Int.J.Curr.Microbiol.App.Sci (2020) Special Issue-10: 483-499

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 Special Issue-10 pp. 483-499
Journal homepage: http://www.ijcmas.com

Original Research Article

Line x Tester Model for Evaluating the Combining Ability of Some New White Maize Inbred Lines

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Keywords

Line x Tester, Combining ability, Hybrid, *gca*, *sca*

A B S T R A C T

Analysis of variance showed that mean sum of squares was highly significant for all the characters. This means the genotypes differ significantly for different traits and there is no or very less environmental influence on the expression of traits. A relatively higher estimate of GCV was obtained for ear height, plant height, grain yield and no. of kernels/row. High heritability coupled with high genetic advance was recorded for the traits ear height, no of kernels/row, grain yield, ear length and test weight depicts the presence of additive gene effects. Results of combining ability revealed that the lines IAMI-14, IAMI-31 and IAMI-16 were found good general combiner for grain yield and most of the traits. The tester CML-540 and CML-545 were identified as a good general combiner for grain yield. The crosses IAMI-31/ CML-540, IAMI-14/CML-540, IAMI-03/CML-545 and IAMI-16/CML-545 were registered as a desirable specific combiner for grain yield and other important traits. Standard heterosis over Shaktiman-2 was found significant for crosses IAMI-31/CML-540 (48.16%), IAMI-14/CML-540 (40.44%), IAMI-03/CML-545 (33.08%) and IAMI-16/CML-545 (30.75 %).

Introduction

Maize (*Zea mays* L.), the queen of cereals, surpasses all other cereals and food crops in its ability to adapt to diverse agro-ecological niches and being cultivated from 58^{o}N to 55^{o}S latitude. Worldwide maize is cultivated on over 185 million hectares in 170 countries with a productivity of 5.62 t/ha. It belongs to the crop family called *Poaceae*. In India, it is traditionally a *kharif* season crop, but it is now cultivated in spring season too. The expansion started in 1960s or may be 50s, first to *rabi* and then to spring season. Further, maize, being a C_4 plant, is physiologically highly efficient. The demand for maize is expected to increase in coming years, the major drivers for which in India include demand for feed for expanding livestock and poultry sector and fodder; processed foods like corn flakes, bakery products, fine cereals and maize-based concentrates due to changing lifestyle; and raw material for expanding industrial sector (starch, ethanol, rubber, paper, cosmetics, pharmaceuticals etc.). In India, maize is the third most important cereal crop after rice and wheat and accounts for around 10 per cent of total food grain production in the country. It was grown over an area of about 9.38 million ha, contributing 28.7 million t in 2017-18 and engaging about 15 million farmers (Dillon *et al.*, 2020).

In India, it is the 3rd most important crop among the cereals. The total maize production during 1950-51 was around 1.73 million MT, which has increased to 28.75 million MT by 2017-18 which is close to 16.6 times higher. The average productivity during the period has increased by 5.5 times to 3032 kg/ha from 547 kg/ha, while area increased by 3 times. Presently, it occupies 8.69 million hectare area and produces around 28.75 million MT of maize (Rakshit and Chikkappa, 2018). Projected demand by 2050 in India for maize production is around 121 million MT (Amarsingh and Singh, 2008). Much of this demand may be credited to rising number of poultry farms. A growth rate of 3% per annum in maize area in the early years of the 21st century was reported by Raju *et al*., 2010. Even though scope for area expansion is limited and it becomes necessary to explore regions having potential for yield expansion.

In Chhattisagarh, maize occupies an area of 1.93 lakh hectare with production and productivity of 4.8948 lakh tonnes and 2536 kg/ha respectively. In Chhattisgarh, an increasing tendency for maize average and production has been observed with the introduction and cultivation of single cross maize hybrids due to its high yield potential. The development of superior hybrids through hybrid development programme requires number of suitable and potential inbred/parent with better combining ability. Identification of inbreds/parents that could be utilized for hybridization programme to ·provide superior maize hybrids. Various types of biometrical techniques are extensively used in crop improvement programmes for evaluating inbred lines in terms of genetic component of variance. Diallel mating design is used to evaluate several inbred lines in terms of combining ability variances and effects. The approach of diallel analysis was developed by Griffing in 1956.

Materials and Methods

The experiment was conducted at Research-cum-instructional farm Ajirma, IGKV, RMD CARS, Ambikapur (C.G.) in Randomized Complete Block Design (RCBD) involving eight new white maize inbreds, four testers (Fig. 1a, 1b and 1c) and their thirty-two direct crosses with three checks NK 30, Hishell and Shaktiman 2 in three replications during *Rabi* 2018-19, which is located at a latitude of $20^0$8'N, longitude of $83^0$15'E and altitude of 592.62 m MSL (mean sea level) for estimation of combining ability effects (GCA & SCA) in maize. Each genotype was grown in two rows of 4 m length. The spacing of 60 cm X 20 cm was adopted between row and within row, respectively. All the recommended agronomic package of practices was adopted during the entire crop growth period. Observations were recorded following standard procedure. 5 plants in each replication were taken randomly for this purpose. 14 quantitative characters viz., plant population per plot, days to 50% pollen shed, days to 50% silking, days to 80% brown husk maturity, ear height (cm), ear length (cm), ear diameter (cm), plant height (cm), number of cobs/ears per plot, number of kernel row/ear, number of kernels per row, 100 grain weight (g), shelling percentage and grain yield (q/ha) were recorded. Data were analyzed for combining ability following approach 2 (Griffings, 1956).

Results and Discussion

Analysis of variance

Analysis of variance (ANOVA) as per the RCBD showed that mean sum of squares were highly significant for all the characters of genotypes (Table 1). This means the genotypes differ significantly for these traits and also it is a pre-requisite for the ANOVA for combining ability analysis.

Genetic parameters, genetic variability, heritability & genetic advance

Genetic parameters such as genetic variability, heritability and genetic advance as percentage of mean were summarized in Table 2 and depicted through Figure 2.

For all the characters the genotypic and phenotypic coefficient of variation are recorded, calculation of high genotypic and phenotypic coefficient of variation was *viz.*, ear height (cm) (499.20 % and 554.15 %), followed by plant height (cm) (418.87 % and 466.98 %), grain yield q/ha (281.039 % and 280.472 %), no. of kernels /row (190.55 % and 202.65 %), final plant stand (cm) (45.99 % and 63.63 %), no. of cobs/plot (47.24% and 70.31%), 100 grain weight (gm) (43.87 % and 51.12 %), ear length (cm) (40.71 % and 48.90 %). Moderate genotypic and phenotypic coefficients of variation are noted for traits *viz.*, Shelling % (17.98 % and 21.48 %), followed by day to 50% pollen shed (16.14 % and 17.38 %), ear diameter (cm) (15.54% and 19.47%), day to 50% silking (13.65% and 14.78%), no. of kernels row/cob (11.78% and 16.79%). Low genetic and phenotypic coefficient of variation is recorded for characters *viz.*, Day to 80% maturity (7.33% and 8.90%). Among the characters studied, high heritability estimates are recorded for all the character ranged from 67.19% (No. of cobs /plot) to 94.02% (No. of kernels/row). High heritability indicates the scope of genetic .enhancement of these traits through selection. This is because of there should be a close association between genotype and phenotype due to relatively smaller involvement of the environment. Genetic advance is a measure of genetic gain under selection. Ear height recorded the highest genetic advance as percentage of mean ear height (cm) (49.14 %), no. of kernels/row (49.11 %), grain yield (37.43 %), ear length (cm) (30.67 %), Plant height (cm) (28.25 %), 100 grain weight (gm) (25.09 %), no of cob/plot (20.29 %), final plant stand (20.24 %), ear diameter (cm) (20.16 %). Moderate genetic advance as percentage of mean are recorded for traits *viz.* no of kernels row/cob (16.61 %), day to 50% pollen shed (10.20 %), Rest of the traits showed low genetic advance as percentage of mean day to 50% silking (9.18 %), shelling percentage (9.13 %), day to 80% maturity (5.10 %). The results revealed that GCV's were not much differ with their respective PCV's, indicating the less influence of the environment on the expression of the traits. Relatively higher estimates of GCV for ear height, plant height, grain yield, and no of kernels per row suggests that the selection can be effective for these traits. Almost all the traits have high heritability estimates indicating the preponderance of additive gene action. High heritability and high genetic advance is recorded for the traits ear height, no of kernels/row, grain yield, ear length etc., that depicts the existence of additive gene effects. Thus such characters can be improved through selection. Higher PCV and GCV were reported previously for grain yield per plant by Yusuf (2010) and Sumathi *et al.*, (2005) and for 100 grain weight by Shakoor *et al*., (2007). Akbar *et al*., (2008) reported moderate PCV and GCV estimate for grain yield per plant, ear weight and harvest index. Most of these findings are in harmony with those obtained by Devi *et al.*, (2003), Sofi and Rather (2007), Rafiq *et al.*, (2010) and Wannows *et al.*, (2010).

Combining ability

Results of combining ability analysis (Table 3, 4 & 5) revealed that the general combining ability mean squares of lines and testers are observed extremely noteworthy for most of the characters viz., 100-kernel weight, days to 50% pollen shed and silking, ear and plant height, grain yield, number of kernels/row, no. of cob/plot, days to 80% maturity, ear diameter. Analysis of variance for specific combining ability also observed very significant dissimilarity for grain yield, 100-kernel weight, ear and plant height, days to 50% pollen shed and 50% silking, and days to 80% maturity. The outcome of analysis of combining abilities obtained presence of both additive and non-additive gene action. Hence, both additive and non-additive variances are much important in variety/hybrid development program.

The GCA and SCA effects are the main criteria used for selection and classification of parents in terms of their potential performance in various cross combinations. Variance due to GCA is observed to be high for plant height (158.08) followed by ear height (107.16), grain yield (48.13) and SCA variance is observed maximum for grain yield (72.18), followed by plant height (74.96), ear height (52.91) the characters like grain yield and days to 80% maturity showed greater SCA variance than GCA variance, representing the preponderance of non-additive gene action. These traits are more valuable for the enhancement of hybrid/breeding development program. Rest of the traits showed greater GCA variance than SCA variance, representing the preponderance of additive gene action. Improvement of these traits can be made possible through selection. The lines with high GCA can be combined to produce a good synthetic genotype.

Inbred line IAMI-14 exhibited the maximum GCA effect, whereas IAMI-52 exhibited the lowest GCA effect, representing the greatest and penurious general combiners in the group of inbred lines considered. IAMI-3, IAMI-14, IAMI-16 and IAMI-31 are found good general combiners for most of the characters like grain yield, ear diameter, ear length, 100 seed weight, no. of kernels / row etc. These Inbred lines could be utilized in maize grain genetic enhancement programs for advancement of the traits of concern as these lines have high potential to transfer desirable traits to their hybrid offspring. Similarly among testers CML-540 and CML-545 is the best general combiner for most of the traits. Out of the 32 crosses, 26 crosses have revealed significant SCA effects (thirteen positive and thirteen negative). The cross IAMI-31 x CML-540 (13.28) followed by IAMI-32 x CML-209 (11.08), IAMI-31 x IAFM-15-48 (10.89), IAMI-13 x CML-209 (8.68), IAMI-14 x CML-540 (7.39) etc. showed positive significant effect. Very noteworthy specific combining ability effects of the hybrids pointed out that significant deviation from what would have been predicted based on their parental concert. These crosses with very much positive and significant estimates of specific combining ability effect could be chosen for development of commercial hybrids to use in maize crop enrichment program. The findings of the present study are in agreement with the findings of Pal *et al.,* (1986), Vasal *et al.*, (1992), Satyanarayana *et al.*, (1994), Srivastava and Singh (2002), Todkar and Navale (2006), Kanagarasu *et al.*, (2010), Pavan *et al.*, (2011), Abrha *et al.*, (2013) and Kachapur *et al.*, (2018).

Heterosis

Investigation on heterosis provides fundamental information regarding the utility of the cross combination and its use for commercial exploitation. Standard heterosis ranged from -46.39% (IAMI-13 x IAFM-15-48) to 48.16% (IAMI-31 x CML-540) over check Shaktiman-2. Fifteen crosses have shown noteworthy standard heterosis effects (Table 6). Among them the positive significant effect was observed in ten crosses and negative significant effect in five crosses. The cross IAMI-31 x CML-540 (48.16%) showed highest positive significant effect followed by IAMI-14 x CML-540 (40.44%). Hybrid IAMI-31 x CML-540 gave highest grain yield 88.44 q/ha of maize followed by IAMI-14 x CML-540 (83.83 q/ha) and IAMI-03 x CML-545 (79.44 q/ha). These are identified superior in terms of grain yield, *gca* effects, *sca* effects and standard heterosis over check Shaktiman – 2 (Table 7). Heterosis increases yield potential and improves adaptation to stress in maize; however, the underlying mechanisms of heterosis and combining ability remain elusive (Araus *et al.*, 2010). Many hybrids gave negative values of heterosis in desirable direction for earlier tasseling, silking and plant height. Many hybrids exposed positive values of heterosis in desirable direction for cobs/plot, grain yield, cob yield, ear girth, ear length and 100 grain weight. These findings are in confirmatory with the results of Mohammed (2005), Muraya *et al.*, (2006), Hussain *et al.*, (2011) and Ali *et al.*, (2014). Heterosis over Shaktiman 2 was observed for several combination and the lines with high values of combining ability will be further selfed to generate stable inbred lines that will be evaluated in commercial breeding programs.

Table.1 Analysis of variance for grain yield and its component in maize

SN	Characters	Mean sum of squares		
		Replication	**Genotypes**	**Error**
	Degree of freedom	2	46	92
1	Plant Population	10.787	53.575**	6.070
2	Day to 50% Pollen shed	0.134	30.375**	0.758
3	Day to 50% Silking	0.085	26.705**	0.715
4	Day to 80% Maturity	1.071	23.140**	1.542
5	Ear height (cm)	62.738	1226.598**	43.418
6	Ear length (cm)	1.651	19.921**	1.252
7	Ear diameter (cm)	0.619	6.550**	0.509
8	Plant height (cm)	436.24	2605.069**	96.068
9	No. of cobs /Plot	6.404	53.932**	7.549
10	No. of kernels row/cob	0.960	5.136**	0.636
11	No. of kernels /row	4.813	184.032**	3.814
12	100 grain Weight (g)	1.954	35.229**	1.838
13	Shelling Percentage	2.620	43.954**	2.677
14	Grain Yield (q/ha)	67.808	1766.83**	42.11

** differ significantly at 1 percent level of probability

Table.2 Genotypic and phenotypic coefficient of variance (GCV and PCV), heritability (h^2) and genetic advance as a percentage of mean for different characters in maize

SN	Characters	Range	GCV %	PCV %	Heritability (h^2)	GA as percentage of mean
1	Plant Population	28.67 - 41.00	45.99	63.63	72.29	20.24
2	Day to 50% Pollen shed	54.00 - 65.67	16.14	17.38	92.87	10.20
3	Day to 50% Silking	57.00 - 68.00	13.65	14.78	92.37	9.18
4	Day to 80% Maturity	94.67-103.33	7.33	8.90	82.36	5.10
5	Ear height (cm)	26.67 - 94.00	499.20	554.15	90.08	49.14
6	Ear length (cm)	9.67 – 18.40	40.71	48.90	83.24	30.67
7	Ear diameter (cm)	9.53 – 14.77	15.54	19.47	79.82	20.16
8	Plant height (cm)	104.03-220.07	418.87	466.98	89.69	28.25
9	No. of cobs /plot	28.67 – 40.00	47.24	70.31	67.19	20.29
10	No. of kernels row/cob	10.00 – 15.60	11.78	16.79	70.21	16.61
11	No. of kernels/row	12.97- 40.13	190.55	202.65	94.02	49.11
12	100 grain weight (g)	15.27-28.37	43.87	51.12	85.82	25.09
13	Shelling Percentage	66.53- 78.47	17.98	21.48	83.71	9.13
14	Grain Yield (q/ha)	10.94 - 89.17	281.039	280.472	73.865	37.436

Table.3 ANOVA for L x T and Combining Ability Analysis in maize

SV	Degree of freedom	Final Plant Stand	Day to 50% Pollen Shed	Day to 50% Silking	Day to 80% Maturity	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Plant height (cm)	No. of cobs/plot	No. of kernels row/cob	No. of kernels/row	100 grain weight (g)	Shelling Percentage	Grain yield (q/ha)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Replication	2	10.787*	0.134	0.085	1.071	62.738*	1.651	0.619	158.761*	6.404*	0.960	4.813*	1.954	2.62	67.858*
Parent	11	80.47*	36.93*	31.90*	21.17*	991.10*	12.90*	3.11*	2212.11*	78.81*	3.11*	38.94*	29.76*	20.66*	891.92*
Crosses	31	37.97*	16.32*	15.80*	21.54*	852.11*	1.57	2.61*	1483.07*	40.08*	2.50*	35.43*	10.07*	7.59*	592.45*
Parent Vs Hybrid	1	277.73*	350.66*	272.40*	1.28	26616.21*	650.81*	169.13*	73892.56*	134.60*	93.13*	6382.11*	945.71*	1535.32*	53096.95*
Line effect	7	130.99*	63.13*	60.92*	24.88*	2248.17*	4.51*	6.71*	4681.61*	131.60*	4.71*	117.99*	20.28*	10.69*	1545.74*
Tester effect	3	2.37	3.71*	5.62*	77.86*	2043.09*	2.11	5.43*	1763.22*	4.09	7.24*	49.10*	26.00*	3.08	704.58*
Line x Tester Effect	1	12.05*	2.23*	2.21*	12.39*	216.62*	0.51	0.85	376.87*	14.71*	1.08	5.95	4.39	7.20	258.67*
Error	62	6.07	0.758	0.705	1.542	43.418	1.25	0.509	96.068	7.54	0.636	3.814	1.838	2.677	46.889
Variance GCA		3.03	1.78	1.72	2.16	107.16	0.15	0.29	158.08	2.95	0.27	1.31	1.04	-1.74	48.13
Variance SCA		1.24	0.83	0.89	3.69	52.91	-0.19	0.16	74.96	1.80	0.20	0.52	0.95	1.42	72.18
Variance GCA/SCA		2.44	2.14	1.93	0.58	2.02	-0.78	1.81	2.10	1.63	1.35	2.51	1.09	-1.22	0.66

*=significant at p=0.05 level **=significant at p=0.01 level

Table.4 General combining ability effects of parents for grain yield and its components in maize

*=significant at p=0.05 level **=significant at p=0.01 level

Characters	Final Plant Stand	Day to 50% Pollen Shed	Day to 50% Silking	Day to 80% Maturity	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Plant height (cm)	No. of cobs / plot	No. of kernels row /cob	No. of kernels /row	100 grain weight (g)	Shelling Percentage	Grain Yield (q/ha)
Parents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Line/Female														
IAMI-03	0.60	-2.35**	-2.28**	0.08	-2.17	-0.42	0.44**	4.66	0.51	-0.56**	1.14*	2.32**	0.75	5.57**
IAMI-13	-7.65**	3.40**	3.30**	-2.08**	-29.86**	-0.31	-1.77**	-38.61**	-7.82**	-0.74**	-7.46**	-1.10**	-1.96**	-2.58**
IAMI-14	0.02	-2.02**	-2.03**	-0.67*	-1.72	0.59*	-0.10	-7.32*	0.18	0.21	0.39	0.69*	0.29	8.37**
IAMI-16	0.94	-0.85**	-0.86**	1.17**	4.31*	0.31	0.33*	7.49*	0.93	-0.42*	2.76**	1.08**	0.43	5.50**
IAMI-19	-0.81	1.90**	1. 97**	1.42**	4.89**	-0.05	0.44**	13.16**	-0.32	-0.26	1.02*	-0.12	0.12	3.62
IAMI-31	1.94**	-1.44**	-1.45**	-1.92**	3.96*	-0.04	0.52**	-9.31**	2.09**	0.84**	1.71**	-0.56*	-0.56	7.09**
IAMI-32	2.44**	2.73**	2.64**	1.58**	18.73**	0.93**	0.16	29.13**	2.01**	0.94**	0.01	-0.62*	-0.17	3.71
IAMI-52	2.52**	-1.35**	-1.28**	0.42	1.86	-1.02**	-0.02	0.81	2.43**	-0.01	0.43	-1.70**	1.10**	-8.01**
SEm ± (Lines)	0.66	0.19	0.19	0.27	1.75	0.24	0.14	2.84	0.70	0.16	0.48	0.28	0.39	1.87
Tester/Male														
CML-209	0.40	-0.56**	-0.49**	-1.83**	12.26**	-0.30	-0.08	-8.20**	-0.03	-0.58**	-1.32**	0.49*	0.11	-5.16**
CML-540	-0.35	-0.23	-0.28*	1.71**	-0.73	-0.16	0.69**	-2.66	-0.45	0.53**	1.08**	0.44*	0.38	5.26**
CML-545	-0.10	0.52**	0.59**	1.38**	3.34**	0.09	-0.25**	-1.17	-0.07	-0.35**	1.38**	0.63**	-0.01	5.07**
IAFM-15-48	0.06	0.27*	0.18	-1.25**	9.66**	0.37*	-0.36**	12.03**	0.55	0.41**	-1.14**	-1.56**	-0.48	-5.13**
SEm± (Tester)	0.44	0.12	0.12	0.17	1.15	0.16	0.09	1.86	0.46	0.11	0.32	0.19	0.26	1.32

Table.5 Specific combining ability effects of crosses for grain yield and its components in maize

Crosses	Final Plant Stand	Day to 50% pollen shed	Day to 50% Silking	Day to 80% Maturity	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Plant height (cm)	No. of cobs/ plot	No. of kernels row/cob	No. of kernels /row	100 Grain weight (g)	Shelling Percentage	Grain Yield (q/ha)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
IAMI-03 * CML-209	-1.65	-0.44	-0.43	-3.25**	-13.67**	0.47	-0.55*	-28.75**	-2.22	-0.25	-0.23	-0.46	0.12	-7.09**
IAMI-03 * CML-540	-3.90**	-0.44	-0.64*	1.21*	4.93	0.13	0.18	6.65	-3.14*	-0.16	1.43	-0.68	1.22	-4.21**
IAMI-03 * CML-545	3.19**	0.48	0.49	2.54**	5.26	-0.59	0.12	3.42	3.49**	0.05	-0.53	1.73**	-0.12	5.98**
IAMI-03 * IAFM-15-48	2.35*	0.40	0.57	-0.50	3.47	0.00	0.24	18.69**	1.86	0.36	-0.68	-0.58	-1.22	5.32**
IAMI-13 * CML-209	1.94	0.81*	0.66*	3.92**	17.68**	-0.25	0.70**	23.11**	2.45*	0.67*	2.57**	0.09	2.33**	8.68**
IAMI-13 * CML-540	2.02	-0.19	0.11	-2.29**	-0.32	0.28	-1.28**	-4.15	1.53	-0.18	-1.83*	-0.90	-0.04	-3.11**
IAMI-13 * CML-545	-1.56	0.06	-0.09	-2.29**	-3.32	0.02	-0.07	-1.58	-0.84	-0.03	-2.13*	-0.85	-0.34	-5.68**
IAMI-13 * IAFM-15-48	-2.40*	-0.69*	-0.68*	0.67	-14.04**	-0.05	0.65**	-17.38**	-3.14*	-0.46	1.39	1.67**	-1.95**	0.13
IAMI-14 * CML-209	0.94	-0.10	-0.01	-0.17	6.01	-0.75	-0.17	0.96	1.11	0.45	-1.08	-0.34	1.15	3.99**
IAMI-14 * CML-540	0.35	-0.44	-0.55	-0.71	-0.92	-0.02	-0.11	-1.30	0.53	0.67*	0.18	1.61**	1.14	7.39**
IAMI-14 * CML-545	0.10	0.15	0.24	-0.04	0.55	0.46	0.10	1.60	-0.18	-0.45	0.69	-1.04*	-0.93	-7.09**
IAMI-14 * IAFM-15-48	-1.40	0.40	0.32	0.92*	-5.64	0.31	0.18	-1.26	-1.47	-0.68*	0.21	-0.23	-1.36*	-4.32**
IAMI-16 * CML-209	0.35	0.73*	0.82*	0.00	6.78*	-0.20	0.07	8.81	0.03	-0.12	-1.04	0.87	-1.49*	-3.13**
IAMI-16 * CML-540	1.10	-0.27	-0.39	0.12	-0.62	-0.40	0.53*	-1.39	1.45	-0.43	-0.72	0.72	-1.60*	0.60
IAMI-16 * CML-545	0.19	-1.02**	-0.93**	1.46**	-1.35	0.61	-0.09	-3.81	0.07	0.32	2.32**	-0.40	1.53*	4.67**
IAMI-16 * IAFM-15-48	-1.65	0.56	0.49	-1.58**	-4.81	0.00	-0.51*	-3.61	-1.55	0.22	-0.56	-1.18*	1.56*	-2.18*
IAMI-19 * CML-209	0.77	-0.02	-0.34	2.75**	5.20	0.06	-0.05	6.91	1.28	-0.02	0.30	0.87	-0.35	-1.86
IAMI-19 * CML-540	0.85	0.98**	1.11**	-0.79	-0.80	0.02	0.62*	-2.35	0.03	-0.53	-0.51	0.72	-1.56*	-0.30
IAMI-19 * CML-545	-0.73	0.56	0.57	0.54	-2.14	-0.04	-0.14	-3.51	-0.34	0.48	0.69	-0.40	0.34	3.16**
IAMI-19 * IAFM-15-48	-0.90	-1.52**	-1.34**	-2.50**	-2.26	-0.04	-0.43	-1.05	-0.97	0.06	-0.48	-1.18*	1.57*	-1.08
IAMI-31 * CML-209	-3.31**	-0.69*	-0.59	-1.92**	-17.34**	-0.18	-0.72**	-14.19**	-4.14**	-1.25**	-2.06*	0.38	-1.60*	-16.86**
IAMI-31 * CML-540	0.44	-0.35	-0.47	0.21	4.80	-0.12	0.61*	8.95	0.61	0.97**	0.73	-0.14	0.56	13.28**
IAMI-31 * CML-545	0.19	0.90**	0.99**	-0.12	1.33	-0.11	-0.15	1.12	-0.43	-0.28	0.77	-1.43**	-0.44	-7.36**
IAMI-31 * IAFM-15-48	2.69*	0.15	0.07	1.83**	11.21**	0.41	0.26	4.12	3.95**	0.56*	0.56	1.19*	1.49*	10.89**
IAMI-32 * CML-209	0.19	-1.52**	-1.34**	-1.08*	-1.97	0.32	0.30	-1.15	-0.05	0.12	0.84	0.14	-1.13	11.08**
IAMI-32 * CML-540	-1.06	0.81*	0.78*	1.37**	-5.10	0.38	-0.40	-1.55	-0.64	-0.73*	1.23	-0.04	1.74*	-6.15**
IAMI-32 * CML-545	-0.98	-0.27	-0.43	-2.29**	0.56	-0.01	0.44	-0.31	-1.34	0.02	-0.86	0.71	0.83	6.57**
IAMI-32 * IAFM-15-48	1.85	0.98**	0.99**	2.00**	6.51*	-0.69	-0.35	3.02	2.03	0.59*	-1.21	-0.81	-1.44*	-11.56**
IAMI-52 * CML-209	0.77	1.23**	1.24**	-0.25	-2.70	0.53	0.41	4.30	1.53	0.40	0.69	-1.55**	0.97	5.00**
IAMI-52 * CML-540	0.19	-0.10	0.03	0.88	-1.97	-0.27	-0.16	-4.84	-0.39	0.36	-0.52	-1.27*	-1.46*	-7.55**
IAMI-52 * CML-545	-0.40	-0.85*	-0.84*	0.21	-0.90	-0.33	-0.22	3.07	-0.43	-0.10	-0.95	1.68**	-0.87	-0.31
IAMI-52 * IAFM-15-48	-0.56	-0.27	-0.43	-0.83	5.57	0.06	-0.04	-2.53	-0.72	-0.66*	0.77	1.13*	1.36*	2.28*
SEm±	1.15	0.32	0.32	0.46	3.03	0.41	0.24	4.92	1.22	0.28	0.84	0.49	0.68	3.74

*=significant at p=0.05 level **=significant at p=0.01 level

Table.6 Standard heterosis of crosses for grain yield in maize

Cross combination	**Standard Heterosis (%) over**			**Cross combination**	**Standard Heterosis (%) over**		
	NK 30	**Hishell**	**Shaktiman 2**		**NK 30**	**Hishell**	**Shaktiman 2**
IAMI-03				**IAMI-19**			
IAMI-03 * CML-209	-37.08**	-31.54**	-6.01	IAMI-19 * CML-209	-33.14**	-27.25**	-0.13
IAMI-03 * CML-540	-21.93**	-15.05*	16.61	IAMI-19 * CML-540	-18.81**	-11.66	21.26**
IAMI-03 * CML-545	-10.90	-3.05	33.08**	IAMI-19 * CML-545	-16.26**	-8.88	25.07**
IAMI-03 * IAFM-15-48	-23.11**	-16.34*	14.84	IAMI-19 * IAFM-15-48	-32.46**	-26.51**	0.88
IAMI-13				**IAMI-31**			
IAMI-13 * CML-209	-54.56**	-50.56**	-32.13**	IAMI-31 * CML-209	-46.26**	-41.52**	-19.72*
IAMI-13 * CML-540	-56.07**	-52.20**	-34.38**	IAMI-31 * CML-540	-0.81	7.92	48.16**
IAMI-13 * CML-545	-59.18**	-55.59**	-39.03**	IAMI-31 * CML-545	-24.17**	-17.49**	13.26
IAMI-13 * IAFM-15-48	-64.11**	-60.95**	-46.39**	IAMI-31 * IAFM-15-48	-15.14*	-7.66	26.75**
IAMI-14				**IAMI-32**			
IAMI-14 * CML-209	-21.49**	-14..57*	17.26	IAMI-32 * CML-209	-18.72**	-11.56	21.40**
IAMI-14 * CML-540	-5.98	2.30	40.44**	IAMI-32 * CML-540	-26.38**	-19.90**	9.95
IAMI-14 * CML-545	-22.42**	-15.59*	15.87	IAMI-32 * CML-545	-12.33*	-4.61	30.94**
IAMI-14 * IAFM-15-48	-30.77**	-24.67**	3.40	IAMI-32 * IAFM-15-48	-44.11**	-39.18**	-16.51
IAMI-16				**IAMI-52**			
IAMI-16 * CML-209	-32.65**	-26.71**	0.60	IAMI-52 * CML-209	-38.69**	-33.29**	-8.42
IAMI-16 * CML-540	-16.81**	-9.48	24.25**	IAMI-52 * CML-540	-41.12**	-35.93**	-12.05
IAMI-16 * CML-545	-12.46**	-4.75	30.75**	IAMI-52 * CML-545	-33.20**	-27.32**	-0.22
IAMI-16 * IAFM-15-48	-31.58**	-25.56**	2.18	IAMI-52 * IAFM-15-48	-41.18**	-35.99**	-12.13

*=significant at p=0.05 level **=significant at p=0.01 level

Table.7 Mean per se performance of superior hybrids

SN	Genotype	Mean value (GY q/ha)	Standard Heterosis Over Shaktiman 2	GCA effect		SCA effect
				Line	Tester	
1	IAMI-31/CML-540	88.44	48.16**	7.09**	5.26**	13.28**
2	IAMI-14/CML-540	83.83	40.44**	8.37**	5.26**	7.39**
3	IAMI-03/CML-545	79.44	33.08**	5.57**	5.07**	5.98**
4	IAMI-32/CML-545	78.17	30.94**	3.71	5.07**	6.57**
5	IAMI-16/CML-545	78.05	30.75**	5.50**	5.07**	4.67**
6	IAMI-31/IAFM-15-48	75.66	26.75**	7.09**	-5.13**	10.89**
7	IAMI-19/CML-545	74.66	25.07**	3.62	5.07**	3.16**
8	IAMI-16/CML-540	74.17	24.25**	5.50**	5.26**	0.60
9	IAMI-32/CML-209	72.47	21.40**	3.71	-5.16**	11.08**

*=significant at p=0.05 level **=significant at p=0.01 level

Fig.1(a) Inbred lines taken for study

Fig.1(b) Inbred lines taken for study

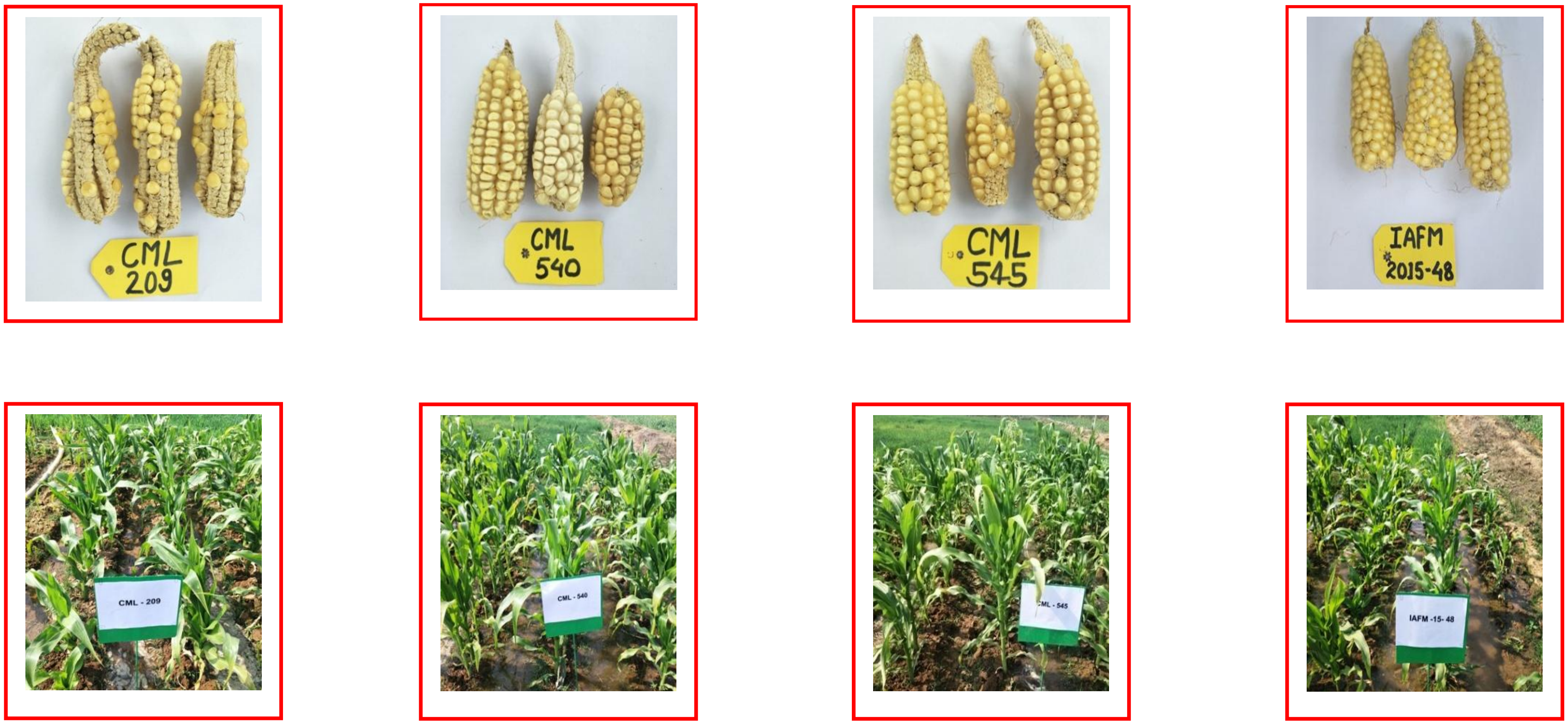

Fig.1(c) Testers lines taken for study

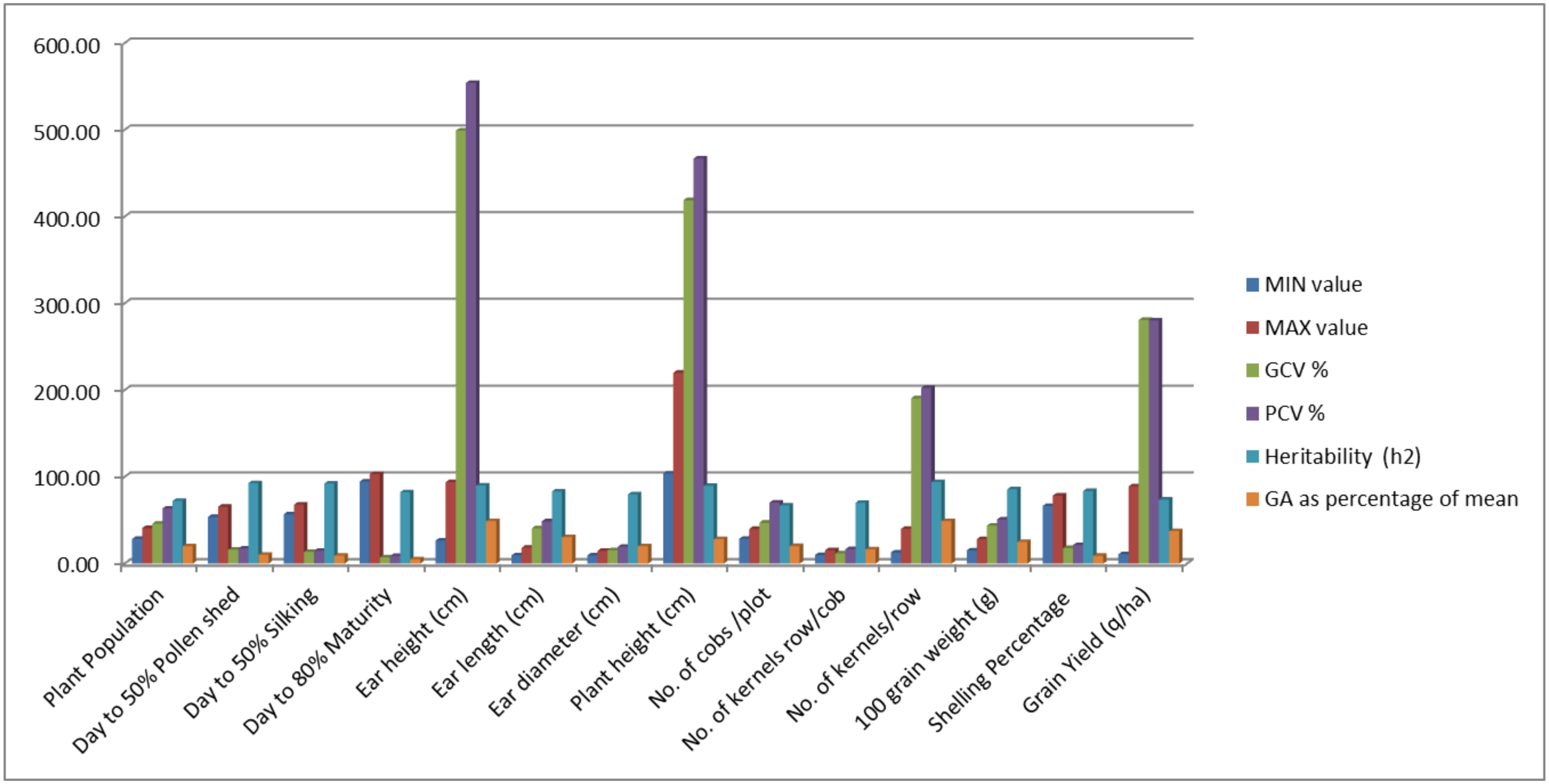

Fig.2 Genotypic and phenotypic coefficient of variance (GCV and PCV), heritability (h^2) and genetic advance as a percentage of mean for different characters in maize

Acknowledgement

Authors are thankful to authorities of ICAR-Indian Institute of Maize Research, Ludhiana and Indira Gandhi Krishi Vishwavidyalay, Raipur CG for their guidance, support, valuable suggestions and kind cooperation.

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