The Andhra Agric. J 69 (2): 210-216, 2022

Heterotic Grouping of Inbred Lines based on Combining Ability for Kernel Yield in Maize (*Zea mays* L.)

D Preethi Suneela, A Prasanna Rajesh, I Sudhir Kumar and E S V Narayana Rao

Department of Genetics and Plant Breeding, Agricultural College, Mahanandi, A. P.

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 heterotic groups by evaluating the performance of 54 crosses, 27 lines and 2 testers in a simple lattice design. 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 were 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 3 groups A, B and AB 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.

Keywords: *Heterotic group, Combining ability and Tester.*

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 India. Heterotic group classification methods used by researchers have great influence on how a maize line is assigned to maize heterotic group (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).

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 lines exhibiting contrasting specific combining ability effects (SCA) with two testers were placed into different heterotic groups.

Exploitation of the selected parental lines in hybrid breeding programmes is vital task for breeder or researcher. Phenotypic selection of parental lines not always fulfills breeder's requirements because phenotype is always linked with the environment. Therefore, it is necessary to choose the parental lines with the help of combining ability analysis.

MATERIAL AND METHODS

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). 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 season 2021. These crosses were evaluated during post rainy season 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	PI 31	16	PI 57
2	PI 33	17	PI 60
3	PI 35	18	PI 61
4	PI 36	19	PI 64
5	PI 40	20	PI 66
6	PI 42	21	PI 159
7	PI 44	22	PI 328
8	PI 47	23	PI 330
9	PI 48	24	PI 331
10	PI 49	25	PI 332
11	PI 50	26	PI 333
12	PI 51	27	PI 334
13	PI 53	Testers	
14	PI 54	1	LM13
15	PI 55	2	LM14

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 was on 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 cob bearing internode was recorded as ear height in centimetres.

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 was Windostat Version 9.3 from Indostat Services. Line x tester analysis was performed using the adjusted means based on the method described by Kempthorne (1957). General Combining Ability (GCA) and Specific Combining Ability (SCA) effects for kernel yield and other characters were calculated based on the line x tester model.

RESULTS AND DISCUSSION:

The analysis of variance revealed significant differences among the 54 genotypes for all the characters studied indicating the presence of higher degree of variability in the material studied (Table 2). The presence of genetic variability among the genotypes could be exploited to enhance selection for further population improvement in maize. Mean performance of 54 maize crosses for kernel yield and other characters is presented in Table 3. The results indicated that significant differences were found in all traits among lines, testers and hybrids. The mean performance for the trait kernel yield per plant among the inbred lines ranged from (66.20 g) PI 330 to (188.00 g) PI 40 and hybrids ranged from PI 42/LM14 (82.40 g) to PI 330/LM13 (200.80 g) with general mean value of 139.29 g.

Estimates of analysis of variance (ANOVA) for combining ability (Table 4) revealed significant differences for kernel yield indicating the presence of variability among the crosses. Further, variance due to lines (females) were highly significant. The contribution towards total hybrid variance was found to be higher from females (lines) than males (testers).

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

The results are in accordance with Italia *et al.* (2022). The contribution towards total hybrid variance was found to be higher from females (lines) than males (testers) for the characters presented. The proportional contribution of the line x tester interaction to the total variance was higher than that of females for kernel yield per plant. Similar results were obtained by Ibrahim *et al*. (2021), Aaty (2021), Alsebaey *et al*.(2021), Kumawat *et al*. (2021), Mousa *et al*. (2021).

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 inbred lines when crossed to 2 testers LM13 and LM14 were used as the base in clarifying the lines into heterotic groups. All the lines having positive GCA effects were taken into 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 B while, inbred lines displaying positive SCA effects with tester B but having negative SCA effects with tester A were put into the heterotic A 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 (Table 5).

Out of 27 lines, 2 lines *viz*., PI 333 and PI 36 recorded significant GCA effects for kernel yield per plant. Inbred lines *viz.,* PI 31, PI 35, PI 36, PI 48 and PI 60 showed positive SCA effects with tester B (LM 14) were placed into (A) heterotic group. Five inbred lines *viz.,* PI 44, PI 49, PI 57, PI 330 and PI 332 were placed into (B) heterotic group, since they had positive SCA effects with tester A (LM 13). Further, 3 inbred lines *viz.,* PI 64, PI 331 and PI 333 were assigned to AB group since they had positive GCA effects with both testers LM13 and LM14. The results indicated positive combining ability of inbred lines evaluated in the study for kernel yield with the genetic background of the two testers. The testers were able to classify 15 out of 27 inbred lines into heterotic groups A, B, and AB based on SCA effects. (Table 6).

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

S.No.	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
	Mean	139.2	54.8	56.5	239.7	93
	Minimum	82	51	53	205	77
	Maximum	200	59	60	285	122
	CD (0.05)	30.9	2	2.2	30.5	16.7
	CV	11.2	1.9	1.9	6.4	9

Table 4. Estimates of ANOVA for general and specific combining ability effects of lines and testers for kernel yield per plant (g)

Source	D.f	Kernel yield per plant (g)
Replications	1	320.1
Treatments	138	1302.63 **
Parents	30	2147.24 **
Crosses	107	722.62 **
Lines	26	1363.40 **
Testers	3	575.7
Lines x Testers	78	514.68 **
Parents vs. Hybrids	1	38025.05 **
Error	138	247.28
Total	277	773.318

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

S.No.	Lines	Testers	Testers	*GCA* effects	*SCA* effects		Heterotic group
		LM 13	LM 14		LM 13	LM 14	
		A Group	B Group		A Group	B Group	
1	PI 31	143.6	164.4	1.458	-4.543	22.109 *	A
2	PI 33	136.8	135	2.908	-12.793	-8.741	-
3	PI 35	141.4	175.1	3.408	-8.693	30.859 **	A
4	PI 36	152	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	149	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	13.958 *	0.157	-0.791	B
17	PI 60	138.2	144	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	23.158 **	30.957 **	-21.991	B
24	PI 331	159.4	153	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

Combining ability is the ability of parents to transmit desirable performance to its progeny. It is the capacity of parents to produce superior progeny or otherwise when crossed with another parents (Izge *et al*., 2007). Combining ability analysis helps in evaluation of inbreds in terms of their genetic value and selection of suitable parents for hybridization (Alabi *et al*., 1987). Inbred lines identified for good general combining ability could be utilized in maize grain improvement programs for traits of interest as these lines have high potential to transfer desirable traits to their progenies as reported by Shenawy *et al.* (2009).

Significant general and specific combining ability effects were detected among the inbred lines, PI 330, PI 333, PI 36, PI 47 and 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), as crosses having good specific combining ability effects. Of the 27 inbred lines tested, 13 out of 27 inbred lines were assigned into A, B and AB heterotic groups. Our findings further support the use of GCA effects as major criteria for classifying inbred lines.

Aaty Y H 2021 Combining ability estimates and gene effects for grain yield and yield components in maize (*Zea mays* L.). European Journal of Agricultural and Rural Education. 2(12).

Alabi S O, Obilana A B and Nwasike C C 1987 Gene action and combining ability for qualitative character in upland cotton. Samaru Journal of Agricultural Research, 5 (12): 39-64.

Alsebaey R H A, Shosha A A, El-Shahed H M and Darwich M M B 2021 Evaluation of some yellow three-way crosses of maize derived *via* line x tester mating method under conditions of two locations. Electronic Journal of Plant Breeding. 25(1):71-83.

Barata C and Carena M 2006 Classification of North Dakota maize inbred lines into heterotic groups on molecular and test cross data. Euphytica 151:339-349.

Fan W H, Yao HM, Chen J, Tan C C, Xu X L Han, L M Luo and Kang M S 2008 Classifying maize inbred lines in to heterotic groups using a factorial mating design. Agronomy Journal 100: 1-7.

Ibrahim K A, Said A A and Kamara M M 2021 Evaluation and classification of yellow maize inbred lines using line x tester analysis across two locations. Journal of Plant Production. 12(6): 605-613.

Italia P B, Izge A U, Sabo M U, Buba U M and Fagam A S 2022 Genetic analysis among elite Nigerian open pollinated varieties and inbred lines of maize (*Zea mays* L.) for grain yield and other yield components. Director Journal of Agriculture Food Science. 10(1): 11-21.

Izge A U, Kadams A M and Gungula D T 2007 Heterosis and inheritance of quantitative characters in diallel cross of Pearl Millet (*Pennisetum glaucum* L.) Journal of Agronomy, 62: 278-285.

Kempthorne O 1957 An Introduction to Genetic Statistics. John Wiley and Sons, New York.

Kumari R, Singh A K and Sharma V K 2016 Heterosis and genetic divergence correlation studies for yield and its related traits in maize (*Zea mays* L.). The Bioscan. 11(3): 1849-1854.

Kumawat R, Dadheech A and Barupal H L 2021 Combining ability and genetic architecture studies in maize. The Pharma Innovation Journal. 10(12): 2307-2313.

Melchinger A E 1999 Genetic diversity and heterosis. In Coors, J, G., Pandel, S. (eds). The genetics and exploitation of heterosis in crops. CSSA-SP. Madison. Wis. 99-118.

Menkir A A, Malake-Berhan C, Ingelbrech TheI And Adepoju A 2004 Grouping of tropical mid-altitude maize inbred lines o the basis of yield data and molecular makers. Theor Appl. Genet. 108: 1582- 1590.

Mousa S T M, Mohamed M A A, Aly R S H and Darwish H A 2021 Combining ability of white maize inbred lines *via* Line x Tester analysis. Journal of Plant Production. 12(2): 109-113.

Shenawy A A, Mosa H E, Motawei A A, Kafer El-Sheikh University (2009) Journal of Agricultural Research, 35(4), 1-9.