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Research Article

Genetic Analysis for Yield and Quality Traits in Maize (*Zea mays* L.)

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Abstract

Line X tester analysis involving 45 crosses generated by crossing between15 elite maize inbred lines with three testers and one standard check was conducted for different traits during 2015 at Chandra Shekhar Azad University of agriculture and technology Kanpur. The objectives of the study were to estimate general and specific combining ability effects of the inbred lines and to evaluate the test cross performance of the hybrids for quantitative and qualitative traits. Data were recorded on plant height, shelling%, 100 seed weigh, protein content, oil content, harvest index, biological yield and grain yield per plant. Analysis of variance indicated significant mean squares due to genotypes for all the recorded traits. There were significant mean square differences due to line general combining ability and tester general combining ability for all the analyzed traits and specific combining ability of line X tester interactions were significant for most of the quantitative and qualitative traits, except 100seed weight and oil content, indicating the importance of both additive and non additive gene actions in controlling these traits.

Keywords: Direct seeding, sowing dates, different maturity class's cultivar, yield attributes, yield

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Introduction

Maize (*Zea mays* L., 2N = 20) is one of the most important grown plants in world. Superior position of maize is due to its wide and variety of utilization. During the centuries maize plant was known for its multifariously uses. Maize as human food, livestock feed, for producing alcoholic and non- alcohol drinks, production of ethanol for fuel and also as medicinal and ornamental plant [1]. Because of very wide utilization of maize, the main goal of all maize breeding programs is to obtain new inbred and hybrids that will outperform the existing hybrids with respect to a number of traits. In working towards this goal, particular attention is paid for grain yield as it is the most important quantitative trait. Grain yield is a complex quantitative trait and its expression depends on number componental traits. Thus, knowledge of interrelationships between quantitative and qualitative traits in improving the efficiency of breeding programs through the use of appropriate and effective techniques is must [2].

Line x tester mating design is one of the prime selection criterions in hybrid breeding programme of maize [3] and this effort is aimed to identify better combing inbred lines for the development of hybrids for quantitative and quality traits. To initiate effective hybrid breeding program, information on the combining ability of inbred lines is an essential and critical factor. In the current study, therefore, an attempt was made to generate information on 15 elite maize inbred lines crossed to three testers of known heterotic groups in line x tester mating fashion and evaluated with the objectives of estimation of the general combining ability and specific combining ability effects of the inbred lines and evaluation of the test cross performance of the hybrids for all the traits.

Materials and Methods

The experiment was conducted to evaluate F_1 performance of maize lines for grain yield and quality traits at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, U.P. during kharif 2015. The breeding material used in this experiment comprised of fifteen lines and three testers. They were selected on the basis of morphological differences for various characters from the genetic stock of maize, which were maintained by selfing them for several generations in maize improvement scheme at kanpur. List and pedigrees of the inbred lines used in the line x tester crosses are given in **Table 1**. All the parents i.e. fifteen lines and three testers were sown and forty five test cross progenies developed by crossing fifteen lines with three testers in a line x tester fashion of [4], during rabi, 2013 and F_0 seeds of all the resultant crosses were procured. Half of the resultant seeds from all the 45 crosses were grown to raise F_1 hybrids during Rabi, 2014. All the 45 F_1s and their parents (15 lines and 3 testers) were grown in a randomized complete block design with three replications during Kharif, 2015 with one standard check (31Y45). Each treatment was sown in single row of 3m long along with row to row and plant to plant spacing of 60 cm and 25 cm respectively. The observations were recorded on 5 plants taken at random in each treatment replication wise. Data were recorded on plant height, shelling%, 100 seed weigh, protein content, oil content, harvest index, biological yield and grain yield per plant on five randomly selected competitive plants of each entry in each replication for the study of different genetic parameters, i.e. general combining ability (gca) and specific combining ability (sca) variance and their effects for the characters under study.

Table 1 Source and pedigree of the parents under investigation

Line Code	Parents	Source
L1	CIMMYT-K12-8-1	CIMMYT, Mexico
L2	CIMMYT-K12-8-2	CIMMYT, Mexico
L3	CIMMYT-K12-40-1	CIMMYT, Mexico
L4	CIMMYT-K12-40-2	CIMMYT, Mexico
L5	CIMMYT-K12-40-3	CIMMYT, Mexico
L6	CIMMYT-K12-40-4	CIMMYT, Mexico
L7	CIMMYT-K12-40-5	CIMMYT, Mexico
L8	CIMMYT-3	CIMMYT, Mexico
L9	CIMMYT-K12-13	CIMMYT, Mexico
L10	CIMMYT-K12-13-1	CIMMYT, Mexico
L11	CIMMYT-K12-13-2	CIMMYT, Mexico
L12	CIMMYT-K12-13-3	CIMMYT, Mexico
L13	CIMMYT-14-1	CIMMYT, Mexico
L14	BLACK DIAMOND	CSAUA&T, Kanpur
L15	TSK-79	CSAUA&T, Kanpur
Testers		
T1	AZAD UTTAM	CSAUA&T, Kanpur
T2	Azad Kamal	CSAUA&T, Kanpur
T3	HKI-163	Karnal

The well sun dried cobs of 5 plants from each treatment were threshed, cleaned grains weighted and average of them recorded as grain yield per plant in gram. The nitrogen content was measured using Micro Kjeldahl's method [5] and the percentage of protein was calculated by using a factor of 6.25.

The oil content in grains was determined by Soxhlet's Ether Extraction method developed by Association of Official Agricultural Chemists, 1970 [6] was used for estimation of oil content. Two samples per treatment per replication were analyzed and oil content was estimated in percentage and average was determined.

The mean of each character for each hybrid was subjected to line x tester analysis and the variance of general combining ability of different cross combinations were estimated as per the procedure developed by [4]. From the expectation of mean squares, the co-variance between half sibs COV (H.S) and Co-variance between full-sibs COV (F.S) were estimated

Results and Discussion

Analysis of variances for combining ability had presented in **Table 2**. Analysis of variances for combining ability revealed that the partitioning of variances due to lines × testers showed highly significant differences for all the eight characters. Variances due to lines were highly significant for all the characters whereas, variances due to testers were also highly significant for all the characters under studied. Variations due to Line ×Tester were significant for all characters except 100 seed weight and oil content. The current finding is in line with the finding of [7].

Table 2 Analysis of variance for combining ability following line × tester mating design for eight characters in maize F_1 generation

	df	Plant Height (cm)	Shelling (%)	100 Seed Weight (g)	Protein Content (%)	Oil Content (%)	harvest Index (%)	Biological Yield (%)	Grain Yield/ Plant (g)
Replicates	2.00	0.79	3.84	0.24	0.02	0.06	0.14	20.25	3.14
Crosses	44.00	363.93**	23.56**	6.96**	0.90**	0.17**	28.23**	6359.82**	623.88**
Line	14.00	708.89**	10.09*	7.04**	0.72**	0.21**	15.28**	3171.86**	297.63**
Tester	2.00	1530.57**	389.59**	92.70**	13.36**	1.86**	321.45**	102623.35**	11310.34**
Line ×Tester	28.00	108.12**	4.16**	0.79	0.10*	0.03	13.76**	1077.83**	23.69**
Error	88.00	10.20	1.29	0.68	0.06	0.05	0.23	69.09	4.88

*,** Significant at 5% and 1% probability levels, respectively

Estimates of general combining ability effects

Estimates of general combining ability effects for grain yield showed that out of the 15 inbred lines studied in line x tester six exhibited positive and significant general combining ability effects while five lines exhibited negative and significant general combining ability effects (**Table 3**).Inbred line L6 exhibited the maximum general combining ability effect, whereas L15 exhibited the lowest general combining ability effect, indicating the existence of best and poorest general combiners in the group of inbred lines studied, respectively.

Table 3 Estimates of general combining ability for 8 characters

Parents Characters	Plant Height (cm)	Shelling (%)	100 Seed Weight (g)	Protein Content (%)	Oil Content (%)	Harvest Index (%)	Biological Yield (%)	Grain Yield/ Plant (g)
Lines								
L1	-5.34**	-0.18	-0.54	-0.31**	-0.21**	3.06**	-27.34**	-1.55
L2	-4.08**	-0.74*	-0.25	-0.20**	-0.05	-0.53**	-9.29**	-3.84**
L3	9.92**	0.62	0.34	0.35**	0.16*	0.69**	6.30	4.01**
L4	6.76**	-0.58	0.64	-0.09	0.06	1.24**	6.56	5.84**
L5	5.04**	-0.08	0.61	-0.12	0.19*	-1.18**	27.55**	6.31**
L6	8.18**	0.22	0.39	-0.24**	-0.04	0.74**	22.02**	7.96**
L7	-0.66	1.44**	-0.75*	0.27**	0.12	-0.17	-18.07**	-6.66**
L8	-19.94**	-1.52**	-0.54	-0.34**	-0.24**	-2.09**	-10.68**	-8.57**
L9	3.97**	-1.61**	0.56	0.50**	0.19*	1.21**	-15.39**	-1.33
L10	1.81	-0.18	0.37	0.41**	0.10	0.34	-2.79	0.83
L11	2.44**	0.62	0.06	0.01	-0.11	-0.97**	13.36**	1.96
L12	5.47**	2.08**	0.57	-0.40**	-0.23**	0.20	16.92**	5.26**
L13	9.48**	1.29**	-0.68	0.06	0.13*	-1.15**	0.88	-3.16**
L14	-14.05**	-0.63	1.49**	0.10	0.00	-1.37**	23.02**	3.74**
L15	-8.99**	-0.75*	-2.29**	-0.01	-0.07	-0.03	-33.06**	-10.80**
SE (gi) lines	1.37	0.36	0.33	0.07	0.07	0.20	2.97	0.80
SE(gi – gj)	1.92	0.51	0.47	0.11	0.10	0.28	4.20	1.13
T1	-5.77**	-2.96**	-0.11	-0.08	-0.13*	2.81**	-21.04**	-0.55
T2	5.89**	2.93**	1.49**	-0.50**	-0.11*	-0.30*	54.66**	16.12**
T3	-0.12	0.03	-1.38**	0.58**	0.23**	-2.51**	-33.62**	-15.57**
SE(gi) testers	0.61	0.51	0.15	0.04	0.03	0.08	1.32	0.36
SE(gi – gj)	0.86	0.23	0.20	0.05	0.05	0.12	1.88	0.51

Inbred lines identified for good general combining ability could be utilized in maize grain improvement programs for improvement of the traits of interest as these lines have high potential to transfer desirable traits to their cross progenies. From the tester T2 was the best general combiner while T3 was poor general combiner for grain yield. Both positive and negative general combining ability effects were reported in maize by several investigators [8-10], both positive and negative general combining ability effects were observed for harvest index % and biological yield %. Five of the lines showed positive and significant general combining ability effect for harvest index % and biological yield. Other six inbred lines showed negative and significant general combining ability effects for harvest index % and biological yield. Line L1 was good general combiner while L8 was poor general combiner for harvest index % (Table 3). L5 was good general combiner, while, L15 poor general combiner for biological yield. The negative value implies that the inbred lines are good combiner as it indicates the tendency of earliness and the reverse is true for those with positive general combining ability effects. The current results are in general agreement with the finding of researchers [11-13].

For plant height, out of 15 lines five lines were found to be good general combiners while eight lines were poor general combiners (Table 3). This indicates that L8 has a tendency to reduce whereas L3 has a tendency to increase plant height in the hybrid progenies. In maize, shorter plant height is desirable for lodging resistance. Inbred lines L2, L7 and L13 were good general combiners while L9, L8 and L15 were poor combiners for shelling % [14-15]. The estimates of general combining ability effect for the testers showed that T2 has the tendency to increase 100 seed weight (g) as it had positive general combining ability effect (Table 3). Inbred lines L9, L10, L3 and L7 were good general combiners while L12, L8, L1, L6 and L2 were poor combiners for protein content. Inbred lines L5 and L9 had positive and significant general combining ability effect for oil content while L8, L12 and L1 had negative and significant general combining ability effects (Table 3). Similar to the current findings positive and negative significant general combining ability effects for protein and oil content were reported by [16-17].

Estimation of specific combining ability

For grain yield, both negative and positive and significant estimates of specific combining ability effects were observed among the crosses (**Table 4**). Cross L15XLT3, L8XT3 and L7XT3 were good specific combiners, whereas, crosses L6XT3, L8XT1 and L9XT3 were poor specific combiners (Table 4). Highly significant specific combining ability effects of the crosses indicate that significant deviation from what would have been predicted based on their parental performances.

These crosses with highly positive and significant estimates of specific combining ability effect could be selected for their specific combining ability to use in maize improvement program. The result of the current study are in agreement with the findings of [18], who reported significant to highly significant level of specific combining ability effects in most of the crosses they studied for grain yield in maize. With respect to harvest index %, crosses L2XT2 and L6XT1 showed the best specific combining ability effects (Table 4) crosses L6XT2 and L2XT2 were good and poor specific combiners, respectively (Table 4) for biological yield.

For plant height, the estimates of specific combining ability effects were found to be significant in13 of the 45 crosses evaluated in the current study crosses L15XT2 and L9XT2 were negative and positive specific combiners, respectively (Table 4). The shortened plant is advantageous in case of lodging resistance. With regard to shelling %, significant estimates of specific combining ability effect were observed substantial number of crosses. Crosses L9XT2 and L10XT2 were best specific combiners as they show the tendency to increase yield.

For 100 seed weight (g) among 45 crosses none of the cross combinations showed significant and positive specific combining ability effects (Table 4). The existence of both positive and negative specific combining ability effects in maize cross has been also reported by [15, 19]. Only three crosses were found to exhibit significant level of specific combining ability effects for protein content. But among the 45 crosses none of the cross combinations showed significant and positive specific combining ability effects for oil content. This result is in conformity with findings of [17].

Proportional contribution of lines, testers and lines × testers towards total variance (%)

Proportional contribution of line, tester and lines × testers for the eight characters had been presented in **Table 5**.

Table 4 Estimates of specific combining ability for 8 characters

Crosses	*Plant Height (cm)*	*Shelling (%)*	*100 Seed Weight (g)*	*Protein Content (%)*	*Oil Content (%)*	*Harvest Index (%)*	*Biological Yield*	*Grain Yield/ Plant (g)*
L1XT1	-3.76	1.13	0.03	0.15	0.03	-3.43**	26.20**	0.54
L1XT2	4.71*	-1.53*	0.27	0.06	-0.06	4.05**	-35.47**	-1.40
L1XT3	-0.95	0.40	-0.30	-0.22	0.03	-0.61	9.28	0.86
L2XT1	-6.50**	0.91	0.14	0.14	0.04	-0.98**	7.19	0.06
L2XT2	5.74*	-1.30*	0.11	0.02	-0.18	-0.07	-4.78	-1.54
L2XT3	0.75	0.39	-0.25	-0.16	0.14	1.04**	-2.40	1.48
L3XT1	-4.36	-0.81	-0.15	-0.20	-0.04	-0.35	4.66	0.71
L3XT2	-3.39	-0.26	0.23	-0.09	-0.02	-0.01	1.09	0.95
L3XT3	7.75**	1.07	-0.08	0.30*	0.07	0.37	-5.76	-1.66
L4XT1	-1.60	0.46	0.05	-0.04	-0.04	-0.24	6.43	1.11
L4XT2	-0.59	-0.79	0.49	-0.12	0.01	2.53**	-19.94**	1.08
L4XT3	2.19	0.33	-0.54	0.16	0.03	-2.29**	13.51*	-2.19
L5XT1	-2.11	0.19	0.25	0.10	-0.14	-0.85*	3.98	-0.25
L5XT2	2.43	-0.49	0.23	0.01	-0.06	1.06**	-0.23	2.61
L5XT3	-0.32	0.30	-0.48	-0.10	0.20	-0.20	-3.75	-2.36
L6XT1	-0.62	0.59	0.27	0.15	0.03	3.46**	-24.89**	0.09
L6XT2	-3.68	-0.63	0.38	0.03	-0.12	-2.30**	28.77**	3.39*
L6XT3	4.30	0.03	-0.65	-0.18	0.10	-1.16**	-3.88	-3.48*
L7XT1	1.79	-0.36	0.54	-0.03	-0.01	1.17**	-15.40**	-2.95*
L7XT2	-6.20*	0.09	0.08	-0.01	-0.06	-1.99**	10.73*	-1.09
L7XT3	4.41	0.28	-0.62	0.04	0.07	0.82*	4.68	4.04**
L8XT1	6.17*	-0.57	0.16	0.18	0.06	0.72*	-17.32**	-3.48*
L8XT2	-4.56	-0.76	0.04	-0.07	-0.06	-1.73**	12.87*	-1.24
L8XT3	-1.61	1.33*	-0.20	-0.12	0.00	1.01**	4.45	4.72**
L9XT1	1.66	-1.09	-0.17	-0.19	0.06	-2.31**	25.49**	2.51
L9XT2	8.06**	2.13**	-0.63	-0.18	0.04	2.50**	-19.08**	0.65
L9XT3	-9.72**	-1.04	0.80	0.37**	-0.10	-0.19	-6.40	-3.16*
L10XT1	3.08	-0.04	-0.08	-0.14	0.05	-1.91**	19.09**	1.36
L10XT2	6.99**	1.81**	-0.61	-0.12	0.03	3.13**	-24.35**	0.46
L10XT3	-10.07**	-1.77**	0.69	0.26*	-0.08	-1.22**	5.26	-1.82
L11XT1	0.06	0.23	0.16	0.03	-0.01	-0.43	7.40	2.09
L11XT2	3.33	1.31*	-0.60	0.08	0.04	-0.89*	9.83	0.22
L11XT3	-3.39	-1.53*	0.43	-0.10	-0.03	1.32**	-17.22**	-2.32
L12XT1	-0.11	-0.71	-0.25	0.14	-0.02	1.60**	-14.49**	-0.41
L12XT2	1.36	1.24	-0.11	-0.05	0.13	-2.09**	24.44**	2.12
L12XT3	-1.26	-0.53	0.36	-0.09	-0.11	0.49	-9.95	-1.72
L13XT1	-4.58	-0.99	-0.56	-0.08	0.08	2.31**	-17.01**	0.05
L13XT2	2.12	1.10	-0.32	0.13	0.00	-2.34**	13.65*	-2.22
L13XT3	2.46	-0.11	0.88	-0.05	-0.08	0.03	3.36	2.17
L14XT1	3.75	1.10	-0.16	-0.09	-0.02	-0.30	2.74	1.35
L14XT2	-4.28	-1.18	-0.22	0.15	0.13	-1.22**	10.47*	-0.89
L14XT3	0.53	0.08	0.38	-0.06	-0.11	1.52**	-13.21*	-0.46
L15XT1	7.12**	-0.04	-0.25	-0.12	-0.05	1.56**	-14.05*	-2.78**
L15XT2	-12.05**	-0.73	0.66	0.16	0.17	-0.63	-7.98	-3.11*
L15XT3	4.93*	0.77	-0.41	-0.05	-0.11	-0.92**	22.03**	5.88*

Table 5 Proportional contribution of lines, testers and their interactions to total variance in a set of line × tester crosses in maize

Sr. No.	Characters	Contribution (%)		
		Lines	Testers	Lines × Testers
1.	**Plant Height (cm)**	61.97	19.12	18.91
2.	**Shelling (%)**	13.61	75.15	11.23
3.	**100 Seed Weight (g)**	32.21	60.55	7.23
4.	**Protein content (%)**	25.52	67.67	6.82
5.	**Oil content (%)**	38.27	49.23	12.49
6.	**Harvest Index (%)**	17.22	51.75	31.02
7.	**Biological yield (%)**	15.86	73.34	10.78
8.	**Grain Yield/ Plant (g)**	15.17	82.40	2.42

Proportional contribution of lines (%)

The proportional contribution of lines varied from 13.61 % (shelling (%)) to61.97% (Plant Height). The maximum contribution of lines were recorded for plant height (cm) (61.97%), while, minimum contribution of lines were recorded for shelling (%) (13.61%) followed by grain yield/ plant (g).

Proportional contribution of testers (%)

The proportional contribution of testers towards the variability for different characters ranged from 19.12% (plant height) to 82.40 % (grain yield/ plant (g)). Maximum contribution of testers were recorded for grain yield/ plant (g) (82.40%) followed by shelling (%) (75.15%), while, minimum contribution of testers were recorded for plant height (cm) (19.12).

Proportional contribution of line × testers (%)

Proportional contribution of line × testers for different characters varied from 2.42 per cent (grain yield/ plant (g)) to 31.02 per cent (harvest index (%)). lines × testers component displayed greater contribution for harvest index (%) (31.02%) followed by plant height (cm) (18.91%), while, lines × testers component displayed lesser contribution for grain yield/ plant (g) (2.42%) followed by protein content % (6.82%).

Conclusion

Using combining ability to select parents is an effective approach in hybrid breeding. General combining ability was significantly different among parents and specific combining ability was also significantly different among crosses. The results of the current study identified that inbred lines with good general combining ability and cross combinations with desirable specific combining ability for the traits studied. The hybrids from two parents with high general combining ability always showed better hybrid performance even though specific combining ability were low. Thus the selection of parents should mainly be based on their general combining ability. This indicates that the possibility of developing desirable cross combinations and synthetic varieties through crossing and or recombination of inbred lines with desirable traits of interest.

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