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Combining ability analysis of maize (*Zea mays* L.) single cross hybrids evaluated in three environments

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Abstract
The purpose of the current research was to evaluate the general combining ability impacts of parents and the specific combining ability effects of hybrids for yield and yield-related features, as well as to investigate their utility in hybrid creation. The 45 single cross hybrids developed through line x tester (L × T) breeding method together with parents (15 L and 3 T) were examined for grain yield and its attributing in three different environments during *kharif* and *rabi* season 2017-18. Results from the investigation revealed that the estimates of GCA effect for grain yield per plant showed that inbred line L_{14} (24.04) exhibited maximum significant positive GCA on pooled basis and among the testers, T_3 was considered as good general combiner for various morphological traits. The estimates of SCA effect among hybrid revealed that maximum significant SCA in positive direction for grain yield/plant were exhibited by hybrid $L_2 \times T_3$ (37.51) on the pooled basis.

Keywords: Maize, combing ability, genetic action

1. Introduction

Among the cereal crops grown in India, maize (*Zea mays* L.) is the third most vital. Due to high demand, maize grain is gaining popularity in India, notably in the poultry feed business. Maize also has a variety of uses as a food and industrial raw material. Combining ability analysis is helpful in determining the type of gene action involved in many quantitative features as well as assessing possible inbred lines. Plant breeders can use this information to create hybrid breeding programmes. Combining ability analysis is a useful method for discovering superior combiners that can be hybridised to exploit heterosis and selecting better hybrids for direct usage or subsequent breeding [1]. The concept of combining ability in plant breeding as a measure of gene action was introduced by Sprague and Tatum in (1942) [2]. The combining analysis also helps to understand the genetic architecture of yield and other component traits and the gene action involved in the expression of these traits that enable breeders to design effective breeding plans. Combining ability analysis is a powerful tool for identifying the best combiners that can be used in crosses to exploit heterosis or accumulate productive genes. It also aids in understanding the genetic architecture of various characters, allowing a breeder to create an effective breeding plan for further improvement of existing breeding material. In crop development, exploitation of hybrid vigour and selection of parents based on combining ability has been employed as a key breeding strategy. The high strategy to assessing the nature of gene action involved in character inheritance is to select parents based on per se performance with good GCA effects [3, 4]. Information on heterotic patterns and combining ability among maize germplasm is critical for maximising hybrid development effectiveness [5, 6].

In order to increase maize production, efforts must be made to develop hybrids with maximum yield potential. The information was generated using Kempthorne's (1957) [7] L x T mating design, which offers trustworthy information on the general and specific combining ability impacts of parents and their hybrid combinations. Several researchers have utilized the design in maize and it is still being used in quantitative genetic studies in maize [8, 9]. In order to assess the combining ability effects of inbred lines and crosses of maize for yield and other significant traits, the current work tried to unravel the genetics of yield and other relevant features.

2. Materials and Methods

The present investigation was perfomed in different environments (E_1- Instructional farm, RCA, *Kharif* 2017-18, E_2- Instructional farm, RCA, *Rabi* 2017-18 and E_3- Instructional Farm, CTAE, *Rabi*-2017-18) at Udaipur. The experimental material consisted of a total of 66 entries (45 F_1 hybrids, 18 parents and 3 checks) were planted in randomized block design with three replications in three different environments with a single row plot of four meter length, maintaining crop geometry of 60 x 25 cm. Observations were recorded on thirteen agro-morphological traits *viz.*, days to 50% tasseling, days to 50% silking, anthesis-silking interval (ASI), 75% brown husk, plant height, ear height, ear length, ear girth, number of grains/row, number of grain/row/ear, 100-seed weight, grain yield per plant, harvest index. All the cultivation practices were followed to obtain a good plant stand.

3. Results and Discussion

The line x tester approach was used in the present study [7].

3.1 Analysis of variance for combining ability

The observed data on 45 hybrids in all individual environments were analyzed. The total variance was partitioned into three parts *viz.* variance due to lines, testers and L×T. The hybrid data was then examined to determine the variance components of lines and testers (GCA) and linestesters (SCA) for all traits in each individual environment.

For all of the characters in all of the environments, analysis of variance revealed that mean squares of lines and testers were significant except for days to 50 per cent tasseling in E_1 and E_3 due to tester and in E_1 due to lines, days to 50 per cent silking in E_1 and E_3 due to tester and in E_1due to lines, days to 75 per cent brown husk in all environment due to testers and in E_2 due to lines, for ear length in E_1 and E_3 due to testers, no. of grain row/ear in E_1 and E_2 due to testers and lines. The mean squares of lines × testers were significant for all the traits except for days to 50 per cent tasseling in all environments, days to 50 per cent silking in E_2 and days to 75 per cent brown and plant height husk in all environments and no. of grain row/ear in E_1 and E_2. Similarly, significant mean squares of linestesters suggested that special combining ability (SCA) variance components contributed significantly. (Table 1) Analysis of variance for combining ability on a pooled basis revealed that mean squares due to lines, testers, and linestesters were significant for all characters. The interactions of lines with environments were significant for anthesis-silking interval. Further, testers × environments interactions were significant for anthesis-silking interval. The interaction of lines × testers × environments were significant for anthesis-silking interval. This manifested that estimates of GCA and SCA effects were highly affected by environments for this character under studied (Table 1)

Table 1: Analysis of variance of combining ability for nineteen characters studied under the experiment in maize during *Kharif* and *Rabi*-2017-18

SN	Characters	Env	Crosses [44]	Tester [2]	Lines [14]	L X T [28]	Error [130]	Model I Tester	Lines	L X T
1	Days to 50% Tasseling	1	5.96**	1.25	9.01**	4.78**	1.79	-0.02	11.22	27.83
		2	4.07**	13.90**	3.46	3.67*	2.16	0.52	2.02	14.11
		3	5.96**	1.25	9.01**	4.78**	1.85	-0.03	11.14	27.34
2	Days to 50%silking	1	6.10**	1.27	9.51**	4.73**	1.74	-0.02	12.09	27.97
		2	3.65*	14.34**	3.42	3.01	2.17	0.54	1.95	7.83
		3	6.14**	1.54	9.39**	4.84**	1.76	-0.01	11.88	28.79
3	Anthesis-Silking interval	1	0.26**	0.36**	0.23**	0.27**	0.01	0.02	0.35	2.45
		2	0.46**	0.12**	0.39**	0.52**	0.01	0.01	0.61	4.84
		3	0.32**	0.21**	0.33**	0.33**	0.01	0.01	0.51	3.00
4	Days to 75% Brown Husk	1	12.19*	4.42	18.09**	9.80	7.59	-0.14	16.34	20.58
		2	4.59	3.21	5.80	4.08	5.29	-0.09	0.80	-11.28
		3	12.41*	3.87	17.90**	10.28	7.60	-0.17	16.02	25.01
5	Plant Height (cm)	1	287.34**	1206.20**	436.49**	147.13	142.41	47.28	457.45	44.02
		2	259.50**	920.75**	321.73**	181.16	130.11	35.14	298.09	476.48
		3	373.28**	1021.26**	667.04**	180.12	119.62	40.07	851.54	564.64
6	Ear Height (cm)	1	167.85**	250.52**	284.47**	103.64**	18.27	10.32	414.08	796.74
		2	178.88**	348.55**	289.09**	111.65**	17.87	14.70	421.90	875.25
		3	180.05**	417.49**	289.26**	108.48**	18.23	17.75	421.62	842.35
7	Ear Length (cm)	1	5.73**	0.95	11.41**	3.24**	0.65	0.01	16.74	24.20
		2	6.82**	2.15*	14.94**	3.09**	0.67	0.07	22.19	22.57
		3	5.50**	0.58	11.04**	3.09**	0.65	-0.00	16.16	22.79
8	Ear Girth (cm)	1	4.26**	5.51**	7.85**	2.37**	0.44	0.23	11.52	18.02
		2	4.41**	5.74**	7.74**	2.64**	0.42	0.24	11.40	20.78
		3	4.69**	4.45**	8.68**	2.71**	0.44	0.18	12.81	21.18
9	No. of grain rows per ear	1	6.78**	13.77**	7.51**	5.91**	0.68	0.58	10.63	48.82
		2	6.56**	15.89**	6.85**	5.74**	0.67	0.68	9.60	47.31
		3	6.88**	17.37**	7.84**	5.65**	0.72	0.74	11.09	46.01
10	No. of Grains per row /ear	1	0.82	2.05	0.57	0.86	1.67	0.02	-1.71	-7.53
		2	0.69	1.65	0.48	0.73	1.79	-0.01	-2.03	-9.89
		3	2.27**	2.23*	2.23*	2.40**	1.14	-0.01	1.70	11.77
11	100 grain wt (gm)	1	59.23**	77.41**	62.01**	56.55**	2.16	3.34	93.10	507.63
		2	57.56**	77.62**	61.15**	54.33**	2.20	3.35	91.71	486.62
		3	56.67**	85.37**	59.83**	53.05**	1.85	3.71	90.19	477.88

12	Grain Yield per plant (gm)	1688.08**	1808.18**	2640.83**	1203.12**	99.81	75.93	3952.69	10297.60
		1664.16**	1748.52**	2610.83**	1184.80**	96.95	73.40	3910.48	10153.21
		1912.35**	1549.85**	3088.78**	1350.03**	64.75	66.00	4704.04	11995.91
13	Harvest Index(%)	28.12**	124.14**	20.75**	24.95**	3.94	5.34	26.15	196.13
		28.26**	122.17**	21.85**	24.76**	3.94	5.25	27.87	194.32
		27.95**	129.77**	20.41**	24.46**	3.90	5.59	25.68	191.84
14	Chlorophyll (%)	3.11**	5.35**	4.70**	2.16**	0.00	0.24	7.30	20.12
		3.21**	9.29**	3.96**	2.40**	0.00	0.41	6.15	22.33
		3.21**	8.65**	4.21**	2.32**	0.00	0.38	6.54	21.57
15	Chlorophyll stability Index (%)	0.00**	0.00**	0.00**	0.00**	0.00	0.00	0.00	0.00
		0.00**	0.00**	0.00**	0.00**	0.00	0.00	0.00	0.00
		0.00**	0.00**	0.00**	0.00**	0.00	0.00	0.00	0.00
16	Carotenoid content (mg/g)	0.91**	4.64**	0.59**	0.80**	0.02	0.21	0.89	7.34
		0.96**	2.43**	1.00**	0.83**	0.01	0.11	1.54	7.61
		0.94**	2.66**	1.04**	0.76**	0.02	0.12	1.60	6.98
17	Protein Content (%)	1.51**	1.72**	2.12**	1.19**	0.06	0.07	3.20	10.48
		1.32**	1.36**	1.88**	1.03**	0.04	0.06	2.86	9.21
		1.76**	1.40**	2.34**	1.50**	0.06	0.06	3.54	13.40
18	Starch Content (%)	15.35**	21.60**	20.00**	12.58**	3.09	0.82	26.30	88.59
		16.67**	25.93**	21.97**	13.36**	3.18	1.01	29.24	95.07
		19.03**	49.31**	24.32**	14.23**	2.38	2.09	34.13	110.63
19	Oil content (%)	1.62**	0.40**	2.32**	1.35**	0.02	0.02	3.58	12.41
		1.57**	0.30**	2.26**	1.31**	0.03	0.01	3.47	11.94
		2.15**	7.10**	2.57**	1.59**	0.01	0.32	3.97	14.71

3.2. Estimation of combining ability effects

On the basis of parental GCA, parents were categoried into good, average and poor combiner (Table 2). The parents showed desribale and significant GCA were considered as good combiner whereas, non-significant GCA effects but in desirable direction were taken as average combiner for the concern trait. The estimates of GCA effect for grain yield per plant showed that inbred line L_{14} (24.04) exhibited maximum significant positive GCA on pooleded basis and lines *viz.* L_2, L_5, L_6, L_7 L_{11} and L_{12} also exhibited significant GCA effects in positive direction in individual as well as across the environment which indicates their superiority in transmission of desirable genes for the higher grain yield per plant. Experimental observations are in line with findings of previous workers *viz.* [5, 10, 11].

On the pooled basis maximum significant SCA in positive direction observed in hybrid $L_{12}xT_3$ for days to 50% tasseling as well as for days to 50% silking, L_3xT_1 for ASI, $L_{13}xT_1$ for days to 75% brown husk, $L_{13}xT_1$ for plant height, L_9xT_3 for ear height, $L_{13}xT_1$ for ear length, L_6xT_2 for ear girth, L_7xT_1 for no. grain rows per ear, L_7xT_1 for 100-grain weight and harvest index, respectively. In Table 3 depicted the hybrids showing significant and positive specific combining ability (SCA) effects for grain yield/ plant on pooled basis and their *per se* performance with their desirability for other traits in maize. Authors [12-16] were also reported the similar results in maize for significant SCA effects.

Table 2: Classification of parents for good, average and poor GCA effects on pooled basis

Parents	Days to 50% Tasseling	Days to 50% silking	Anthesis-Silking interval	Days to 75% Brown Husk	PH (cm)	EH (cm)	EL(cm)	EG (cm)	No. of grain rows/ear	No. of Grains/ row /ear	100 grain wt (gm)	Grain Yield / plant (gm)
T 1	A	A	P	P	P	P	P	G	P	A	P	P
T2	P	P	P	P	G	P	G	P	P	A	A	P
T3	A	A	A	A	A	G	P	P	G	P	G	G
L1	P	P	P	P	A	G	P	A	G	P	G	P
L 2	A	A	P	A	P	P	P	G	P	P	G	P
L 3	P	P	G	P	P	P	P	A	P	P	P	G
L 4	G	G	P	A	A	G	A	P	A	A	P	A
L5	A	A	P	A	P	P	P	P	P	P	A	G
L 6	P	P	G	P	P	P	G	P	G	A	G	G
L 7	G	A	G	A	G	G	G	G	G	P	A	G
L8	P	P	P	P	A	G	P	P	P	G	P	P
L9	P	P	P	P	P	P	P	P	G	P	P	P
L10	A	A	P	A	P	P	P	P	P	A	P	P
L 11	P	P	G	P	P	P	G	A	A	A	G	G
L 12	P	A	P	P	P	A	P	P	G	P	G	G
L 13	A	A	P	G	P	P	P	P	P	A	P	P
L14	G	G	P	G	G	G	G	G	P	P	G	G
L15	P	P	P	P	A	A	P	P	P	P	A	G

Parents	Harvest Index(%)	Chlorophyll (%)	Chlorophyll stability Index (%)	Carotenoid content (mg/g)	Protein Content (%)	Starch Content (%)	Oil content (%)
T 1	P	G	G	P	P	P	P
T 2	P	P	P	P	P	G	G
T 3	G	P	G	G	G	P	P
L 1	A	P	P	P	P	A	G
L 2	A	P	P	P	P	A	P
L 3	P	P	G	P	G	P	G
L 4	A	G	P	G	P	P	G
L 5	G	P	P	G	P	A	G
L 6	P	P	P	P	G	G	G
L 7	P	G	G	G	P	G	G
L 8	P	P	P	G	P	A	P
L 9	P	P	A	P	P	P	P
L 10	P	G	P	G	P	P	G
L 11	G	G	G	P	G	P	P
L 12	G	P	P	P	G	P	P
L 13	P	P	P	P	P	A	P
L 14	P	G	G	G	G	G	G
L 15	A	G	G	P	A	P	P

Note: T=Tester, L=Line, PH=Plant height, EL=Ear length, EG=Ear girth, EH=Ear height

Table 3: On a pooled basis, hybrids with significant and positive specific combining ability (SCA) effects for grain yield per plant and their per se performance with their desirability for other maize traits showed significant and positive SCA effects

S. N.	Hybrids	SCA effects	Grain yield per plant (g)	Trait showing desirable and significant SCA effects
1	L_1 x T_2	35.54**	141.70	ASI, ear height, ear length, no. of grain rows/ear, chlorophyll content, CSI, carotenoid content,
2	L_5 x T_1	18.77**	142.51	Ear height, 100 grain wt,
3	L_6 x T_1	16.80**	144.00	Ear height, 100 grain wt, protein content, starch content,
4	L_8 x T_1	20.88**	120.99	100 grain wt,
5	L_{10}x T_1	23.27**	123.58	100 grain wt, chlorophyll content,
6	L_{13} x T_1	13.83**	89.82	75% Brown husk,plant height, ear height, 100 grain wt, chlorophyll content, CSI, protein content,
7	L_7 x T_2	9.56**	148.76	100 grain wt, chlorophyll content,
8	L_{15} x T_2	13.93**	149.63	100 grain wt, chlorophyll content, starch content
9	L_3 x T_3	14.56**	148.13	Ear length, ear girth, no. of grain rows/ear, 100 grain wt, chlorophyll content, CSI, protein content, starch content
10	L_9x T_3	20.35**	144.04	Plant height, ear height, no. of grain rows/ear, 100 grain wt, protein content, starch content.

4. Conclusion

The results of GCA effect for grain yield/plant showed that inbred line L_{14} (24.04) exhibited maximum significant positive GCA on pooled basis and lines *viz.* L_2, L_5, L_6, L_7 L_{11} and L_{12} also exhibited significant GCA effects in positive direction in individual as well as across the environment which indicates their superiority in transmission of desirable genes for the higher grain yield/plant. From the testers, T_3 was reported as good general combiner for grain yield/plant and also for anthesis-silking time, ear height, no. of grain rows/ear, 100-grain weight and harvest index on pooled basis. The estimates of SCA effect among hybrid revealed that maximum significant SCA in positive direction for grain yield /plant were exhibited by hybrid $L_2 \times T_3$ (37.51) on the pooled basis and same hybrids also showed maximum positive SCA effect for no. grain per rows/ear. The nine hybrids *viz.*, $L_5 \times T_1$, $L_6 \times T_1$, $L_8 \times T_1$, $L_{10} \times T_1$, $L_{13} \times T_1$, $L_7 \times T_2$, $L_{15} \times T_2$, $L_3 \times T_3$ and $L_9 \times T_3$ showed positive significant SCA effects in all the individual environments as well as on pooled basis for grain yield/plant.

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6. References

1. Nigussie M, Zelleke H. Heterosis and combining ability in a diallel among eight elite maize populations. Afric. Crop Sci. J. 2001;9(1):471-479.
2. Sprague G, Tatum L. General versus specific combining ability in single crosses of corn. J of the American Society of Agron. 1942;34:923-932.
3. Vasal SK. Hybrid maize technology: Challenges and expanding possibilities for research in the next century. In: Vasal, S.K., C.F. Gonzalez and F. Xingming (ed). Proc. 7th Asian Reg. Maize Workshop. Los Banos, Philippines, 1998 Feb 23-27, 58-62.
4. Krishna Bal, Birender Singh, Shyam Sundar Mandal, Rashmi Kumari, Tushar Ranjan. Heterosis in relation to genetic divergence in short duration maize (*Zea mays* L.). Environment Conservation Journal. 2021, 137-142.
5. Barh A, Singh NK, Verma SS, Kumar M. Heterosis and combining ability studies for selection of parental lines and derived test crosses in maize. Ecology, Environment and conservation. 2016;22:195-202.
6. Kandel BP. Status, prospect and problems of hybrid maize (*Zea mays* L.) in Nepal: a brief review. Genetic Resources and Crop Evolution. 2021;68(1):1-10.
7. Kempthorne O. An Introduction to Genetical Statistics. John Willey and Sons Inc, New York, 1957, 323-331.
8. Joshi VN, Dubey RB, Marker S. Combining ability for polygenic traits in early maturity hybrids of maize (*Zea*

mays L.). Ind. J of Gen. and Plant Breed. 2002;62:312-315.

9. Sharma S, Narwal R, Kumar MS, Dass S. Line x tester analysis in maize (*Zea mays* L.), Forage Res. 2004;30:28-30.
10. Kumar D, Chandra NK, Singh SP. Combining Ability Analysis in Maize. Progressive Agriculture. 2015;15:212-223.
11. Kumar SVV, Babu DR. Combining ability and heterosis in maize (*Zea mays* L.) for grain yield and yield components. International Journal of Agriculture, Environment and Biotechnology. 2016;9(5):763-772.
12. Tesfaye D, Abakemal D, Habte E. Combining Ability of Highland Adapted Double Haploid Maize Inbred Lines using Line x Tester Mating Design. East African Journal of Sciences. 2019;13(2):121-134.
13. Chaurasia NK, Nirala RBP, Singh B. Combining Ability and Heterosis Studies in Maize (*Zea mays* L.) under Kharif Season. Int. J Curr. Microbiol. App. Sci. 2020;9(11):2576-2586.
14. Iseghohi I, Abe A, Meseka S, Mengesha W, Gedil M, Menkir A. Assessing effect of marker-based improvement of maize synthetics on agronomic performance, carotenoid content, combining ability and heterosis. Agronomy. 2020;10(11):1625.
15. Nyombayire A, Derera J, Sibiya J, Ngaboyisonga C. Heterotic Groups, Gene Action and Heterosis Among Maize Inbred Lines Selected for the Major Agro-ecologies of Rwanda. Journal of Plant Sciences. 2021;9(5):245-252.
16. Lemi YM. Hybrid performance and combining ability of quality protein maize (*Zea mays* L.) inbred lines adapted to mid-altitude Agroecology of Ethiopia (Doctoral dissertation, Jimma University), 2021.