__Original Research Article__

Heterotic Classification of Inbred Lines of Maize Based on Combining Ability for Kernel Yield

ABSTRACT:

Grouping of maize inbred lines into heterotic groups is an initial step in exploitation of heterosis. Hence a field study was conducted to classify 27 inbred lines into two heterotic groups by evaluating the performance of 54 crosses along with lines and testers in a simple lattice design. The 27 inbred lines were crossed to two broad based heterotic testers. Highly significant differences were noticed for kernel yield per plant, days to anthesis, days to silking and plant height among all the genotypes. One cross PI 330 × LM 13 was found to be promising among the crosses. Highly significant GCA and SCA effects for kernel yield per plant was recorded. Five inbred lines were identified as good general combiners for kernel yield per plant while nine test crosses were found to be good specific combiners. Out of 27 inbred lines, the testers could classify 15 inbred lines into heterotic groups based on GCA and SCA effects and mean kernel yield per plant. The study demonstrated the applicability of combining ability effects in classifying the inbred lines.

Key words: Combining ability, Heterotic group, Tester

INTRODUCTION:

Classification of inbred lines into heterotic groups in maize breeding program is of prime importance owing to its application in exploitation of heterosis. Heterotic grouping is the initial step in maize breeding program which would provide maximum utilization of heterotic effects(Melchinger, 1999). Extensive studies on classification of inbred lines into heterotic groups has not been done in the India. Heterotic group classification methods used by researchers have great influence on how a maize line is assigned to maize heterotic group (X.M. Fan *et al*., 2008). The traditional method uses specific combining ability with some line-pedigree information and /or field hybrid yield information to assign a maize line to a heterotic group. Establishment of the best combination of inbreds among the heterotic groups is crucial to the development of successful maize hybrids (Barata and Carena, 2006). Globally, maize is a cereal crop ranked third in importance followed by wheat and rice. It is a unique crop and known as the "Queen of cereals" due to its excellent genetic output potential (Kumari *et al*., 2016). Maize is expected to overtake rice as the world's most important grain by 2030, owing to rising demand for dairy and meat products in developing countries and declining rice production in China and India(Salvi *et al*., 2007). It is a key kernel crop for the worldwide agriculture business because of its high output.

When large number of inbred lines are available and proven testers exist, the performance of the lines in test crosses with proven testers can be used as a main criterion for grouping of lines. In this study, combining ability effects were used to classify inbred lines into heterotic groups. The *sca* effects help breeders to determine heterotic patterns among populations or inbred lines to identify promising single crosses and assign them into heterotic groups (Lahane*et al*., 2014). Heterotic patterns are important as they guide breeders to decide on the germplasm to be used in hybrid production over a long period thus simplifying germplasm management and organization (Nepir*et al.*, 2015 and Oppong *et al.*, 2019).Apart from selection of superior lines and analysis of their combining ability, placing them in well-defined heterotic groups is essential to increase the probability of success in heterosis breeding. Identification and utilization of heterotic groups and their patterns is essential in maize heterosis breeding (Badu-Apraku*et al.*, 2015).

Exploitation of the selected parental lines in hybrid breeding programmes is vital task for breeder or researcherPhenotypic selection of parental lines not always fulfils breeder's requirements because phenotype is always linked with the environment. Therefore, it is necessary to choose the parental lines accordingly with the help of combining ability analysis and there is a continuous need to evolve new hybrids, which should exceed the existing hybrids in yield and quality (Mir *et al.*, 2015).

MATERIAL AND METHODS:

Experimental site: The present study was carried out during post rainy during 2021-22 at Agricultural Research Station (ARS), Peddapuram, Andhra Pradesh which is located at a latitude of 17º.07' N, longitude of 82º.14' E and altitude of 46.26 meters above Mean Sea Level (MSL).

Experimental material: The experimental material comprised of 27 lines and 2 testers (Table 1) belonging to A and B heterotic groups which were used to generate 54 test crosses during rainy 2021.These crosses were evaluated during post rainy 2021-22, in two replications and each genotype was planted in two rows each of 3 meter in length with spacing of 60 cm between rows and 20 cm within row by using simple lattice design. All the recommended crop management practices were adopted for raising a good crop.

Table 1. List of parental lines of maize (*Zea mays* L.) used in the study

S.No.	Inbred line	S.No.	Inbred line
1.	PI31	16.	PI57
2.	PI 33	17.	PI60
3.	PI35	18.	PI61
4.	PI36	19.	PI64
5.	PI40	20.	PI66
6.	PI42	21.	PI159
7.	PI44	22.	PI328
8.	PI47	23.	PI330
9.	PI48	24.	PI331
10.	PI49	25.	PI332
11.	PI50	26.	PI333
12.	PI51	27.	PI334
13.	PI53	**Testers**	
14.	PI54	1.	LM13
15.	PI55	2.	LM14

Generation of data:Data was collected for kernel yield per plant, days to anthesis, days to silking, plant height and ear height. The data collected from the experiment for kernel yield is on a plot basis. The kernel yield per plant was recorded in grams by weighing the kernels obtained after drying and shelling of ears from individual plant. The number of days from the date of sowing to the day on which 50 per cent of plants of each genotype in a plot shown full tassel emergence was recorded as days to anthesis. The number of days to silking was determined by the number of days from date of sowing till 50 % of the total number of plants in the plot showed silk emergence. The height of the plant was measured at the dry silk stage from base of the plant (ground level) to the tip of the tassel in centimeters. Height from ground level upto the base of the upper most bearing internode was recorded as ear height in centimeters.

Statistical analysis:

The statistical analysis was performed for the mean data recorded on the five randomly selected plants from each entry from each replication. The statistical software used for analysis of the data is Windostat Version 9.3 from Indostat Services. Line x tester analysis was calculated using the adjusted means based on the method described by Kempthorne (1957) and adopted by Singh and Choudhry (1979). General combining ability (GCA) and specific combining ability effects for kernel yield and other characters were calculated based on the line x tester model.

RESULTS AND DISCUSSION:

Analysis of variance: The analysis of variance revealed significant differences among 54 genotypes for all the characters studied indicating the presence of higher degree of variability in the material studied (Table 2). Mean performance of 54 maize crosses for kernel yield and other characters is presented in (Table 3).

Line x tester analysis: Kernel yield per plant was subjected to combining ability analysis (Table 4) in which analysis of variance (ANOVA) for combining ability revealed significant differences for kernel yield per plant indicating the presence of variability among the crosses.

Classifying inbred lines into heterotic groups:

In classifying inbred lines into heterotic groups, criteria given by Menkir's*et al* (2004) was followed with some modifications. The combining ability effects of the inbred lines when crossed to 2 testers LM13 and LM14 were used as the bases in classifying the lines into heterotic groups. All the lines having positive GCA effects were taken in to consideration while grouping the lines. Inbred lines showing positive SCA effect with the tester A but having negative SCA effect with tester B were placed in the heterotic group A while, inbred lines displaying positive SCA effects with tester B but having negative SCA effects with tester A were put into the heterotic B group. Inbred lines exhibiting positive SCA effects with both the testers were assigned into heterotic AB group. Of the 27 inbred lines, 15 lines recorded positive GCA effects for kernel yield and only 5 lines (PI 330, PI 333, PI 36, PI 47, PI 57) had significant GCA effects presented in Table 5. On contrary Riboniesa*et al* (2008) classified 21 inbred lines using single tester and assigned 11 inbred lines in to two heterotic groups. Alphonse Nyombayire*et al* (2021) classified 3 maize inbred lines (S4, S6 and S7) that were considered as testers discriminated the seven local lines into three heterotic groups.Elmyhun*et al* (2020) classified 8 inbred lines into 2 heterotic groups.

Inbred lines *viz.*,PI 31, PI 35, PI 36, PI 48, PI 60 that showed positive SCA effects with tester B (LM 14) were placed in (A) heterotic group. Five inbred lines *viz.*, PI 44, PI 49, PI 57, PI 330, PI 332 were placed in B heterotic group, since they had positive SCA effects with tester A (LM 13). Further, 3 inbred lines *viz.*, were assigned to AB group since they had positive GCA effects with both testers LM13 and LM14 i.e., A and B heterotic group. The results suggest that the inbred lines evaluated in the study indicated positively for kernel yield with the genetic background of the two testers. Positive heterosis for kernel yield were reported by Ali *et al* (2022) and Mideksa*et al* (2022).The testers were able to classify 15 out of 27 inbred lines into heterotic groups A, B, and AB based on SCA effects presented in (Table 6). Assigning lines to heterotic groups would avoid the development and evaluation of crosses that should be discarded, allowing maximum heterosis to be exploited by crossing inbred lines belonging to different heterotic groups. Ashok kumarmeena*et al* (2017)

Table2: Analysis of variance for grain yield and yield contributing characters:

Source of variation	D.f	Days to 50 % tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear girth (cm)	Kernel rows cob-1	Number of kernels row-1	100 kernel weight (g)	Protein content (%)	Grain yield per plant (g)
		Mean Sum of Squares											
Replications	1	0.5	1.25	1.25	112.5	1.82	0.08	0.45	0.73	0.09	11.49	0.01	212.04
Treatments (Unadj.)	143	12.21 **	12.39 **	12.397 **	1148.51 **	431.72 **	6.42 **	2.42 *	2.80 **	27.72 **	27.22 **	1.75 **	1313.14 **
Blocks within replications (Adj)	22	2.22 **	2.54 **	2.54 **	450.75 **	86.53	1.87	1.41	0.93	7.11	9.43	0.05	316.81
Error	121	0.9	1.03	1.03	200.5	68.57	1.29	1.69	1.05	6.63	9.67	0.05	232.79
Total	287	6.64	6.81	6.81	691.73	250.65	3.88	2.03	1.91	17.15	18.4	0.9	777.45

Table 3: Mean performance of kernel yield per plant and other agronomic characters of 54 crosses of maize:

S.N.	Cross	Kernel yield per plant (g)	Days to anthesis	Days to silking	Plant height (cm)	Ear height (cm)
1	PI 31/LM13	144	51	53	247	95
2	PI 31/LM14	164	54	56	257	105
3	PI 33/LM13	137	53	54	255	117
4	PI 33/LM14	135	53	54	252	102
5	PI 35/LM13	141	53	54	230	97
6	PI 35/LM14	175	53	56	217	80
7	PI 36/LM13	152	55	57	270	107
8	PI 36/LM14	173	55	57	272	117
9	PI 40/LM13	137	52	53	265	107
10	PI 40/LM14	137	53	54	267	122
11	PI 42/LM13	137	52	54	235	90
12	PI 42/LM14	82	52	55	205	77
13	PI 44/LM13	182	56	57	250	95
14	PI 44/LM14	126	54	56	245	87
15	PI 47/LM13	148	52	54	265	85
16	PI 47/LM14	137	53	54	242	92
17	PI 48/LM13	142	53	54	245	102
18	PI 48/LM14	169	53	54	233	98
19	PI 49/LM13	168	54	56	270	103
20	PI 49/LM14	149	55	56	255	103
21	PI 50/LM13	136	52	54	225	80
22	PI 50/LM14	140	53	54	238	98
23	PI 51/LM13	141	59	60	270	98
24	PI 51/LM14	95	56	58	235	88
25	PI 53/LM13	130	56	58	250	90
26	PI 53/LM14	135	54	56	245	93
27	PI 54/LM13	143	57	59	265	103
28	PI 54/LM14	137	54	56	240	108
29	PI 55/LM13	120	55	57	250	80
30	PI 55/LM14	159	51	53	235	88
31	PI 57/LM13	161	56	56	248	90
32	PI 57/LM14	154	54	56	243	100
33	PI 60/LM13	138	56	56	270	110
34	PI 60/LM14	144	54	55	250	108
35	PI 61/LM13	126	54	56	235	88
36	PI 61/LM14	108	55	57	233	98
37	PI 64/LM13	156	55	57	253	95
38	PI 64/LM14	158	55	57	245	88
39	PI 66/LM13	122	56	58	250	90
40	PI 66/LM14	159	54	56	245	103
41	PI 159/LM13	135	53	55	248	98
42	PI 159/LM14	134	56	56	233	80

43	PI 328/LM13	129	54	55	225	85
44	PI 328/LM14	117	54	56	227	87
45	PI 330/LM13	200	57	58	280	105
46	PI 330/LM14	142	57	59	280	110
47	PI 331/LM13	159	53	55	285	102
48	PI 331/LM14	153	54	56	270	105
49	PI 332/LM13	163	53	54	242	115
50	PI 332/LM14	144	54	56	232	105
51	PI 333/LM13	177	52	54	265	112
52	PI 333/LM14	171	53	55	277	120
53	PI 334/LM13	138	57	58	252	97
54	PI 334/LM14	104	56	58	227	87

Table 4: ANOVA of L x T mating design for combining ability of crosses for kernel yield per plant (g)

Source of Variations	Df	Sum of squares	Mean sum of squares	F Ratio	Probability
Replicates	1	320.1	320.1	1.294	0.25720
Crosses	107	77320.8	722.6	2.922	0.00000 ***
Lines	26	35448.6	1363.4	2.649	0.00052 ***
Testers	3	1727.1	575.7	1.119	0.34675
Lines x Testers	78	40145.1	514.7	2.081	0.00009 ***
Error	138	34125.7	247.3		

Table 5: Estimates of general and specific combining ability effects of lines and testers for kernel yield per plant (g):

S.N.	Lines	Testers LM 13 A Group	Testers LM 14 B Group	*gca* effects	*sca* effects LM 13 A Group	*sca* effects LM 14 B Group	Heterotic group
1.	**PI 31**	143.6	164.4	1.458	-4.543	22.109 *	**A**
2.	**PI 33**	136.8	135.0	2.908	-12.793	-8.741	**-**
3.	**PI 35**	141.4	175.1	3.408	-8.693	30.859 **	**A**
4.	**PI 36**	152.0	172.6	21.008 **	-15.693	10.759	**A**
5.	**PI 40**	136.6	136.6	-1.692	-8.393	-2.541	**-**
6.	**PI 42**	136.8	82.4	-22.892 **	13.007	-35.541 **	**-**
7.	**PI 44**	181.6	126.4	7.358	27.557 *	-21.791	**B**
8.	**PI 47**	148.2	137.2	11.083 *	-9.568	-14.716	**-**
9.	**PI 48**	141.6	169.1	5.933	-11.018	22.334 *	**A**
10.	**PI 49**	168.0	149.0	9.795	11.519	-1.629	**B**
11.	**PI 50**	135.8	140.2	-9.292	-1.593	8.659	**-**
12.	**PI 51**	140.6	95.2	-23.942 **	17.857	-21.691	**-**
13.	**PI 53**	129.8	134.6	-7.692	-9.193	1.459	**-**
14.	**PI 54**	142.6	137.4	-4.942	0.857	1.509	**-**
15.	**PI 55**	119.8	158.8	-12.917 *	-13.968	30.884 **	**-**
16.	**PI 57**	160.8	154.0	13.958 *	0.157	-0.791	**B**

17.	**PI 60**	138.2	144.0	1.008	-9.493	2.159	**A**
18.	**PI 61**	125.8	107.5	-21.417 **	0.532	-11.916	**-**
19.	**PI 64**	156.3	157.8	5.483	4.132	11.484	**AB**
20.	**PI 66**	121.8	158.8	-0.092	-24.793 *	18.059	**-**
21.	**PI 159**	135.2	134.4	-7.992	-3.493	1.559	**-**
22.	**PI 328**	129.6	117.6	-15.092 **	-1.993	-8.141	**-**
23.	**PI 330**	200.8	142.0	23.158 **	30.957 **	-21.991	**B**
24.	**PI 331**	159.4	153.0	5.383	7.332	6.784	**AB**
25.	**PI 332**	162.6	144.4	4.908	11.007	-1.341	**B**
26.	**PI 333**	177.2	171.4	22.808 **	7.707	7.759	**AB**
27.	**PI 334**	137.6	103.6	-11.692 *	2.607	-25.541 *	**-**

Table 6: Inbred lines assigned under different heterotic groups:

Heterotic group	**Inbred lines**
A group	PI 31, PI 35, PI 36, PI 48, PI 60
B group	PI 44, PI 49, PI 57, PI 330, PI 332
AB group	PI 64, PI 331, PI 333

Summary and Conclusions:

The analysis of variance revealed significant differences among genotypes for all the characters indicating presence of intrinsic variation in the genotypes. Significant general and specific combining ability effects were detected among the inbred lines PI 330, PI 333, PI 36, PI 47, PI 57 were identified as good general combiners among the 27 inbred lines and 9 crosses viz., (PI 330/BML7), (PI 330/LM13), (PI 31/LM14), (PI 33/BML7), (PI 35/LM14), (PI 44/LM13), (PI 47/BML6), (PI 48/LM14), (PI 55/LM14) were noted to have good specific combining ability effects. Of the 27 inbred lines tested, 13 were assigned into A, B and AB heterotic groups. Our findings further support the use of SCA effects as major criteria for classifying inbred lines.

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