Combining ability in maize (Zea mays) for grain yield

ABSTRACT

This study was carried out with the goal of evaluating the combining ability for yield and yield components in some newly developed white maize lines. Twenty two inbred lines of maize, which were derived from different genetic source at the Agricultural Research Station during the 2023 growing season a total of 40 hybrids , along with 2 commercial check hybrids (Karimnagar makka, kaveri ekka), were evaluated Agricultural Research Stations. The analysis revealed highly significant differences for all traits studied.The statistical analysis showed~~A~~ among the inbred lines, KML-122,KML-7,KML-6 were identified as good general combiners for grain yield and yield contributing traits like days to 50 per cent anthesis, days to 50 per cent silking, days to maturity, plant height ~~B~~ based on *sca* effects, the hybrids,HG-7,HG-22,HG-31 were identified as specific combiners for yield and yield attributing traits. The successful identification and utilization of these high-GCA inbred lines can substantially contribute to the development of superior maize hybrids, enhancing overall productivity and sustainability in maize cultivation.Information about ~~D~~data were recorded on twelve morphological ~~N~~ non additive effects were found important for all characters .

Comment [M1]: Name o place use capital word

Key words : Combining ability, gca , sca, Line x Tester model, Maize

Comment [M2]: I those are abbreviation please use capital words GCA, SCA

INTRODUCTION:

Maize (*Zea mays* L.) is a versatile crop that can be grown in a variety of climates and soils. It is the second most widely grown crop in the world, after rice. This crop is used for food, feed and industrial products. Maize (*Zea mays* L.) is the world's third leading cereal crop after wheat and rice. It accounts to 8 and 25% of the world's total area and production, respectively under cereal crops. In India, maize occupies an area of 98.90 lakh hectares with an average production of 316.5 lakh tonnes with productivity of 3200 kg ha^{-1}, while in Telangana it is grown in an area of 5.11 lakh hectares with production of 30.08 lakh tonnes and productivity of 5875 kg ha^{-1} during, 2020-21 (Anonymous, 2022). Major maize growing districts in Telangana are Kamareddy (13400 ha), Jagtial (11709 ha), Nizamabad (8671 ha), Mahboobabad (9034 ha), Rangareddy (8884 ha), Nagarkurnool (5179 ha), Siddipet (4390 ha) and Vikarabad (3271 ha) (PJTSAU, 2020-21**).**

Assessing inbred lines is vital for producing hybrids, necessitating a clear understanding of the nature and number of tester parents required for this evaluation. The top crosses test, which incorporates both broad and narrow base testers, is commonly used for this purpose. However, determining the optimal testers for the line x tester model remains an ongoing challenge.

In breeding programs, the selection of appropriate testers is a key decision. The line x tester mating design is used to estimate the value of a genotype by evaluating its productivity, desirable traits, genetic components, and combining abilities. The two main genetic parameters, general combining ability (GCA) and specific combining ability (SCA), are crucial for formulating effective breeding strategies.

Moreover, the degree of genetic components for a specific trait is primarily influenced by the environmental conditions under which the breeding populations are tested. Consequently, it is essential to choose lines with high general combining ability (GCA) that are genetically diverse to produce superior hybrids (Amoon and Abdul Hamed, 2020). The line x tester design is widely utilized for the initial evaluation of the combining ability of new inbred lines (Jenkins, 1978; Hallauer and Miranda, 1988; Barata and Carena, 2006; Fan et al., 2008). Sprague and Tatum (1942) categorized the combining ability effects into general combining ability (GCA) and specific combining ability (SCA). An ideal tester should gather extensive data while evaluating the combining potential of inbred lines. Genetic variation is vital for breeders, as it provides the genetic resources needed for successful breeding programs.

2 MATERIAL AND METHODS

Experimental material

The base materials for the experiment included 20 inbred lines and two testers LM 13 and LM 14 were obtained from Maize Genetics Unit, ICAR, Ludhiana respectively. These 67 germplasm lines were evaluiated during Kharif, 2023 -2024 in Line x Tester design.

Experiment design

These lines were evaluated in Line x Tester mating design during rabi 2023, at experimental farm of maize genetics unit, ARS, Karimnagar. The experimental material consists 40 test cross hybrids, five checks ,Kaveri Ekka, Pioneer 3302, karimnagar makka ,P -3202, PAC 741,PAC-751 as checks, which were evaluated in randomized block design with bocks and two replications and using 20 parental inbred lines evaluated separately in randomized block design with two replications during kharif 2023 outperform either of the parents in terms of yield and other desirable traits. Harnessing heterosis through the development of heterotic groups has been proven to be an effective strategy for maximizing crop productivity. Heterotic grouping, the classification of inbred lines into distinct groups based on their ability to combine favourably in hybrids, has been a successful approach in maize breeding programmes. Heterotic grouping plays a crucial role in the development of high-yielding maize hybrids. Traditionally, heterotic grouping has been determined through field performance trials and assessment of morphological traits. Morphological characteristics such as plant height, ear length, kernel weight and other quantitative traits are visually observable and provide valuable insights into the performance of maize inbred lines. However, these traditional methods are time-consuming and may not fully capture the underlying genetic diversity and relatedness among inbred line

Table 1 : Analysisof varianceforrandomizedblockdesign for yield and Yield Component Characters in Maize Genotypes

Character	**Mean Sum of Squares**		
Source of varaiation	**Replications**	**Genotypes**	**Error**
d.f	1	66	66
Days to 50% anthesis	7.17	1.80**	0.42
Days to 50 % silking	12.54	1.80**	0.57
Days to maturity	1.07	3.04**	0.77
Plant height (cm)	8.12	4396.40**	9.39
Ear height (cm)	74.62	950.53**	9.47
Ear length (cm)	6.71	11.50**	1.42
Ear girth (cm)	2.19	28.64**	2.77
No. of kernel rows per ear	0.11	5.42**	0.72
No. of kernels per row	3.61	92.44**	10.26
100 kernel weight (gm)	10.77	30.05**	4.76
Grain yield	142644.70	13193028.80**	559330.70
Moisture	1.05	9.01**	2.61

Table 2 : Estimates of general combining ability (GCA) effects for inbred lines for yield and yield attributing traits in maize

		Characters											
S. No	**Genotypes**	**Days to50 % anthesis**	**Days to50 % silking**	**Days tomat uriy**	**Plant height(cm)**	**Earht(c m)**	**Earle ngth(cm)**	**Ear diameter**	**Number ofkernel s Per ear**	**No.of kernels per row**	**Tes t wt**	**moist ure**	**Yield**
	Lines												
1	KML-121	-0.338	-0.425	-0.363	34.488 **	-17.300**	-3.945 **	-3.413**	0.300	6.563 *	-5.613**	-1.866	2300.925**
2	KML-122	-0.588	-0.675	-0.613	-11.988 **	-4.300*	-0.670	-1.191	0.300	0.688	-0.363	-0.991	-544.175
3	KML-123	0.163	0.325	-0.113	14.013 **	5.200*	0.355	-2.271*	-0.200	3.188	0.888	-0.416	-82.925
4	KML-124	-0.088	-0.425	-0.363	13.738 **	-0.800	1.755 **	2.649 *	1.300 **	1.688	0.888	-0.066	456.825
5	KML-125	-0.088	-0.175	-0.363	11.513 **	4.700*	-0.970	0.192	-0.700	-0.563	-0.613	0.409	-393.175
6	KML-126	-0.588	-0.425	-0.363	1.263	1.450	0.855	1.512	-0.700	2.188	0.388	-0.116	557.075
7	KML-127	0.163	0.325	0.638	9.513**	4.200 **	0.030	-0.953	-0.700	-0.063	1.138	-0.216	690.575
8	KML-128	-0.338	-0.175	-0.113	4.763*	4.450 *	0.880	2.787	0.300	-0.563	0.388	-0.316	499.075
9	KML-129	0.163	0.575	0.638	3.763	-2.550	0.805	0.829	1.300**	1.688	1.138	0.584	300.825
10	KML-130	0.913 *	0.825 *	0.388	10.013 **	0.20	0.930	2.897	0.800	0.938	-1.863	-0.491	-45.675
11	KML-131	0.163	-0.175	-0.113	- 10.738 **	-5.050	-1.070	1.808 *	0.700	-0.313	0.388	0.784	-356.425
12	KML-132	-0.338	-0.675	-0.613	-15.488 **	-5.300	0.330	0.794	-0.200	1.438	-1.363	-1.141	2055.82 **
13	KML-133	-0.088	0.325	0.388	5.513 **	3.200	-0.745	-0.353	-0.700	1.313	1.113	0.009	-188.425
14	KML-134	-0.588	-0.675	-0.613	15.013 **	2.700	-0.595	0.354	-0.200	1.813	2.388	-0.466	-411.675
15	KML-135	-0.588	-0.425	-0.363	6.513 **	3.200	0.830	2.837**	1.300	-2.063	1.113	0.784	421.825
16	KML-136	0.163	0.325	0.388	10.763	4.950*	0.605	0.429	0.700	1.938	0.138	0.309	-178.675
17	KML-137	0.663	0.575	0.638	-3.488 *	0.200	-0.095	-1.971	-0.200	-1.813	-1.613	0.859	159.825
18	KML-138	0.913 *	0.825 *	0.888 *	5.513 **	0.200	-0.445	-2.968 **	1.200 *	-2.313	1.638	0.409	-344.675

19	KML-139	0.663	0.575	0.388	-5.988 *	0.800	0.880	1.269	0.300	2.438	2.888 *	1.534	-526.675
20	KML-140	-0.338	-0.425	-0.363	-2.238	1.450	0.280	-1.623	1.300 *	1.888	0.738 *	0.409	231.575
	Tester												
1	LM-13	-0.113	-0.175	-0.138	2.263 *	0.175	0.260	0.725*	0.300 *	0.838	-0.738 *	-0.054	181.550
2	LM-14	0.113	0.175	0.138	2.263 *	-0.175	-0.260	-0.725 *	-0.300 *	-0.838	2.192	0.054	-181.550
	GCALine		0.79	0.88	3.02	3.04	1.50	1.50	0.70	2.61	3.79	1.69	843.19
	GCA Tester		0.25	0.28	0.95	0.96	0.35	0.47	0.22	1.10	4.38	0.53	266.64

*Significanceat 5% probability, **significanceat1%probability

Table 3 : Meansumof squares

Sourceof variation	Df	Meansumof squares									
		Days to 50% anthesis	Days to 50 % Silking	Days to maturity	Plant height (cm)	Ear height	Ear length (cm)	Ear diameter	Number of kernel rowsper ear	Number of kernel per row	Test wt
Replicates	1	7.75	13.55	1.16	11.64	82.266	4.266	1.323	0.03	7.25	9.87
Treatments	61	108.45**	1.87**	3.08**	4508.59**	1001.922**	11.36**	29.11**	4.75**	84.41**	26.46**
Parents	21	51.72**	2.89**	2.16**	88.55**	87.35**	7.516**	19.24**	1.12	18.93*	7.70
Line	19	24.47**	1.44*	1.65*	92.63**	93.52**	7.664**	18.15**	1.11	17.37	6.91
Tester	1	0.25	0.0	0.25	12.25	20.250	0.062	7.92	0.00	12.25	2.250
Parents (L vs T)	1	27.00**	33.27**	13.82**	87.30*	37.23	12.144*	51.25**	2.62	55.30*	28.00*
Parents vs Crosses	1	18.84**	12.93**	100.89**	257230.40**	56570.11**	364.09**	818.16**	173.56**	3991.54**	901.45**
Crosses	39	37.88*	1.03*	1.07	408.57**	69.55**	4.39**	14.19**	2.37**	19.49*	14.12**
Line effect	19	18.13	1.08	0.95	617.35*	109.96*	5.780	15.71	2.25	20.39	13.82
Tester effect	1	1.01	2.45	1.51	409.51	2.450	5.408	42.06	7.20	56.11	43.51
Line *Tester effect	19	18.73750*	0.92368	1.17	199.74**	32.68**	2.96*	11.209**	2.25	16.66	12.88**
Error	61	27.75	0.60	0.83	9.35	9.430	1.423	2.918	0.75**	10.84	5.05
Total	123	143.95	1.33	1.95	2240.70	502.23	6.378	15.89	2.73	47.30	15.71

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Table 4 : Grain yield (g/plant) and moisture content analysis

Sourceof variation	Df	Grain yield (g/plant)	Moisture %
Replicates	1	245373.03	0.149
Treatments	61	13395438.27	9.28**
Parents	21	576345.88**	5.57*
Line	19	525461.71	5.42*
Tester	1	193600.00	1.44
Parents (L vs T)	1	1925891.13	12.64*
Parents vs Crosses	1	726600998.52**	361.95**
Crosses	39	2010704.42**	2.245
Line effect	19	2596436.55	2.48
Tester effect	1	2636832.20	0.231
Line *Tester effect	19	1392018.20*	2.107
Error	61	598164.93	2.62
Total	123	6941911.94	5.90

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Table 5 : Estimates of specific combining ability (SCA) effects for hybrids for yield and yield attributing traits in maize

S. No.	Genotypes	Characters											
		Days to50 % tasseling	Days to50 % silking	Days tomaturity	Plantheight(cm)	Earheight(cm)	Earlength(cm)	Eargirth(cm)	Number ofkernelsperrow	Number ofKernel perear	100 kernelweight(g)	Grainyield (kgha^{-1})	Moisture
	Hybrids												
1	HG -1	-0.63	-0.82	-0.86	1.76	-5.1	0.84	-3.00*	-1.83	-0.30	0.51	727.70	1.10
2	HG-2	0.63	0.82	0.86	1.76**	5.17	-0.84	3.00*	1.83	0.30	-0.51	-727.70	-1.10
3	HG-3	-0.88	-0.57	-0.61	-7.76**	0.32	0.56	-0.72	1.91	-0.30	0.76	-343.55	1.32
4	HG-4	0.88	0.57	0.61	7.76	-0.32	-0.56	0.72	-1.91	0.30	-0.76	343.55	-1.32
5	HG-5	0.36	-0.07	0.38	-5.26	-0.67	0.79	0.84	2.91	0.20	1.01	564.70	-0.59
6	HG-6	-0.36	0.07	-0.38	5.26	0.67	-0.79	-0.84	2.91	-0.20	-1.01	-564.70	0.59
7	HG-7	-0.38	-0.32	-0.36	-15.01**	-3.67	-0.96	-0.88	0.41	-1.30	-1.48	-1338.05	0.20
8	HG-8	0.38	0.32	0.36	15.01**	3.67	0.96	0.88	-0.41	1.30	1.48	1338.05	-0.20
9	HG-9	-0.38	-0.57	-0.86	-2.26	1.32	-0.68	-1.70	-1.33	0.70	0.51	-76.05	0.32
10	HG-10	0.38	0.57	0.86	2.26	-1.32	0.68	1.70	1.33	-0.70	-0.51	76.05	-0.32
11	HG-11	1.11 *	1.17	1.13	-0.01	2.57	-1.16	1.42	-5.08**	0.70	-3.48	-458.30	0.05
12	HG-12	-1.11	-1.17	-1.13	0.01	-2.57	1.16	-1.42	5.08	-0.70	3.48	458.30	-0.05

13	HG-13	-0.13	-0.07	0.13	-0.76	-0.67	1.16	0.91	0.66	0.70	0.01	1048.20	0.35
14	HG-14	0.13	0.07	-0.13	0.76	0.67	-1.16	-0.91	-0.66	-0.70	-0.01	-1048.20	-0.35
15	HG-15	0.13	-0.07	-0.11	5.98*	-2.92	0.41	-1.08	0.16	-0.30	0.26	88.20	-0.94
16	HG-16	0.13	0.07	0.11	-5.98*	2.92	-0.41	1.08	-0.16	0.30	-0.26	-88.20	0.94
17	HG-17	-0.13	0.17	0.13	-3.51	-2.42	-0.41	0.72	-0.08	-0.30	1.01	181.95	1.35
18	HG-18	0.13	-0.17	-0.13	3.51	2.42	0.41	-0.72	0.08	0.30	-1.01	-181.95	-1.35
19	HG-19	0.61	0.42	0.88	2.23	0.82	-0.23	-1.33	-2.83	-0.80	-1.23	-304.05	-1.12
20	HG-20	-0.61	-0.42	-0.88	-2.23	-0.82	0.23	1.330	2.83	0.80	1.23	304.05	1.12
21	HG-21	-0.13	-0.07	-0.11	7.48*	1.57	-1.83	-2.55	-2.08	-1.30	-2.23	-928.80	-0.29
22	HG-22	0.13	0.07	0.11	-7.48*	-1.57	1.83	2.55	2.08	1.30	2.23	928.80	0.29
23	HG-23	0.36	0.42	0.38	-14.26**	-5.67	-0.08	-0.24	0.16	0.20	-2.98	-287.05	-0.42
24	HG-24	-0.36	-0.42	-0.38	14.26**	5.67	0.08	0.24	-0.16	-0.20	-2.98	287.05	0.42
25	HG-25	-0.38	-0.07	-0.11	-3.76	0.32	-0.56	0.96	-0.58	0.70	1.26	93.20	-0.77
26	HG-26	0.38	0.07	0.11	3.76	-0.32	0.56	-0.96	0.58	-0.70	-1.26	-93.20	0.77
27	HG-27	0.11	0.42	0.38	11.23**	2.32	1.19	3.29*	0.91	1.20	0.01	252.45	-0.14
28	HG-28	-0.11	-0.42	-038	-11.23**	-2.32	-1.19	-3.29*	-0.19	-1.20	-0.01	-252.45	0.14
29	HG-29	0.11	-0.07	0.13	8.73**	4.82	-0.83	0.08	-1.83	-0.30	-1.48	-241.55	-0.49
30	HG-30	-0.11	0.07	-0.13	-8.73**	-4.82	0.83	-0.08	1.83	0.30	1.48	241.55	0.49
31	HG-31	0.13	0.42	-0.61	4.48	1.07	-0.31	1.44	2.16	0.70	4.51	910.45	-0.37
32	HG-32	0.13	-0.42	0.61	-4.48	-1.07	0.31	-1.44	-2.16	-0.70	-4.51	-910.45	0.37
33	HG-33	-0.13	0.17	-0.36	0.73	4.82	1.24	0.11	1.91	1.20	1.26	308.45	-0.62
34	HG-34	0.13	-0.17	0.36	-0.73	-4.82	-1.24	-0.11	-1.91	-1.20	-1.26	-308.45	0.62
35	HG-35	-0.38	-0.57	-0.11	3.23	1.32	-0.11	1.11	0.41	-0.80	1.51	283.95	0.77
36	HG-36	0.38	0.57	0.11	-3.23	-1.32	0.11	-1.11	-0.14	0.80	-1.51	-283.95	-0.77
37	HG-37	0.36	-0.32	-0.11	7.73	-0.67	0.51	-2.04	1.16	-0.30	0.26	-565.55	-0.09
38	HG-38	-0.36	-0.07	0.11	-7.73	0.67	-0.51	2.04	-1.16	0.30	-0.26	565.55	0.09

39	HG-39	0.86	0.07	0.63	2.48	0.57	0.46	2.66	2.91	-0.30	0.01	83.70	0.37
40	HG-40	-0.86	0.17	-0.63	-2.48	-0.57	-0.46	-2.66	-2.91	0.30	-0.01	-83.70	-0.37

3. RESULTS AND DISCUSSION

The data recorded on 40 hybrids, 22 parents along with 0 check were used for combining ability analysis using Line × Tester mating design (L × T).

Analysis of variance for line × tester

The analysis of variance for the combining ability of all the traits in the current study.

The results indicate that treatments were significant for all the traits examined. However, the variance due to replications was non-significant.The variance between parents and crosses was significant for all traits. The variance due to lines was significant for all traits. The variance due to testers was significant for moisture trait. When the effects of parents were divided into lines, testers, and line × tester interactions, the interaction effects (lines × testers) were significant for traits such as days to 50% anthesis, days to 50% silking, anthesis silking interval, ear height, the number of kernel rows per ear, the number of kernels per row, 100 kernel weight, and grain yield per plant. This suggests there is sufficient variability in the material studied.

Significant differences among the parents indicate a high level of diversity among the parents in the study. The hybrids also showed significant differences, highlighting the varying performance of the cross combinations. The significant differences between parents and hybrids for all traits suggest that a considerable amount of average heterosis is present in hybrids for these characters.

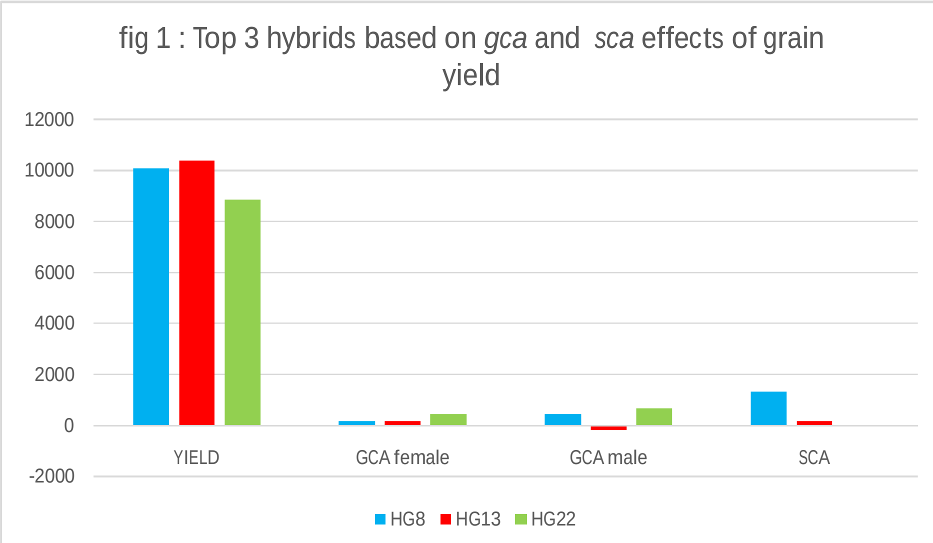
Gca and sca effects

Comment [M6]: GCA and SCA

The estimates of GCA effects revealed that the parents' viz., Based on significant *gca* effect, the parents KML-122,KML-7,KML-6 were identified as good general combiners for grain yield and yield contributing traits like days to 50 per cent anthesis, days to 50 per cent silking, days to maturity, plant height, were proved to be good general combiner for yield and yield contributing characters.

In this study, the GCA to SCA variance ratio was less than one for days to 50 percent anthesis, 50 percent silking, anthesis-silking interval, days to maturity, plant height, ear height, and grain yield per plant, as ear length, ear girth, number of kernel rows per ear, number of kernels per row, and 100 kernel weight, moisture suggesting these traits are governed by non-additive gene action

These results align with previous findings by Mousa et al. (2021)



4. CONCLUSION

Based on significant *gca* effect, the parents KML-122,KML-7,KML-6 were identified as good general combiners for grain yield and yield contributing traits like days to 50 per cent anthesis, days to 50 per cent silking, days to maturity, plant height.

Based on *sca* effects, the hybrids HG-7, HG-22, HG-31 were identified as specific combiners for yield and yield attributing traits.

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Comment [M7]: Check please the guideline for references

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