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COMBINING ABILITY FOR YIELD AND QUALITY TRAITS IN SINGLE CROSS HYBRIDS OF MAIZE (*ZEA MAYS* L.)

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ABSTRACT

Combining ability of some polygenic and quality traits was studied in a set of diallel crosses involving 10 maize inbreds (P_1 to P_{10}) to know the inheritance pattern of yield attributes. Analysis of variance exhibited highly significant differences among themselves for all the traits in all environments. The ratio of gca /sca was less than unity there by indicating the preponderance of non-additive gene effects in the expression of most of the characters studied. The parents P_1, P_2 and P_3 for grain yield, P_5 and P_8 for oil content, P_6, P_8 and P_9 for starch content and P_7, P_8 and P_{10} for protein content were identified as most promising parents due to having good general combining ability. Among the crosses significant and desirable sca effects $P_3 \times P_1$ and $P_3 \times P_2$ for grain yield, $P_7 \times P_4$ and $P_5 \times P_9$ for oil content, $P_1 \times P_3$ and $P_9 \times P_5$ for starch content and $P_9 \times P_6$ & $P_8 \times P_3$ for protein content, respectively. Therefore, these crosses could be utilized for further selection of high yielding and quality progenies to achieve a quantum jump in maize improvement.

INTRODUCTION

The commercial exploitation of maize hybrid cultivar was first made in U.S.A as early as 1878. However, hybrid maize cultivation was made possible by Shull and Jones in first two decades of the last century. Hybrid maize occupied sizeable acreage in U.S.A. in early thirties and made rapid strides thereafter. It began with double cross hybrids and by sixties, with the availability of vigorous high yielding inbred lines, along with improved crop and seed production technologies, the focus shifted to single crosses (Dhillon *et al*., 2000). This shift from multi-parent (MP) hybrids to two parent (TP) single cross hybrids was made possible due to the successful development of vigorous and productive inbred lines as a result of population improvement programmes.

The breeding strategy for single cross hybrid development in maize (*Zea mays* L.) requires identification of high *per se* performing vigorous and productive inbred lines combined with good seed quality traits and desirable combining ability effects in cross combination to identify single crosses with high heterotic effects. The two parent conventional single cross hybrids practically replaced double cross and three way cross hybrids in most of the developed countries (Mauria *et al*. 1998). Single cross hybrids are considered most desirable as the breeding and seed production is much easier than the multi-parent hybrids (Vasal *et al*. 1995). Corn oil is considered desirable for human nutrition as it contains a high percentage (about 80%) of unsaturated fatty acids like oleic and linolenic acid and has a very low content of cholesterol (Singh *et al*. 1998). In spite of this, limited breeding work has been done for exploiting the potentiality of maize as a source of edible oil in India. In general, oil content is negatively correlated with yield. Efforts are being made to keep balance in potential yield of maize and its oil content by selecting appropriate genotypes having high oil content. Maize is the major source of starch produced worldwide. In USA 95% starch manufactured is from maize. Efforts are needed to develop maize hybrids and composite having high amylase and amylopectin for use in the industry as specialized starch. Hybrids like "Hi starch" which was developed to take care for quality and amount of starch belong to full season maturity group which requires assured moisture conditions. Selection of parents on the basis of phenotypic performance alone is not a sound procedure since phenotypically superior lines may yield poor recombination. It is therefore, essential that parents should be chosen on the basis of their genetic value. The performance of parent may not necessarily reveal it to be a good or poor combiner. Therefore, gathering information on nature of gene effects and their expression in terms of combining ability is necessary. At the same time, it also elucidates the nature of gene action involved in the inheritance of characters. The concept of good combining ability refers to the potential of a parental form of producing by its crossing with another parent superior offspring for the breeding process and it is widely used in the breeding of cross-pollinated plants. Information and exact study of combining ability can be useful in regard to selection of breeding methods and selection of lines for hybrid combination. The present study was, therefore, undertaken with a view to estimate general and specific combining ability variances and effects in maize for seed yield and quality traits.

MATERIALS AND METHODS

Fifty diverse inbred lines were grown in Randomized block design (RBD) with three replications in *Kharif* 2008 at Department of Genetics and Plant Breeding, Allahabad School of Agriculture, Sam Higginbottam Institute of Agriculture, Technology and Sciences, Allahabad. Out of these fifty inbred lines, ten vigorous and productive lines were finally selected to be used as parents in crossing programme. These 10 inbred lines were crossed as per diallel mating design (Griffing, 1956, Method I model II) during Rabi 2008-09 to generate 90 F_1 crosses. Parental lines and their 90 F_1s along with 4 checks *viz.,* Ashwani, Varun, DHM 117 and MRM 3765 were evaluated in Kharif 2009 under three environments. The data were analyzed of seed yield, oil content, starch and protein content for different methodology. The Soxhlet method developed by A.O.A.C. (1970) was used for the estimation of oil content was estimated in percent. For starch content was determined by Anthrone Reagent two samples of maize grains per treatment per replication were analyzed. Two samples of maize grain per treatment per replication were analyzed for nitrogen content by Micro Kjeldhal's Method and obtain protein content the value of nitrogen content was multiplied by a factor of 6.25 and averaged and their mean values were subjected to various statistical and biometrical analyses. The analysis of variance was carried out for individual as well as over the environments as per the standard procedure (Fisher, 1936). The variances for general combining ability and specific combining ability were tested against their respective error variances derived from ANOVA reduced to mean level. Significance test for GCA and SCA effects were performed using t-test. Estimates of combining ability were computed according to Kempthrone (1957) and average degree of dominance by Kempthrone and Curnow (1961).

RESULTS

The data on 90 crosses in all the environments were analyzed and the total variance was partitioned into components. Analysis of variance for combining ability (Table 1) exhibited significant for all the characters in all the environments. The estimates of sca variance were of higher magnitude than gca variance and the ratio of gca /sca was less than unity for all the character in all the environments.

General combining ability

Grain yield per plant for the parental lines *viz.,* P_1 (6.71), P_2 (3.71), P_3 (4.82) and P_5 (4.56) showed significant positive gca effects (Table 2), whereas, parent P_8 (-5.53) showed significant negative gca effects in environment E_1. Similarly in environment E_2, the parental lines *viz.,* P_2 (4.59), P_3 (4.82), P_4 (10.16) and P_7 (3.26) exhibited significant positive gca effects while, parent P_6 (-3.53), P_9 (-4.21) and P_{10} (-6.76) showed significant negative gca effects. In environment E_3, parental line P_2 (9.12), P_3 (4.78), P_4 (4.89) showed significant positive gca effects while, none of the parent showed recorded significant negative gca effects. The estimates of positive gca effects for this trait ranged from 0.04 (P_6) to 6.71 (P_1) in environment E_1, from 0.12 (P_2) to 10.16 (P_4) in environment E_2 and from 4.78 (P_3) to 9.12 (P_2) in environment E_3. Parental line P_2 exhibited consistent significant positive gca effects in all the environments. The highest gca effects for oil content revealed that parental lines *viz.,* P_1 (0.23), P_2 (0.09), P_4 (0.04), P_5 (0.14), P_8 (0.20), P9 (0.20) and P_{10} (0.11) showed significant positive gca effects, whereas, parents P_3 (-0.25), P_6 (-0.10) and P_7 (-0.01) showed significant negative gca effects in environment E_1. Similarly in environment E_2, the parental lines *viz.,* P_1 (0.24), P_2 (0.10), P_4 (0.04), P_5 (0.14), P_8 (0.20), P_9 (0.20) and P_{10} (0.11) exhibited significant positive gca effects while, parent P_3 (-0.26), and P_6 (-0.10) showed significant negative gca effects. In environment E_3, parental line P_1 (0.24), P_2 (0.10), P_4 (0.03), P_5 (0.13), P_8 (0.20), P_9 (0.21) and P_{10} (0.12) showed significant positive gca effects while, P_3 (-0.27), and P_6 (-0.09) showed significant negative gca effects. The estimates of positive significant gca effects for this trait ranged from 0.01 (P_7) to 0.23 (P_1) in environment E_1, from 0.04 (P_4) to 0.24 (P_1) in environment E_2 and from 0.03 (P_4) to 0.24 (P_1) in environment E_3. The estimates of significant gca effects for starch content revealed that out of 10 parents, the parental lines *viz.,* P_1 (0.27), P_2 (0.41), P_6 (0.24) and P_{10} (0.27) showed significant positive gca effects, whereas, parents P_4 (-0.18), P_5 (-0.28), P_8 (-0.42) and P_9 (-0.26) showed significant negative gca effects in environment E_1. Similarly in environment E_2, the parental lines *viz.,* P_1 (0.30), P_2 (0.37), P_6 (0.21) and P_{10} (0.30) exhibited significant positive gca effects while, parent P_4 (-0.17), P_5 (-0.25), P_8 (-0.38) and P_9 (-0.27) showed significant negative gca effects. In environment E_3, parental line P_1 (0.27), P_2 (0.42), P_3 (0.03), P_6 (0.14) and P_{10} (0.27) showed significant positive gca effects while, P_4 (-0.28), P_5 (-0.26), P_8 (-0.41) and P_9 (-0.29) showed significant negative gca effects. The estimates of positive significant gca effects for this trait ranged from 0.05 (P_3) to 0.41 (P_2) in environment E_1, from 0.21 (P_6) to 0.37 (P_2) in environment E_2 and from 0.03 (P_3) to 0.42 (P_2) in environment E_3. The estimates of estimates of significant gca effects for protein content revealed that the parental lines *viz.,* P_6 (0.30), P_7 (0.02), P_8 (0.32), P_9 (0.40) and P_{10} (0.25) showed significant positive gca effects, whereas, parents P_1 (-0.36), P_2 (-0.08), P_3 (-0.62), P_4 (-0.54) and P_5 (-0.54) recoded significant negative gca effects in environment E_1. Similarly in environment E_2, the parental lines *viz.,* P_6 (0.30), P_7 (0.03), P_8 (0.31), P_9 (0.39) and P_{10} (0.24) exhibited significant positive gca effects while, parent P_1 (-0.38), P_2 (-0.06), P_3 (-0.63), P_4 (-0.54) and P_5 (-0.72) showed significant negative gca effects. In environment E_3, parental line P_6 (0.32), P_8 (0.34), P_9 (0.41) and P_{10} (0.27) showed significant positive gca effects while, P_1 (-0.48), P_2 (-0.03), P_3 (-0.70), P_4 (-0.54) and P_5 (-0.73) showed significant negative gca effects. The estimates of positive significant gca effects for this trait ranged from 0.02 (P_7) to 0.40 (P_9) in environment E_1, from 0.03 (P_7) to 0.39 (P_9) in environment E_2 and from 0.27 (P_{10}) to 0.41 (P_9) in environment E_3.

Specific combining ability

For sca effects for grain yield per plant (Table 3) revealed that the range of positive sca effects for this trait ranged from 0.03 ($P_{10} \times P_2$) to 30.24 ($P_3 \times P_2$) in environment E_1, from 0.21 ($P_7 \times P_6$) to 37.13 ($P_5 \times P_6$) in environment E_2 and from 0.03 ($P_3 \times P_9$) to 37.15 ($P_7 \times P_3$) in environment E_3. Data for this trait

Table 1: Analysis of variance for combining ability for grain yield per plant, oil content, starch content and protein content in maize

Source of variation	df	Mean Sum of Squares Grain yield per plant			Oil content			Starch content			Protein content		
		E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3
Replication	2	3.71*	0.39	2.48	14.16**	7.93**	1.05	0.19	3.69*	6.61**	4.58*	44.87**	14.69**
Treatments	99	5.41**	6.29**	1.93**	2291.85**	2773.70**	178.26**	283.1**	325.56**	1307.44**	1133.55**	25052.01**	21569.85**
Parents	9	2.21*	1.71	0.69	1582.97**	1799.04**	114.75**	476.1**	522.33**	2070.08**	1024.46**	21847.63**	18693.49**
Hybrids	89	5.68**	6.53**	2.06**	2389.15**	2902.87**	186.68**	265.9**	307.91**	1241.14**	1142.86**	25346.04**	21793.88**
Parent /Hybrids	1	10.26**	27.05**	0.63	12.06**	48.69**	0.28	71.0**	125.41**	344.78**	1287.54**	27723.28**	27519.12**
F_1's	44	5.39**	4.66**	3.30**	2712.00**	3300.06**	216.44**	263.1**	301.98**	1128.10**	957.83**	21364.94**	20886.36**
Error	198	66.36	51.46	356.81	0.001	0.002	0.001	0.005	0.004	0.001	0.001	0.003	0.002
Variance													
GCA		12.73	24.25	5.76	0.03	0.03	0.03	0.08	0.07	0.07	0.15	0.15	0.18
SCA		329.25	230.42	386.97	0.21	0.21	0.22	1.39	1.42	1.59	1.31	1.33	1.34
Reciprocal		132.51	136.28	159.91	0.09	0.09	0.08	0.6	0.6	0.56	0.53	0.53	0.52
GCA/SCA		0.04	0.11	0.01	0.12	0.13	0.13	0.05	0.05	0.05	0.12	0.11	0.14

*, ** Significant at 5 % and 1 % level of significance respectively

Table 2: General combining ability effects for grain yield per plant, oil content, starch content and protein content in maize

S. No.	Parents	Env.	Grain yield /plant	Oil content	Starch content	Protein content
1	P1	E_1	6.71**	0.23**	0.27**	-0.36**
		E_2	0.12	0.24**	0.30**	-0.38**
		E_3	-2.89	0.24**	0.27**	-0.48**
2	P2	E_1	3.71*	0.09**	0.41**	-0.08**
		E_2	4.59**	0.10**	0.37**	-0.06**
		E_3	9.12**	0.10**	0.42**	-0.03**
3	P3	E_1	3.25	-0.25**	0.05**	-0.62**
		E_2	4.82**	-0.26**	0.02	-0.63**
		E_3	4.78**	-0.27**	0.03**	-0.70**
4	P4	E_1	2.44	0.04**	-0.18**	-0.54**
		E_2	10.16**	0.04**	-0.17**	-0.54**
		E_3	4.89**	0.03**	-0.13**	-0.54**
5	P5	E_1	4.56**	0.14**	-0.28**	-0.73**
		E_2	0.69	0.14**	-0.25**	-0.72**
		E_3	-1.68	0.13**	-0.26**	-0.73**
6	P6	E_1	0.04	-0.10**	0.24**	0.30**
		E_2	-3.53*	-0.09**	0.21**	0.30**
		E_3	-2.26	-0.09**	0.14**	0.32**
7	P7	E_1	-0.96	-0.01**	0.00	0.02**
		E_2	3.26*	0.00	0.02	0.03*
		E_3	-3.02	0.01	0.00	0.02
8	P8	E_1	-5.53**	0.20**	-0.42**	0.32**
		E_2	-2.62	0.20**	-0.38**	0.31**
		E_3	-7.47*	0.20**	-0.41**	0.34**
9	P9	E_1	-3.91	0.20**	-0.26**	0.40**
		E_2	-4.21**	0.20**	-0.27**	0.39**
		E_3	-0.99	0.21**	-0.29**	0.41**
10	P10	E_1	-1.18	0.11**	0.27**	0.25**
		E_2	-6.76**	0.11**	0.30**	0.24**
		E_3	-0.48	0.12**	0.27**	0.27**
	Gi	E_1	3.91	0.01	0.03	0.02
		E_2	3.44	0.00	0.03	0.00
		E_3	4.07	0.02	0.02	0.00
	Gi-Gj	E_1	5.83	0.01	0.05	0.03
		E_2	5.13	0.01	0.05	0.01
		E_3	6.51	0.03	0.02	0.01

*, ** Significant at 5 % and 1 % level of significance respectively

P_1 = AAI$_1$, P_2 = AAI$_2$, P_3 = AAI$_3$, P_4 = CM 149, P_5 =AAI$_4$, P_6 = CM 137, P_7 = CM 138, P_8 = CM150, P_9 = AAI$_5$, P_{10} = AAI$_6$

further revealed that hybrids $P_3 \times P_2$ (30.24) exhibited highest positive significant sca effects in environment E_1. Similarly in environment E_2, hybrid $P_5 \times P_6$ (37.13) depicted highest positive significant sca effects. Where as in environment E_3, hybrid $P_7 \times P_3$ (37.15) exhibited highest significant positive sca effects. The sca effects for this trait ranged from 0.03 ($P_1 \times P_3$) to 0.59 ($P_7 \times P_4$) in environment E_1, from 0.02 ($P_{10} \times P_6$) to 0.58 ($P_7 \times P_4$) in environment E_2 and from 0.06 ($P_9 \times P_{10}$) to 0.62 ($P_7 \times P_4$) in environment E_3. Hybrids $P_7 \times P_4$ (0.59) exhibited highest positive significant sca effects in environment E_1, similarly in environment E_2, hybrid $P_7 \times P_4$ (0.58) and environment E_3, hybrid $P_7 \times P_4$ (0.62) respectively. For starch content positive sca effects ranged from 0.11 ($P_{10} \times P_3$) to 1.94 ($P_1 \times P_3$) in environment E_1, from 0.09 ($P_2 \times P_3$) to 1.85 ($P_1 \times P_3$) in environment E_2 and from 0.06 ($P_{10} \times P_3$) to 1.91 ($P_1 \times P_3$) in environment E_3 respectively, hybrids $P_1 \times P_3$ (1.94) exhibited highest positive significant sca effects in environment E_1, similarly in environment E_2, hybrid $P_1 \times P_3$ (1.85) and

Table 1: Specific combining ability for grain yield per plant, oil content, starch content and protein content in maize

S.No.	Hybrids	Env.	Grain yield /plant	Oil content(%)	Starch content(%)	Protein content(%)
1	P1 × P2	E1	-11.10**	0.15**	-1.65**	1.09**
		E2	-18.60**	0.13**	-1.63**	1.08*
		E3	-2.80	0.16**	-1.64**	1.09**
2	P1 × P3	E1	-16.52**	0.03*	1.94**	0.60**
		E2	-16.02**	-0.08*	1.85**	0.61**
		E3	-13.02	-0.09*	1.91**	-0.45**
3	P1 × P4	E1	-18.38**	0.50**	1.38**	1.02**
		E2	-10.77**	0.51**	1.25**	1.01**
		E3	-9.63	0.50**	1.32**	-0.53**
4	P1 × P5	E1	7.65	0.20**	0.15*	0.34**
		E2	7.30	0.18**	0.20*	0.34**
		E3	10.70	0.20**	0.17**	0.35**
5	P1 × P6	E1	-1.18	-0.53**	1.24**	-0.98**
		E2	15.90**	-0.54**	1.24**	-0.99**
		E3	5.05	-0.54**	1.23**	-0.99**
6	P1 × P7	E1	5.35	0.22**	-0.87**	0.61**
		E2	14.72**	0.20**	-0.86**	0.60**
		E3	9.43	0.24**	-0.87**	0.61**
7	P1 × P8	E1	-16.53**	0.05*	0.94**	-0.36**
		E2	4.00	0.08*	0.94**	-0.35**
		E3	-1.08	0.03	0.94**	-0.36**
8	P1 × P9	E1	2.70	-0.68**	0.67**	-0.31**
		E2	1.53	-0.69**	0.67**	-0.31**
		E3	-13.37	-0.69**	0.67**	-0.27**
9	P1 × P10	E1	-22.20**	-0.45**	1.10**	-0.41**
		E2	-12.37**	-0.43**	1.10**	-0.40**
		E3	-9.53	-0.44**	1.10**	-0.40**
10	P2 × P1	E1	0.47	0.27**	-0.21*	-0.54**
		E2	-9.16	0.27**	-0.32**	-0.57**
		E3	-13.38	0.23**	-0.32**	-0.46**
11	P2 × P3	E1	-10.77**	-0.15**	0.06	-0.01
		E2	-12.72**	-0.15**	0.09*	0.00
		E3	7.47	-0.13**	0.05	0.00
12	P2 × P4	E1	27.67**	0.07*	-1.74**	-0.23*
		E2	12.20**	0.07*	-1.75**	-0.23**
		E3	22.25**	0.08*	-1.25**	-0.25**
13	P2 × P5	E1	-1.98	-0.01	-0.10*	0.25*
		E2	-3.18	0.01	-0.10*	0.25**
		E3	15.58**	-0.05	-0.10**	0.25**
14	P2 × P6	E1	-2.37	0.29**	-0.83**	0.69**
		E2	-0.12	0.27**	-0.82**	0.71**
		E3	6.50	0.30**	-0.84**	0.70**
15	P2 × P7	E1	7.42	-0.10*	0.83**	-0.22*
		E2	2.78	-0.09*	0.84**	-0.05*
		E3	-5.80	-0.10*	0.83**	-0.04*
16	P2 × P8	E1	10.90*	-0.04*	0.45**	-0.49**
		E2	4.00	-0.04*	0.45**	-0.50**
		E3	-2.52	-0.03	0.45**	-0.52**
17	P2 × P9	E1	-10.10	0.22**	-0.35**	-0.20*
		E2	-19.83**	0.20**	-0.45**	-0.20**
		E3	12.33	0.20**	-0.40**	-0.20**
18	P2 × P10	E1	-9.07	-0.34**	0.50**	0.04
		E2	-16.30**	-0.34**	0.00	0.06*
		E3	20.06**	-0.35**	0.25**	0.05*
19	P3 × P1	E1	18.58**	-0.21**	0.22**	0.40**
		E2	18.32**	-0.32**	0.22**	0.42**
		E3	16.01**	-0.32**	0.21**	-0.42**
20	P3 × P2	E1	30.24**	-0.51**	-1.62**	-1.19**
		E2	19.52**	-0.49**	-1.54**	-1.19**
		E3	20.18**	-0.48**	-1.67**	-1.11**
21	P3 × P4	E1	-4.95	-0.11**	0.16*	0.34**
		E2	-0.62	-0.11**	0.15*	0.35**
		E3	-18.95**	-0.10*	0.16**	0.36**
22	P3 × P5	E1	-17.07**	0.11**	-0.01	-0.34**
		E2	2.33	0.09*	-0.01	-0.35**
		E3	-7.90	0.08*	-0.02	-0.35**
23	P3 × P6	E1	-14.30**	0.30**	0.01	1.41**
		E2	-3.08	0.30**	-0.54**	1.40**
		E3	5.32	0.27**	-0.04	1.40**
24	P3 × P7	E1	2.05	-0.11**	0.30**	0.24*
		E2	-18.77**	-0.10*	0.26**	0.25**
		E3	-4.13	-0.10*	0.28**	0.25**
25	P3 × P8	E1	2.85	-0.50**	-0.14*	1.04**
		E2	-1.75	-0.49**	-0.13*	1.03**

Table 1: Cont...

S.No.	Hybrids	Env.	Grain yield /plant	Oil content(%)	Starch content(%)	Protein content(%)
		E3	9.80	-0.50**	-0.15**	1.04**
26	P3 × P9	E1	-9.97	-0.54**	-0.50**	0.15*
		E2	8.47	-0.55**	-0.50**	0.13*
		E3	0.03	-0.54**	-0.50**	0.14**
27	P3 × P10	E1	6.98	0.38**	-0.86**	0.61**
		E2	-19.65**	0.41**	-0.85**	0.61**
		E3	4.10	0.39**	-0.87**	0.60**
28	P4 × P1	E1	19.45**	-0.24**	0.65**	-0.15*
		E2	20.26**	-0.22**	0.64**	-0.14*
		E3	11.98	-0.23**	0.61**	-0.28**
29	P4 × P2	E1	14.71**	-0.26**	0.21*	-1.24*
		E2	11.50**	-0.27**	0.27**	-1.25**
		E3	2.05	-0.26**	0.65**	-1.23**
30	P4 × P3	E1	-24.65**	0.30**	0.16*	0.13*
		E2	-23.66**	0.31**	0.21**	0.12*
		E3	-11.61	0.30**	0.12**	0.23**
31	P4 × P5	E1	15.01**	-0.40**	-0.83**	-1.30**
		E2	-9.68*	-0.41**	-0.81**	-1.31**
		E3	0.60	-0.24**	-0.83**	-1.30**
32	P4 × P6	E1	-36.55**	0.05*	0.96**	1.31**
		E2	-11.97**	0.05*	1.03**	1.30**
		E3	-6.48	0.03	0.96**	1.32**
33	P4 × P7	E1	4.97	0.07*	0.15*	1.11**
		E2	-6.00	0.06*	0.15*	1.10**
		E3	15.05**	0.06*	0.14**	1.10**
34	P4 × P8	E1	2.15	0.07*	0.46**	0.45**
		E2	-12.88**	0.08*	0.46**	0.44**
		E3	-9.62	0.07*	0.46**	0.45**
35	P4 × P9	E1	-0.33	-0.01	0.18*	-0.30**
		E2	13.40**	0.01	0.19*	-0.30**
		E3	3.95	0.02	0.19**	-0.30**
36	P4 × P10	E1	2.62	-0.38**	-0.69**	0.31**
		E2	6.05	-0.40**	-0.69**	0.29**
		E3	12.65	-0.38**	-0.69**	0.30**
37	P5 × P1	E1	-2.31	-0.02*	-0.47**	0.74**
		E2	-0.46	-0.03*	-0.43**	0.73**
		E3	12.32	-0.01	-0.44**	0.84**
38	P5 × P2	E1	-6.04	0.12**	-1.06**	-0.15*
		E2	5.89	0.12**	-1.00**	-0.17*
		E3	-8.34	0.16**	-1.07**	-0.21**
39	P5 × P3	E1	-7.30	-0.20**	0.02	-0.10*
		E2	3.57	-0.19**	0.05	-0.10*
		E3	-2.81	-0.18**	0.03	-0.03*
40	P5 × P4	E1	-12.04**	0.00	0.14*	-0.43**
		E2	1.35	-0.02*	0.13*	-0.44**
		E3	10.61	-0.13**	0.09*	-0.44**
41	P5 × P6	E1	-13.80**	-0.31**	0.13*	1.18**
		E2	37.13**	-0.30**	0.14*	1.20**
		E3	7.75	-0.30**	0.12**	1.20**
42	P5 × P7	E1	-10.18	0.50**	0.00	0.23*
		E2	4.62	0.51**	0.00	0.24**
		E3	9.72**	0.50**	0.00	0.24**
43	P5 × P8	E1	-8.02	-0.11**	0.16*	0.18*
		E2	-12.05**	-0.10*	0.18*	0.18*
		E3	5.25	-0.12**	0.15**	0.19**
44	P5 × P9	E1	-25.62**	0.52**	-0.02	-0.12*
		E2	-11.22**	0.50**	-0.17*	-0.12*
		E3	1.88	0.53**	-0.02	-0.12**
45	P5 × P10	E1	-5.27	-0.16**	-0.13*	-0.45**
		E2	-12.02**	-0.13**	-0.15*	-0.45**
		E3	-13.17	-0.18**	-0.15**	-0.45**
46	P6 × P1	E1	7.52	0.34**	0.23**	-0.33**
		E2	-1.05	0.36**	0.26**	-0.32**
		E3	8.45	0.36**	0.35**	-0.20**
47	P6 × P2	E1	-6.66	0.15**	-0.77**	1.27**
		E2	2.50	0.16**	-0.66**	1.28**
		E3	-20.11**	0.16**	-0.68**	1.25**
48	P6 × P3	E1	-25.10**	0.43**	0.60**	0.94**
		E2	-7.53	0.45**	0.14*	0.94**
		E3	10.28	0.41**	0.66**	1.01**
49	P6 × P4	E1	15.05**	-0.52**	-0.34**	-0.55**
		E2	23.35**	-0.54**	-0.36**	-0.55**
		E3	13.93	-0.54**	-0.28**	-0.54**
50	P6 × P5	E1	6.71	-0.25**	1.38**	-1.59**

Table 1: Cont...

S.No.	Hybrids	Env.	Grain yield /plant	Oil content(%)	Starch content(%)	Protein content(%)
		E2	8.69	-0.26**	1.41**	-1.58**
		E3	1.44	-0.24**	1.47**	-1.61**
51	P6 × P7	E1	-10.33	-0.01	-0.60**	0.30**
		E2	-6.25	0.01	-0.60**	0.25**
		E3	-2.18	-0.03	-0.60**	0.30**
52	P6 × P8	E1	-3.97	-0.16**	0.50**	0.24*
		E2	3.85	-0.15**	0.50**	0.26**
		E3	-9.77	-0.15**	0.50**	0.25**
53	P6 × P9	E1	14.68**	-0.14**	-0.26**	-0.45**
		E2	-5.57	-0.14**	-0.26*	-0.44**
		E3	7.07	-0.16**	0.74**	-0.44**
54	P6 × P10	E1	-1.45	-0.06*	-0.02	1.36**
		E2	7.37	-0.07*	-0.01	1.36**
		E3	-1.03	-0.03	-0.03	1.36**
55	P7 × P1	E1	-11.81**	0.11**	-0.10*	-0.58**
		E2	-17.10**	0.11*	-0.08	-0.60**
		E3	-13.75	0.10*	-0.10*	-0.48**
56	P7 × P2	E1	-2.84	-0.01	1.53**	1.01**
		E2	-8.90	-0.04*	1.58**	1.14**
		E3	-26.59**	-0.03	1.53**	1.12**
57	P7 × P3	E1	15.00**	-0.46**	-0.37**	-0.67**
		E2	11.74**	-0.47**	-0.37**	-0.68**
		E3	37.15**	-0.47**	-0.37**	-0.60**
58	P7 × P4	E1	3.17	0.59**	-0.09	0.50**
		E2	1.14	0.58**	-0.09	0.47**
		E3	4.52	0.62**	-0.13**	0.47**
59	P7 × P5	E1	-2.80	0.15**	-0.63**	1.20**
		E2	-10.54*	0.15**	-0.65**	1.21**
		E3	-15.57*	0.16**	-0.64**	1.18**
60	P7 × P6	E1	1.34	-0.03*	-0.26**	-0.14*
		E2	0.21	-0.04*	-0.22*	-0.12*
		E3	13.01	0.00	-0.15**	-0.18**
61	P7 × P8	E1	3.52	-0.24**	-0.27**	0.34**
		E2	-15.12**	-0.26**	-0.27**	0.35**
		E3	-0.63	-0.25**	-0.24**	0.35**
62	P7 × P9	E1	-20.55**	-0.35**	0.75**	0.44**
		E2	-18.80**	-0.34**	0.75**	0.45**
		E3	-13.80	-0.30**	0.75**	0.45**
63	P7 × P10	E1	-14.42**	-0.10**	-0.63**	0.55**
		E2	-12.40**	-0.11*	-0.64**	0.56**
		E3	0.82	-0.11*	-0.64**	0.55**
64	P8 × P1	E1	-13.49**	-0.54**	0.36**	-0.79**
		E2	0.58	-0.52**	0.34**	-0.78**
		E3	-0.41	-0.52**	0.37**	-0.67**
65	P8 × P2	E1	4.62	0.33**	-0.67**	0.18*
		E2	4.18	0.31**	-0.62**	0.17**
		E3	-12.38	0.31**	-0.68**	0.13**
66	P8 × P3	E1	-8.78	0.28**	-0.58**	1.45**
		E2	-6.34	0.29**	-0.55**	1.47**
		E3	-15.83**	0.29**	-0.58**	1.56**
67	P8 × P4	E1	0.13	-0.13**	-0.06	0.88**
		E2	13.22**	-0.11*	-0.08	0.88**
		E3	-8.79	-0.09*	-0.10*	0.88**
68	P8 × P5	E1	11.60**	0.05*	-0.05	-0.10*
		E2	-6.77	0.04*	-0.07	-0.09*
		E3	7.69	0.03	-0.07*	-0.12*
69	P8 × P6	E1	-4.19	-0.47**	0.76**	-0.95**
		E2	-0.75	-0.47**	0.79**	-0.95**
		E3	7.55	-0.47**	0.87**	-0.98**
70	P8 × P7	E1	-16.80**	0.52**	-0.69**	-0.40**
		E2	-6.26	0.54**	-0.73**	-0.42**
		E3	7.00	0.55**	-0.70**	-0.44**
71	P8 × P9	E1	-0.82	0.41**	0.14*	0.14*
		E2	12.10**	0.38**	0.15**	0.15*
		E3	4.48	0.39**	0.14**	0.15**
72	P8 × P10	E1	-4.57	0.30**	-1.80**	1.35**
		E2	-5.57	0.31**	-1.80**	1.34**
		E3	10.78	0.31**	-1.80**	1.34**
73	P9 × P1	E1	6.27	-0.30*	0.47**	0.30**
		E2	-3.30	-0.28**	0.50**	0.30**
		E3	5.36	-0.28**	0.51**	0.37**
74	P9 × P2	E1	-17.89**	-0.35**	0.18*	-0.80**
		E2	4.93	-0.34**	0.17*	-0.82**
		E3	-14.45*	-0.35**	0.15**	-0.85**

Table 1: Cont...

S.No.	Hybrids	Env.	Grain yield /plant	Oil content(%)	Starch content(%)	Protein content(%)
75	P9 × P3	E1	-0.80	-0.01	1.59**	-1.41**
		E2	-12.91**	-0.02*	1.66**	-1.42**
		E3	-8.51	0.01	1.63**	-1.33**
76	P9 × P4	E1	-19.39**	0.25**	-0.56**	0.96**
		E2	-11.51**	0.22**	-0.54**	0.96**
		E3	5.19	0.27**	-0.59**	0.96**
77	P9 × P5	E1	0.56	0.13**	-0.61**	-0.39**
		E2	-1.85	0.14**	-0.73**	-0.39**
		E3	-4.53	0.17**	-0.58**	-0.41**
78	P9 × P6	E1	14.86**	0.23**	-0.96**	1.48**
		E2	-10.02**	0.22**	-0.88**	1.49**
		E3	1.60	0.22**	-1.83**	1.46**
79	P9 × P7	E1	5.93	0.01	0.38**	-0.49*
		E2	12.00**	0.01	0.41**	-0.50**
		E3	-20.65**	-0.04	0.42**	-0.52**
80	P9 × P8	E1	2.80	0.47**	0.00	-0.54**
		E2	7.09	0.44**	0.02	-0.55**
		E3	10.06*	0.47**	0.03	-0.57**
81	P9 × P10	E1	9.75	0.07*	0.65**	-1.90**
		E2	13.10**	0.05*	0.98**	-1.91**
		E3	-8.18	0.06*	-0.03	-1.91**
82	P10 × P1	E1	-12.74**	-0.04*	0.43**	-0.36**
		E2	-5.78	-0.03*	0.47**	-0.36**
		E3	-14.14	0.00	0.38**	-0.26**
83	P10 × P2	E1	0.03	-0.30**	-1.00**	0.40**
		E2	-3.82	-0.29**	-1.40**	0.39**
		E3	5.33**	-0.30**	-1.32**	0.34**
84	P10 × P3	E1	3.44	0.51**	0.11*	-0.21*
		E2	4.93	0.54**	0.19*	-0.19**
		E3	-16.11**	0.54**	0.06*	-0.13*
85	P10 × P4	E1	3.31	0.22**	-0.49**	0.71**
		E2	-15.60**	0.22**	-0.46**	0.70**
		E3	-21.61**	0.24**	-0.59**	0.70**
86	P10 × P5	E1	13.50**	0.07*	-0.56**	0.00
		E2	4.73	0.09*	-0.52**	0.03*
		E3	-16.42**	0.07*	-0.60**	0.00
87	P10 × P6	E1	6.74	0.03*	0.96**	-0.96**
		E2	3.07	0.02*	1.05**	-0.98**
		E3	-14.44*	0.03	1.00**	-1.00**
88	P10 × P7	E1	-2.85	-0.25**	-0.70**	0.16*
		E2	15.06**	-0.24**	-0.68**	0.15**
		E3	-2.57	-0.25**	-0.75**	0.12*
89	P10 × P8	E1	14.77**	-0.41**	1.42**	-0.19**
		E2	2.86	-0.45**	1.45**	-0.21**
		E3	2.92	-0.44**	1.36**	-0.23**
90	P10 × P9	E1	-14.28**	-0.08*	0.21*	0.68**
		E2	2.01	-0.08*	-0.05	0.68**
		E3	0.94	-0.10*	0.85**	0.67**
	Sij	E1	10.51	0.01	0.09	0.05
		E2	9.25	0.01	0.08	0.01
		E3	14.36	0.05	0.04	0.01
	Sii-Sjj	E1	20.75	0.03	0.17	0.09
		E2	18.28	0.02	0.16	0.02
		E3	28.12	0.09	0.08	0.02

*, ** Significant at 5 % and 1 % level of significance respectively

P_1 = AAI_1, P_2 = AAI_2, P_3 = AAI_3, P_4 = CM 149, P_5 = AAI_4, P_6 = CM 137, P_7 = CM 138, P_8 = CM150, P_9 = AAI_5, P_{10} = AAI_6

environment E_3, hybrid $P_1 \times P_3$ (1.91) respectively. Sca effects for starch content revealed that the range of positive sca effects ranged varied from 0.13 ($P_4 \times P_3$) to 1.48 ($P_9 \times P_6$) in environment E_1, from 0.03 ($P_{10} \times P_5$) to 1.49 ($P_9 \times P_6$) in environment E_2 and from 0.05 ($P_2 \times P_{10}$) to 1.56 ($P_8 \times P_3$) in environment E_3. Hybrids $P_9 \times P_6$ (1.48) exhibited highest positive significant sca effects in environment E_1, similarly, in environment E_2, hybrid $P_9 \times P_6$ (1.49), environment E_3, hybrid $P_8 \times P_3$ (1.56), respectively.

DISCUSSION

The significant mean square due to parents for different characters indicates significant contribution of parents toward general combining ability (gca) variance component for these traits. The estimates of sca variance were of higher magnitude than gca variance for all the character in all the environments. Besides this, the ratio of gca/sca was less than unity there by indicating the preponderance of non-additive gene effects in the expression of these traits. Similar results were reported by EL-Diashy (2007) and Abdel-Moneam *et al*. (2009). Under these circumstances, for exploitation non-additive gene action and to improve these characters, one has to resort to the breeding procedures, which lead to heterozygous end products such as recurrent selection and reciprocal recurrent selection. The estimates of gca effects for yield and yield contributing characters revealed that parental lines P_1 (AAI_1), P_2 (AAI_2), P_3 (AAI_3) and P_4 (CM 149) were best general combiners for grain yield per plant and also showed significant positive gca effects for most of the yield contributing characters and simultaneously possess high values indicating the *per se* performance of parents could prove as an useful index for combining ability, whereas it also reveals that P_7 (CM 138), P_8 (CM 150) and P_9 (AAI_5) were best *per se* performers but they were not good combiners. So these parents could be used extensively in hybrid breeding programme aimed at increasing maize grain yields. The high significant positive gca effects for different characters could be helpful in identifying outstanding parents with favorable alleles for yield and other desirable components. The high gca effects were due to additive effects and additive × additive gene effects (Griffing, 1956 and Sprague, 1966).

These cross mostly were from high × high, high × low, low × high, average × low general combining parents. This suggested an additive × additive, additive × dominant, dominant × additive gene effect was significant involved in their inheritance. Positive sca effects usually represent dominance and epistatic component of variation. Paul and Duara (1991) reported that parents with high gca always produce with high estimates of SCA. On the other hand Ivy and Hawlader (2000) reported that good general combining parents does not always show high sca effects in their hybrid combination. Similar findings for identification of superior parental lines and hybrids based on gca and sca effects for grain yield and its components traits in maize were reported by Joshi *et al.* (2002), Marker *et al.* (2002) and Meseka *et al.* (2006). The result of oil content was revealed that among parents, the best combiner were P_1 (AAI_1), P_2 (AAI_2), P_4 (CM 149), P_5 (AAI_4), P_8 (CM 150), P_9 (AAI_5) and P_{10} (AAI_6) among these P_1 (AAI_1), P_2 (AAI_2), P_5 (AAI_4), P_8 (CM 150), P_{10} (AAI_6) possessed higher oil content and therefore, can be used in improving oil content. The crosses $P_7 \times P_4$ (CM 138 × CM 149), $P_5 \times P_9$ ($AAI_4 \times AAI_5$), $P_8 \times P_7$ (CM 150 × CM 138), $P_{10} \times P_3$ ($AAI_6 \times AAI_3$), $P_1 \times P_4$ (AAI_1 × CM 149) and $P_5 \times P_7$ (AAI_4 × CM 138) in environment E_1 (Table 3). Similarly in environment E_2 hybrids $P_7 \times P_4$ (CM 138 × CM 149), $P_8 \times P_7$ (CM 150 × CM 138), $P_{10} \times P_3$ ($AAI_6 \times AAI_3$), $P_1 \times P_4$ (AAI_1 × CM 149 and $P_5 \times P_7$ (AAI_4 × CM 138 (Table 3). Where as in environment E_3 hybrids viz., $P_7 \times P_4$ (CM 138 × CM 149), $P_8 \times P_7$ (CM 150 × CM 138), $P_{10} \times P_3$ ($AAI_6 \times AAI_3$), $P_5 \times P_9$ ($AAI_4 \times AAI_5$), and $P_1 \times P_4$ (AAI_1 × CM 149 (Table 3) in all the three environments were having at least one good general combiner. Thus it is evident that gene action involved in their expression was non additive type. Hence they can be used in heterosis breeding to improve oil content. Further introgression of these parents by developing new gene combination brought through recurrent selection in further breeding programme will bring about change in gene frequent and may give high level of oil content. Therefore, there is a good scope for selection from segregating generating in isolating hybrids with high oil per cent. The protein content of maize has nutritional/value and it was demonstrated that protein per cent can be increased by breeding (Wang *et al*, 2007). In the present investigation parental line P_6 (CM 137), P_8 (CM 150) and P_9 (AAI_5) contributed maximum favourable gene for good general combiner. The five best hybrids exhibiting highest positive significant sca effects for protein content are viz., $P_9 \times P_6$ (AAI_5 × CM 137), $P_8 \times P_3$ (CM 150 × AAI_3), $P_3 \times P_6$ (AAI_3 × CM 137), $P_6 \times P_{10}$ (CM 137 × AAI_6) and $P_8 \times P_{10}$ (CM 150 × AAI_6) in all the three environments were having at least one good general combiner. Thus it is evident that gene action involved in their expression was non-additive type. Hence they can be used in heterosis breeding to improve protein content. Further introgression of these parents by developing new gene combination brought through recurrent selection in further breeding programme will bring about change in gene frequent and may give high level of protein content. Maize is the major source of starch produce worldwide and recovery of starch from maize is an economical process. Hence, it is desirable to develop maize hybrids with improved quality and amount of starch. The five best hybrids were $P_1 \times P_3$, $P_9 \times P_5$, $P_7 \times P_2$, $P_{10} \times P_8$ and $P_1 \times P_4$ among these hybrids $P_1 \times P_4$ and $P_1 \times P_3$ exhibited significant positive sca effects for oil and protein content and $P_7 \times P_2$ also showed positive sca effect for protein content. The mean performance of these five hybrids was also quite high for starch, protein, and oil content as well as for grain yield. Hence these hybrids can be sending in multi-location testing for their released as single cross for improving both yield and nutritional quality. Overall results regarding combining ability, revealed that different crosses exhibited differential response for sca effects in different environments for all the quantitative traits, i.e., there were very little or no reproducibility for sca effects of these crosses in all the environments. It showed effects of the environments in the performance of the crosses. The hybrid possessing high yield potential with significant SCA effects could be used for better hybrid selection. The information on the nature of gene action with respect to variety and characters might be used depending on the breeding objectives. Parent P_1 (AAI_1) was adjusted as best parent for yield and yield contributing characters. In addition parents P_2 (AAI_2), P_3 (AAI_3) and P_4 (CM 149) were also found good combiner for grain yield. Therefore, they can be used to constitute a composite maize cultivar for low to moderate normal conditions.

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