performance. This assumption is based on the principle that gca effect reflects additive gene action. Sometimes, the immediate hybrid may not perform well despite both the parents possessing high gca effects for a trait, due to interaction of the parental gca effects which may cause distortions on expectation. The reverse trend may also happen with low performing parents showing high hybrid values than expected. This interaction is measured by the sca effects of the hybrids. It is to be remembered that interaction effects are not fixable. The point for consideration here is to identify the hybrids which could be forwarded further for selection in the segregating generation and hybrids suitable for heterosis breeding. The specific combining ability is the deviation from the performance predicted on the basis of gca (Allard, 1960). According to Sprague and Tatum (1942) the specific combining ability is controlled by non-additive gene action. The sca effect is an important criterion for the evaluation of hybrids.

The sca effects calculated of each of the hybrids presented in table 3. The sca effect for most of the traits was non-significant in nature. Out of 87 F_1 hybrids, top ten hybrids were identified based on grain yield (q/ha) and there heterosis, gca status and their sca effect have been present in table 4. Among these top ten hybrids, YP⊗4#07-20 x CI-5 cross showed significant positive sca effect (8.82) and higher degree of heterosis (53.3%) over standard check (Pinnacle) for grain yield (67.29 q/ha) and the parents were of high x low gca nature. The potentiality of the cross from high x low combination is attributed to the interaction between dominant alleles from good general combiner and recessive alleles from poor combiner (Senthil and Bharathi, 2009). In general, the good specific combiners for different characters involved parents with high x high, high x low, low x high and low x low general combinations. In majority of the cases, the crosses exhibiting high sca effect were found to have both or one of the parents as good general combiner for the characters studied (Vinay Kumar *et al*, 2011).

CONCLUSION

Two factors are considered important for the evaluation of an inbred line in the production of hybrid maize; characteristics of the line itself and behavior of the line in a particular hybrid combination. As performance of hybrid can be subdivided into two categories i.e., general and specific combining ability (Rojas and Sprague, 1952), superiority of a line on the basis of combining ability estimates can only be decided precisely after knowing the purpose of a certain breeding programme whether, it is to develop high yielding OPV's (open pollinated varieties) or the superior combinations of hybrids. Lines which had higher gca effects can be used in synthetic variety development more effectively. However, when high yielding specific combinations are desired, especially in hybrid maize development, sca effects could help in the selection parental material for hybridization. From the above investigation we can conclude that YP⊗4#07-20 x CI-5 was found to be a good specific combiner and can be used as a potential single cross hybrid combination and tested further.

Table 1: Mean sum of squares for parents and hybrids in respect of 12 characters in maize

Sources of variation	Degrees of freedom	Days to 50% tasseling	Days to 50% silking	Plant height (cm)	Ear length (cm)	Ear circumference (cm)	Number of kernel rows per ear
Replication	1	57.52	94.54	1610.96	38.88	0.48	5.69
Parents	31	5.98**	4.87**	412.71**	5.29*	1.52**	0.87**
Females (Lines)	28	6.51**	5.15**	437.01**	5.51*	1.62**	0.76**
Males (Testers)	2	0.50	0.67	18.67	4.67	0.69	0.17
Females Vs Males	1	1.98*	5.38**	520.50**	0.27	0.29	5.28**
Hybrids	86	2.68**	4.87**	245.35	3.51	0.84	0.57**
Parents Vs Hybrids	1	156.12**	86.23**	8169.72**	78.26**	56.75**	4.80**
Error	118	1.38	2.25	210.05	3.67	0.94	0.37
σ^2GCA		0.01	0.02	1.19	0.01	0.00	0.00
σ^2SCA		-0.01	0.06	-49.44	-0.57	-0.19	0.03
σ^2GCA/ σ^2SCA		-0.15	0.39	-0.02	-0.01	-0.01	0.03

Sources of variation	Degrees of freedom	No of kernels per row	100-grain weight (g)	Shelling (%)	Grain yield per plant (g)	Fodder yield (t/ha)	Grain yield (q/ha)
Replication	1	67.77	0.04	5.97	64.57	2.07	12.50
Parents	31	32.01**	59.77**	11.91**	165.29**	5.11**	69.48**
Females (Lines)	28	29.23**	61.45**	13.01**	140.81**	5.60**	60.71**
Males (Testers)	2	12.33**	41.17**	2.43	443.89**	0.71**	169.75**
Females Vs Males	1	149.31**	50.26**	0.01	293.58**	0.08	114.33**
Hybrids	86	16.66**	42.51**	6.43**	84.48	5.16**	38.07
Parents Vs Hybrids	1	1550.76**	1066.18**	94.51**	110834.70**	195.50**	11577.87**
Error	118	2.53	2.25	3.41	85.39	0.19	36.08
σ^2GCA		0.02	0.12	0.01	0.07	0.02	0.05
σ^2SCA		5.63	14.38	1.46	-2.95	1.74	-1.17
σ^2GCA/ σ^2SCA		0.004	0.01	0.01	-0.02	0.01	-0.04

* Significant at 5% ** Significant at 1%

Table 2: General combining ability (gca) effects of parents in respect of 12 characters

Sl.No	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
	Females (Lines)												
1	YP ⊗ 4 #07-1	-0.13	0.93	12.25*	0.28	1.17**	0.41	2.06**	4.14**	-1.8**	3.9	0.48**	2.51
2	YP ⊗ 4 #07-2	-2.46**	-2.07**	5.09	0.68	-0.18	-0.06	-0.11	3.14**	-0.25	-0.41	-0.54**	-0.61
3	YP ⊗ 4 #07-3	-0.29	0.09	5.09	1.56	0.16	0.31	1.59*	3.8**	0.59	4.51	-0.07	2.6
4	YP ⊗ 4 #07-4	-1.63**	-1.24	-4.41	0.54	0.39	0.31	1.73*	2.47**	0.25	3.59	-0.14	1.98
5	YP ⊗ 4 #07-5	0.21	1.26	-14.91*	-1.81*	-0.66	-0.53*	-2.34**	-3.03**	0.79	-5.16	-2.19**	-3.89
6	YP ⊗ 4 #07-6	-0.96*	0.93	-19.75**	-1.51	-1.06*	-0.73**	-4.01**	-5.03**	-1.7**	-6.63	-1.7**	-5.67*
7	YP ⊗ 4 #07-7	0.21	0.43	-7.08	-1.42	-0.46	-0.53*	-2.51**	-3.86**	-1.18	-5.22	-0.99**	-3.84
8	YP ⊗ 4 #07-8	0.54	0.76	-3.41	1.48	0.08	0.37	1.86**	-4.53**	1.24	4.34	1.43**	3.05
9	YP ⊗ 4 #07-9	0.54	0.76	11.25	0.96	0.06	0.04	0.43	-1.53**	0.72	0.19	1.68**	0.36
10	YP ⊗ 4 #07-10	0.21	0.59	0.75	-0.72	0.37	-0.03	0.19	-0.36	-1.23	-0.74	2.01**	-0.4
11	YP ⊗ 4 #07-11	-0.79	-1.57*	-16.75**	-0.96	-1.04*	-0.49	-2.57**	-2.36**	-0.6	-6.94	-1.94**	-3.87
12	YP ⊗ 4 #07-12	0.04	-0.91	-2.25	-0.44	-0.06	-0.16	-0.94	-2.7**	-1.53*	-2.94	-0.32	-1.27
13	YP ⊗ 4 #07-13	-1.13*	-1.74**	-12.58*	0.08	0.02	0.34	2.03**	2.64**	-0.01	2.53	1.2**	2.38
14	YP ⊗ 4 #07-14	1.04*	1.26	4.59	0.19	0.2	-0.23	-1.34	1.14*	-0.33	-3.14	0.58**	-2.04
15	YP ⊗ 4 #07-15	0.04	0.26	5.75	-0.29	-0.01	-0.36	-2.31**	-1.2*	0.34	-3.18	0.78**	-2.59
16	YP ⊗ 4 #07-16	0.71	1.26	6.25	1.64*	0.49	-0.09	-0.27	2.3**	-0.41	-1.89	0.21	-0.88
17	YP ⊗ 4 #07-17	1.37**	1.26	1.92	0.58	-0.28	-0.19	-1.01	-5.7**	1.44*	-2.31	0.23	-1.64
18	YP ⊗ 4 #07-18	1.37**	1.76**	8.59	1.14	0.34	0.01	-0.04	0.8	-1.81**	-1	2.16**	-0.34
19	YP ⊗ 4 #07-19	1.71**	1.76**	13.42*	-0.79	-0.29	-0.43	-2.37**	-0.7	0.72	-4.43	1**	-3.56
20	YP ⊗ 4 #07-20	0.04	0.43	-6.58	-1.01	-0.43	0.71**	3.56**	-0.36	2.09**	8.73*	-1.32**	5.95*
21	YP ⊗ 4 #07-21	1.04*	0.43	-0.58	0.03	0.16	-0.06	-0.84	4.47**	-0.91	-0.97	-0.27	-0.57
22	YP ⊗ 4 #07-22	-0.29	0.43	-4.25	-0.19	-0.19	-0.23	-1.24	-1.03	-1.78**	-3.72	0.33	-2.25
23	YP ⊗ 4 #07-23	0.71	0.76	3.59	-0.64	0.09	-0.26	-1.57*	-4.36**	0.3	-2.42	0.98**	-1.57
24	YP ⊗ 4 #07-24	-0.63	-1.91**	0.42	0.58	-0.11	0.21	1.23	-0.03	0.95	2.9	-0.55**	1.7

Sl.No	Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
	Female (Lines)												
25	YP ⊗ 4 #07-25	-0.46	-1.91**	1.92	-0.09	0.31	0.44	2.36**	3.64**	1.55*	4.71	0	3.82
26	YP ⊗ 4 #07-26	-0.96*	-2.07**	3.25	0.96	0.82*	0.21	1.13	5.14**	0.94	3.69	-1.25**	2.02
27	YP ⊗ 4 #07-27	-0.96*	-1.41*	-1.41	-0.84	0.21	0.47	2.53**	1.47*	-1.48*	5.37	-1.04**	4.21
28	YP ⊗ 4 #07-28	-0.29	-0.74	-2.58	-0.29	0.07	0.47	2.36**	5.3**	2.04**	5.79	-1.29**	3.85
29	YP ⊗ 4 #07-29	1.21*	0.26	12.42*	0.29	-0.21	0.11	0.46	-3.7**	1.12	0.86	0.53**	0.57
	Males (Testers)												
30	Prabha	0.24	0.26	2.74	0.2	0.04	0.05	0.26	-1.09**	0.05	0.19	0.2**	0.31
31	KDMI-10	-0.06	0.01	1.41	0	0.06	0	0.03	0.37*	-0.18	0.16	0.17**	0.03
32	CI-5	-0.18	-0.27	-4.16*	-0.2	-0.1	-0.05	-0.29	0.72**	0.13	-0.35	-0.37**	-0.34
	CD at 5% female	1.35	1.83	17.19	2.24	1.14	0.742	1.96	1.58	1.80	10.46	0.49	6.79
	CD at 1% female	1.80	2.43	22.84	2.98	1.51	0.98	2.61	2.10	2.39	13.89	0.65	9.02
	S.Em±	0.68	0.92	8.68	1.13	0.57	0.37	0.99	0.80	0.91	5.28	0.25	3.43
	CD at 5% male	0.44	0.59	5.53	0.72	0.37	0.23	0.63	0.51	0.58	3.36	0.16	2.18
	CD at 1% male	0.58	0.78	7.35	0.96	0.49	0.31	0.83	0.68	0.77	4.47	0.21	2.90
	S.Em±	0.22	0.30	2.79	0.36	0.18	0.12	0.31	0.26	0.29	1.70	0.08	1.10

*-Significant at 5% Level **-Significant at 1% level

X1 - Days to 50% tasseling
X2 - Days to 50% silking
X3 - Plant height (cm)
X4- Ear length (cm)
X5 - Ear circumference (cm)
X6 – Number of kernel rows per cob
X7 – Number of kernels per row
X8- 100-grain weight (g)
X9 – Shelling percentage (%)
X10 – Grain yield per plant (g)
X11 – Fodder yield (t/ha)
X12-Grain yield (q/ha)

Table 3: Specific combining ability (sca) effects of single cross hybrids of maize in respect of 12 characters

Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
1	YP ⊗ 4 #07-1 x Prabha	0.76	0.4	5.59	-0.25	0.06	0.08	0.24	0.76	-1.01	-0.96	1.32**	0.2
2	YP ⊗ 4 #07-1 x KDMI -10	-0.44	-0.34	7.92	-0.3	0.09	0.04	0.27	-0.21	1.96	1.36	-0.46	0.23
3	YP ⊗ 4 #07-1 x CI-5	-0.32	-0.06	-13.51	0.55	-0.15	-0.12	-0.51	-0.55	-0.95	-0.4	-0.86**	-0.43
4	YP ⊗ 4 #07-2 x Prabha	-0.4	-0.1	4.76	-0.75	-0.29	-0.25	-1.39	4.76**	-0.61	-3.1	1.38**	-1.9
5	YP ⊗ 4 #07-2 x KDMI -10	-0.11	0.16	-7.91	0.2	0.34	0.2	1.23	-6.21**	0.51	3.33	-0.29	2.12
6	YP ⊗ 4 #07-2 x CI-5	0.51	-0.06	3.16	0.55	-0.05	0.05	0.16	1.45	0.1	-0.24	-1.09**	-0.22
7	YP ⊗ 4 #07-3 x Prabha	-0.57	-1.26	-8.74	-1.24	-0.57	-0.42	-1.79	-6.91**	0.55	-4.62	-0.73*	-3.3
8	YP ⊗ 4 #07-3 x KDMI -10	0.72	1.49	1.59	1.77	0.51	0.54	2.13	5.63**	1.83	8.17	1.04**	5.06
9	YP ⊗ 4 #07-3 x CI-5	-0.16	-0.23	7.16	-0.53	0.06	-0.12	-0.34	1.28	-2.38*	-3.55	-0.31	-1.76
10	YP ⊗ 4 #07-4 x Prabha	0.26	0.57	6.76	0.43	0.59	0.78	4.18**	2.93**	2.79*	9.37	0.93**	6.38
11	YP ⊗ 4 #07-4 x KDMI -10	-0.94	-1.17	-1.41	1.03	0.28	-0.16	-0.9	2.46*	-0.44	-1.9	-1.29**	-1.63
12	YP ⊗ 4 #07-4 x CI-5	0.68	0.6	-5.34	-1.46	-0.87	-0.62	-3.28**	-5.39**	-2.35*	-7.47	0.36	-4.75
13	YP ⊗ 4 #07-5 x Prabha	-0.07	0.07	9.26	0.73	0.44	0.01	-0.06	2.43*	2.65*	-0.09	1.28**	0.15
14	YP ⊗ 4 #07-5 x KDMI -10	0.22	0.33	-4.41	-2.02	-0.62	-0.13	-0.33	-0.04	-1.92	-2.05	-1.04**	-0.69
15	YP ⊗ 4 #07-5 x CI-5	-0.16	-0.4	-4.84	1.29	0.18	0.12	0.39	-2.39*	-0.73	2.13	-0.24	0.54
16	YP ⊗ 4 #07-6 x Prabha	1.1	4.4**	7.09	1.48	0.84	0.61	3.71**	3.43**	3.19**	4.39	0.15	4.19
17	YP ⊗ 4 #07-6 x KDMI-10	0.39	-1.84	-0.58	-0.57	-0.12	-0.53	-2.27	3.96**	-1.04	-4.48	0.78*	-3.73
18	YP ⊗ 4 #07-6 x CI-5	-1.49	-2.56*	-6.51	-0.91	-0.72	-0.08	-1.44	-7.39**	-2.15	0.09	-0.93**	-0.46
19	YP ⊗ 4 #07-7 x Prabha	-1.07	-0.6	1.93	-0.05	0.34	-0.19	-0.79	4.76**	-0.68	-0.05	0.48	-1.15
20	YP ⊗ 4 #07-7 x KDMI-10	0.72	0.66	-7.25	0.55	-0.42	0.17	0.63	-2.71**	-0.76	0.64	-1.29**	1.29
21	YP ⊗ 4 #07-7 x CI-5	0.34	-0.06	5.32	-0.5	0.08	0.02	0.16	-2.05*	1.44	-0.59	0.81**	-0.14
22	YP ⊗ 4 #07-8 x Prabha	0.6	0.07	2.76	0.25	-0.27	0.41	1.84	-2.57*	1.25	7.06	0.32	4.85
23	YP ⊗ 4 #07-8 x KDMI-10	-0.11	0.33	-7.41	-1.35	-0.27	-0.23	-1.33	-1.54	-0.87	-3.34	1.39**	-2.82
24	YP ⊗ 4 #07-8 x CI-5	-0.49	-0.4	4.66	1.1	0.54	-0.18	-0.51	4.11**	-0.38	-3.72	-1.71**	-2.04
25	YP ⊗ 4 #07-9 x Prabha	-0.9	-1.43	-13.91	-1.04	-0.72	-0.55	-2.72*	-1.57	0.12	-5.04	0.12	-4.06
26	YP ⊗ 4 #07-9 x KDMI-10	-0.11	-0.17	12.92	1.47	1.01	0.6	2.8*	0.96	0.64	6.26	1.79**	4.51

Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
27	YP ⊗ 4 #07-9 x CI-5	1.01	1.6	0.99	-0.43	-0.29	-0.05	-0.08	0.61	-0.76	-1.22	-1.91**	-0.44
28	YP ⊗ 4 #07-10 x Prabha	0.43	0.74	-4.41	0.2	-0.19	0.31	1.81	-2.24*	-1.08	4.87	-1.87**	2.79
29	YP ⊗ 4 #07-10 x KDMI-10	0.22	-0.01	2.92	0.65	0.19	0.17	0.63	-0.21	-0.16	1.24	-0.24	0.79
30	YP ⊗ 4 #07-10 x CI-5	-0.66	-0.73	1.49	-0.85	0	-0.48	-2.44*	2.45*	1.24	-6.11	2.11**	-3.58
31	YP ⊗ 4 #07-11 x Prabha	-0.07	-0.1	0.59	0.38	0.18	-0.02	0.18	3.26**	0.74	0.82	-1.07**	0.1
32	YP ⊗ 4 #07-11 x KDMI-10	0.22	-0.34	-7.58	-0.32	-0.39	0.14	0.7	-1.21	-1.19	-0.78	-0.14	0.73
33	YP ⊗ 4 #07-11 x CI-5	-0.16	0.44	6.99	-0.06	0.21	-0.12	-0.88	-2.05*	0.45	-0.04	1.21**	-0.82
34	YP ⊗ 4 #07-12 x Prabha	0.1	-0.76	9.09	0.71	0.84	0.75	3.94**	-3.41**	-0.93	10.55	1.02**	5.85
35	YP ⊗ 4 #07-12 x KDMI-10	-0.11	0.99	-4.58	-0.48	-0.27	-0.2	-0.93	1.13	0.89	-4.27	0.19	-2.02
36	YP ⊗ 4 #07-12 x CI-5	0.01	-0.23	-4.51	-0.23	-0.57	-0.55	-3.01*	2.28*	0.04	-6.29	-1.21**	-3.83
37	YP ⊗ 4 #07-13 x Prabha	0.76	0.57	-9.07	-1.3	-0.49	-0.05	-0.22	1.26	0.4	-0.29	-1.05**	-0.25
38	YP ⊗ 4 #07-13 x KDMI-10	1.06	1.33	-0.75	-0.15	0.04	0	0.2	-1.21	-0.12	0.42	1.48**	0.06
39	YP ⊗ 4 #07-13 x CI-5	-1.82*	-1.9	9.82	1.45	0.45	0.05	0.02	-0.05	-0.28	-0.13	-0.43	0.18
40	YP ⊗ 4 #07-14 x Prabha	0.6	0.07	0.26	-0.57	0.28	0.11	1.04	7.76**	0.42	0.81	-0.43	0.98
41	YP ⊗ 4 #07-14 x KDMI-10	-0.61	-0.17	-7.41	0.68	-0.6	-0.43	-2.73*	-3.21**	0.09	-4.25	0.29	-3.14
42	YP ⊗ 4 #07-14 x CI-5	0.01	0.1	7.16	-0.11	0.32	0.32	1.69	-4.55**	-0.51	3.44	0.14	2.17
43	YP ⊗ 4 #07-15 x Prabha	-1.4	-1.93	7.09	-1.44	-0.96	-1.05*	-6.99**	-9.91**	-0.35	-9.92	2.57**	-7.51
44	YP ⊗ 4 #07-15 x KDMI-10	0.39	0.33	-0.58	0.37	0.53	0.5	3.23**	5.63**	-0.02	4.51	-1.56**	3.07
45	YP ⊗ 4 #07-15 x CI-5	1.01	1.6	-6.51	1.07	0.43	0.55	3.76**	4.28**	0.37	5.41	-1.01**	4.43
46	YP ⊗ 4 #07-16 x Prabha	-0.57	0.57	2.09	-0.07	0.44	0.08	0.28	-3.41**	-1.95	0.72	0.68*	0.72
47	YP ⊗ 4 #07-16 x KDMI-10	0.72	0.83	-2.08	0.48	-0.57	-0.06	-0.3	0.13	1.28	-0.2	-0.14	-0.59
48	YP ⊗ 4 #07-16 x CI-5	-0.16	-1.4	-0.01	-0.41	0.13	-0.02	0.02	3.28**	0.67	-0.51	-0.54	-0.13
49	YP ⊗ 4 #07-17 x Prabha	0.76	1.07	-15.57	1.25	0.06	-0.02	-0.39	-2.41*	-0.75	-0.96	-1.13**	-0.58
50	YP ⊗ 4 #07-17 x KDMI-10	-0.44	-0.67	3.75	-2.05	-0.56	-0.46	-2.17	0.13	-1.12	-4.66	-1.01**	-3.16
51	YP ⊗ 4 #07-17 x CI-5	-0.32	-0.4	11.82	0.8	0.5	0.48	2.56*	2.28*	1.87	5.61	2.14**	3.74
52	YP ⊗ 4 #07-18 x Prabha	0.26	0.07	14.26	1.93	-0.11	0.28	1.24	1.59	-0.5	2.92	0.73*	2.26
53	YP ⊗ 4 #07-18 x KDMI-10	0.06	-0.17	-4.41	-0.52	0.08	-0.16	-0.73	-1.37	0.83	-1.07	-0.34	-1.31

Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
54	YP ⊗ 4 #07-18 x CI-5	-0.32	0.1	-9.84	-1.41	0.03	-0.12	-0.51	-0.22	-0.33	-1.84	-0.39	-0.95
55	YP ⊗ 4 #07-19 x Prabha	-0.07	-0.43	7.43	0.61	-0.07	0.31	1.58	-1.41	0.87	2.51	-0.2	1.99
56	YP ⊗ 4 #07-19 x KDMI-10	0.72	0.83	3.25	0.72	0.06	-0.13	-0.1	-3.87**	-0.06	-2.54	1.48**	-0.58
57	YP ⊗ 4 #07-19 x CI-5	-0.66	-0.4	-10.68	-1.33	0.01	-0.18	-1.48	5.28**	-0.81	0.02	-1.28**	-1.41
58	YP ⊗ 4 #07-20 x Prabha	0.1	-0.6	0.93	-0.17	0.16	-0.62	-3.06*	-4.24**	-1.2	-10.62	1.47**	-5.91
59	YP ⊗ 4 #07-20 x KDMI-10	-0.61	-0.34	0.75	-0.07	0.39	-0.16	-0.73	2.29*	-1.32	-2.61	-0.96**	-2.9
60	YP ⊗ 4 #07-20 x CI-5	0.51	0.94	-1.68	0.24	-0.55	0.78	3.79**	1.95*	2.52*	13.23*	-0.51	8.82*
61	YP ⊗ 4 #07-21 x Prabha	0.6	0.9	-12.57	-0.45	0.28	0.55	3.44**	-0.07	-0.2	6.44	-0.73*	4.19
62	YP ⊗ 4 #07-21 x KDMI-10	-0.61	-1.34	6.75	-0.1	-0.29	-0.7	-4.73**	-1.54	-0.42	-7.22	-0.81**	-4.96
63	YP ⊗ 4 #07-21 x CI-5	0.01	0.44	5.82	0.55	0.01	0.15	1.29	1.61	0.62	0.77	1.54**	0.77
64	YP ⊗ 4 #07-22 x Prabha	-0.07	-0.6	-4.91	-0.44	-0.82	-0.29	-1.36	1.43	-3.88**	-2.26	-1.83**	-2.16
65	YP ⊗ 4 #07-22 x KDMI-10	-0.28	0.16	7.92	0.37	1.06	-0.03	-0.23	0.96	1.24	-0.23	1.49**	-0.16
66	YP ⊗ 4 #07-22 x CI-5	0.34	0.44	-3.01	0.07	-0.24	0.32	1.59	-2.39*	2.64*	2.49	0.34	2.32
67	YP ⊗ 4 #07-23 x Prabha	0.43	0.57	-6.74	-0.69	-0.31	-0.85	-4.62**	3.26**	-1.36	-9.85	0.22	-6.31
68	YP ⊗ 4 #07-23 x KDMI-10	-0.28	-0.17	4.59	1.52	0.48	1*	5.1**	-0.71	1.71	11.5	-0.51	8.18
69	YP ⊗ 4 #07-23 x CI-5	-0.16	-0.4	2.16	-0.83	-0.17	-0.15	-0.48	-2.55*	-0.35	-1.65	0.29	-1.87
70	YP ⊗ 4 #07-24 x Prabha	0.26	0.24	-1.57	1.25	0.39	0.68	3.98**	-0.07	1.79	11.02	-1.55**	6.49
71	YP ⊗ 4 #07-24 x KDMI-10	-0.44	-0.51	-1.75	-1	-0.57	-0.46	-2.5*	-2.04*	0.21	-7.92	-0.52	-3.93
72	YP ⊗ 4 #07-24 x CI-5	0.18	0.27	3.32	-0.25	0.18	-0.22	-1.48	2.11*	-2	-3.09	2.07**	-2.56
73	YP ⊗ 4 #07-25 x Prabha	-0.4	-0.26	-2.07	-1.44	-0.57	-0.15	-1.26	-2.74**	0.99	-2.39	-1.55**	-1.96
74	YP ⊗ 4 #07-25 x KDMI-10	0.39	-0.01	2.25	-0.08	0.06	-0.1	-0.03	4.29**	-0.59	-2.35	-0.82**	-1.12
75	YP ⊗ 4 #07-25 x CI-5	0.01	0.27	-0.18	1.52	0.51	0.25	1.29	-1.55	-0.4	4.74	2.37**	3.09
76	YP ⊗ 4 #07-26 x Prabha	0.6	0.4	1.59	0.21	0.36	0.18	0.98	1.26	-1.6	0.8	0.45	0.51
77	YP ⊗ 4 #07-26 x KDMI-10	-0.11	-0.34	5.92	1.07	0.34	0.54	2.5*	1.79	1.28	9.91	-0.17	5.6
78	YP ⊗ 4 #07-26 x CI-5	-0.49	-0.06	-7.51	-1.28	-0.7	-0.72	-3.48**	-3.05**	0.32	-10.71	-0.28	-6.11
79	YP ⊗ 4 #07-27 x Prabha	-0.4	-0.76	5.26	1.51	0.27	0.01	0.18	-0.57	-0.48	0.28	-1.27**	0.28
80	YP ⊗ 4 #07-27 x KDMI-10	-1.11	-0.51	0.59	-0.53	-0.05	-0.33	-1.4	-1.04	-2.36*	-4.37	1.21**	-2.97

Sl.No	Single cross hybrids	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
81	YP ⊗ 4 #07-27 x CI-5	1.51	1.27	-5.84	-0.98	-0.22	0.32	1.22	1.61	2.84*	4.08	0.06	2.69
82	YP ⊗ 4 #07-28 x Prabha	-0.57	-0.43	-6.07	-0.19	-0.44	-0.39	-2.06	4.09**	-0.1	-6.47	-0.37	-3.99
83	YP ⊗ 4 #07-28 x KDMI-10	-0.28	-0.17	0.25	-0.18	-0.16	0.27	1.17	-2.37*	-0.07	3.28	0.01	2.76
84	YP ⊗ 4 #07-28 x CI-5	0.84	0.6	5.82	0.37	0.6	0.12	0.89	-1.72	0.17	3.19	0.36	1.23
85	YP ⊗ 4 #07-29 x Prabha	-1.07	-1.43	-1.07	-0.87	0.24	-0.32	-1.96	-1.41	0.92	-5.91	0.67*	-2.83
86	YP ⊗ 4 #07-29 x KDMI-10	0.72	0.83	-3.25	-1.12	-0.57	0.14	0.87	0.13	-0.01	3.59	0.44	1.32
87	YP ⊗ 4 #07-29 x CI-5	0.34	0.6	4.32	1.99	0.33	0.18	1.09	1.28	-0.91	2.32	-1.11**	1.52
	CD at 5%	2.34	3.16	29.78	3.89	1.97	1.28	3.40	2.74	3.12	18.12	0.84	11.76
	CD at 1%	3.11	4.20	39.56	5.16	2.61	1.71	4.52	3.64	4.14	24.07	1.12	15.63
	CV%	1.18	1.60	15.04	1.96	0.99	0.65	1.71	1.39	1.57	9.15	0.43	5.94

Table 4: Performance of promising hybrids for grain yield

Sl.No	Single cross hybrids	Mean grain yield (q/ha)	Heterosis			gca effects female x male	sca effects	Other characters with significant sca effects
			SH	HB	RH			
1.	YP⊗4#07-20 X CI-5	67.29	53.3**	72.77**	88.21**	High x Low	8.82*	HGW,GYP,NKPR,SP
2.	YP⊗4#07-4 X Prabha	61.54	40.2**	43.17**	47.62**	Low x Low	6.38	HGW,FYH, NKPR,SP
3.	YP⊗4#07-24 X Prabha	61.35	39.78**	51.89**	54.84**	Low x Low	6.49	NKPR, FYH
4.	YP⊗4#07-8 X Prabha	61.07	39.15**	51.21**	77.03**	High x Low	4.85	HGW
5.	YP⊗4#07-3 X KDMI-10	60.55	37.97**	18.93	43.18**	High x High	5.06	HGW,FYH
6.	YP⊗4#07-26 X KDMI-10	60.52	37.88**	18.85	45.48**	Low x High	5.60	NKPR
7.	YP⊗4#07-23 X KDMI-10	59.51	35.58**	16.87	25.45*	Low x High	8.18	NKRPE, NKPR
8.	YP⊗4#07-28 X KDMI-10	59.50	35.57**	16.86	37.41**	High x High	2.76	HGW
9.	YP⊗4#07-27 X CI-5	59.42	35.4**	49.76**	64.53**	Low x Low	2.69	SP
10.	YP⊗4#07-25 X CI-5	59.42	35.4**	82.54**	86.77**	High x Low	3.09	FYH

*-Significant At 5% Level **-Significant at 1% level

NKRPE= Number of kernel rows per ear, NKPR= Number of kernels per row, SP= Shelling percentage, HGW = 100-grain weight, GYP = Grain yield per plant, FYH = Fodder yield per hectare, GYH = Grain yield per hectare.

REFERENCES

Allard, R. W. 1960, Principles of plnt breeding. John Wiley & sons. Inc., New York & London.

Dehghanapour, Z., Ehdaie, B., Moghaddam, M., Grifffinh, B. and Hayman, B., 1997, Diallel analysis of agronomic characters in white endosperm corn. *J. Genet. and Breeding,* **50** (4) 3757-365.

Dhillon, B. S., 1975, the application of partial diallel crosses in plant breeding review. *Crop Improve*, 2: 1-7.

East, E. M., 1936, Heterosis, *Genetics*., **21:**375-397.

El-Hosary, A. A. Mohamed, M. K., Sedhom, S. A. and Abo-El-Hassan, G.K.A., 1994a, Performance and combining ability in diallel crosses of maize, *Ann. Agric. Sci.,* **32** (1): 203-216.

Ganesh reddy. M, Mohan Kumar, H. D and Salimat, P. M., 2008, Combining ability analysis in chilli (Capsicum annum L.). *Karnataka. J. Agric.Sci* 21(4): 494-497.

Griffing.B., 1956. Concept of genetal and specific combining ability in relation to diallel crossing system. *Australian J. BiolSci*., 9:463-93.

Guo, P. Z., Gardner, C.O. and Obaidi, M., 1986, Genetic variations and gene effect controlling prolificacy and other traits in maize (*Zea mays* L.) *Acta Genetica Sinica,* **13**: 35-42.

Herbert, Y. and Gallis, A., 1986, Heterosis and genetics and variation for quantitative characters in a 12 x 12 diallel mating design maize, *in:* Biomentrics in Plant Breeding. (M. J. Kearse and C. P. Werner, (eds.) Briminlgham, U. K., pp.140-152.

Kempthorne, O., 1957, An introduction to genetic statistics, John Wiley and Sons, New York.

Mohammed, A. A., 1993, Effect of nitrogen fertilization levels on the performance and combining ability of maize hybrids (*Zea mays* L.). *Ann. Agric. Sci.*, **38**(2): 531-549.

Morris, M. L., J. Risopoulos and D. Beck., 1999, Genetic changes in farmers recycle maize seed: A review of the evidence, CIMMYT Econ, working paper No.99-07, Mexico, D. F., CIMMYT. 1pp.

Pal, A. K. and Prodhan, H. S., 1994, Combining Ability analysis of grain yield and oil content along with some other attributes in maize (*Zea mays* L.). *Indian J. Genet. and Plant Breeding*, **54**(4): 376-380.

Pal, S. S., Khera, A. S. and Dhillon, B. S., 1986, genetic analysis and selection advance in maize population. *Maydica*, **31:** 153-162.

Paul, S. K. and Duara, P. K., 1991, Combining ability for yield and maturity in maize (*Zea mays* L.). *International J. Tropical Agric.*, **9**(4): 205-254.

Rojas, B. A and G. F. Sprague, 1952, a comparison of variance components in corn yield trials:III general and specific combining ability and their interaction with location and years. *Agron. J.*, 44: 462-6.

Satyanarayana, E. Kumar, R. S. and Sharma, M. Y., 1994, Inheritance studies of maturity components and yield in selected hybrids of maize (*Zea mays*

L.). *Mysore J. Agric. Sci.*, **28**(1): 25-30.

Sanghi, A. K., Agarwal, K. N. and Qadri, M. I., 1982, gene effects and heterosis for grain yield and ear traits in maize. *Indian J. Genet.*, **42:** 360-363.

Sedhom, S. A., 1994, Estimation of general and specific combining ability in maize under different planting dates. *Ann. Agric. Sci.*, **28**(1): 25-30.

Simmomds, N. W., 1979, Principles of crop improvement. Longman Group Ltd., London., pp.110-116.

Sinobas, J. and Monteagudo, I., 1994, Genetic analysis of a diallel cross between Spanish and American maize populations. *Investigation Agraria Production-y-Protection Vegetables*, **9**(2): 167-179.

Shull, G. H., (1908). The composition of field maize. *Reporter American Breeder's Association.* **4:** 296-301.

Sprangue, G. P and Tatum, L. S., 1942, General vs specific combining ability in six crosses of corn. *J. Amer. Soc. Agron*., **34:** 923-932.

Vacaro, E., Barbosa, Neto, J. F., Pegoraro, D. G., Nuss, C. N. and Conceicao, L. D. H., 2002, Combining ability of 12 populations. *Pesuisa gropecuria Brasilerira*, **37:** 67-72.

Vasal, S. K., Ganeson Srinivasan, F., Beck, D. L., Crossa, J., Pandey, S. and De Leon, C., 1992, Heterosis and combining ability of CIMMYT's tropical late white maize germplasm. *Maydica*, **37** (2): 217-223.

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