Classifying white inbred lines into heterotic groups using yield combining ability effects

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Abstract

The classification of maize inbred lines into heterotic groups is an important undertaking in hybrid breeding. This study aimed to evaluate the field performance of 42 white maize test crosses and classify the 21 inbred lines into two heterotic groups. Twenty-one white inbred lines were crossed to two line testers representing the dent and flint heterotic pattern. The resulting test crosses were evaluated for their yield and other agronomic traits. The entries were arranged in alpha lattice design with three replications. Highly significant differences were noted in grain yield and plant height among the test crosses. Three test crosses were identified as promising single cross hybrids with yield potential greater than 6 t/ha having yield advantage of 60% over the hybrid check. Highly significant GCA and SCA effects for grain yield were detected among the inbred lines. Three inbred lines were identified as good general combiners. Three test crosses were noted as good specific combiners. The tester inbred lines classified 11 of the 21 tested lines into heterotic groups based on SCA effects and test crosses mean grain yield. This study demonstrates the usefulness of combining ability effects in classifying inbred lines.

Key words: corn breeding, general combining ability (GCA), heterosis, specific combining ability (SCA)

Introduction

In hybrid breeding classifying maize inbred lines into heterotic groups is the initial step in maize breeding program which would provide maximum exploitation of heterosis. Systematic studies on classifying inbred lines into heterotic groups have been reported. Melchinger (1999) proposed that when large number of inbred lines is 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. Vasal et al (1992a, 1992b) used this approach in evaluating the performance of test crosses of 92 tropical and 88 subtropical maize lines using two dent and two flint line testers. In recent years the combined analysis of field and molecular marker data were employed in classifying inbred lines and populations to obtain a clearer picture on promising heterotic patterns and groups (Reif et al, 2003 and Menkir et al 2004). At the beginning of a hybrid breeding program, Reif et al (2003) suggested that SSR-based genetic distances in combination with field evaluation provide a solid basis for the detection of promising heterotic groups and patterns. Recent studies indicate that SSR-based grouping of inbred lines (Magulama et al 2007a) and morphology-based grouping of varieties (Magulama et al 2007b) followed by factorial mating appeared more efficient than usual diallel mating in

finding promising hybrids. A new set of inbred lines is available at University of Southern Mindanao (USM) but limited or no information is available on heterotic groups among inbred lines. Such information would be useful in making and evaluating crosses. In this study, we used yield combining ability effects to classify inbred lines into heterotic groups. The lines exhibiting contrasting specific combining ability effects (SCA) with two testers were placed into separate heterotic groups.

This study was undertaken to evaluate the field agronomic of 42 test crosses and to classify 21 white inbred lines into heterotic group using specific combining ability effects for yield.

Methodology

Field trial Twenty-one white inbred lines and the two tester lines belonging to A and B groups were used to generate test crosses. Each of the 21 lines was crossed to two testers, CML 254 and CML 247 representing each side of dent and flint heterotic group. The 42 test crosses including the hybrid between the two testers and its reciprocal and a check hybrid were evaluated for their agronomic performance at Southern Mindanao Agricultural Research Center (14° 13'N, 40 m above see level) from December 2006 to March 2007. The

entries were arranged in (0, 1) alpha lattice design (Patterson and Williams 1976) with three replications. Each replication consisted of nine incomplete blocks with each block had five plots. Each entry was planted into two 3-m row plots spaced at 65 x 25 cm between furrows and between hills at two plants per hill. Plants in each plot were thinned two weeks after planting leaving one plant per hill. The plants were fertilized with complete fertilizer (14-14-14) at rate of 60-60-60 NPK per ha during planting, and urea (46-0-0) at rate of 60-0-0 NPK per ha 25 days after planting. Other recommended cultural management practices in maize were strictly followed.

Data gathered Data were collected from the experiment on a plot basis for grain yield, plant height, silking date, ear diameter, and ear length. Measurement of plant height was recorded from 10 random sample plants from each plot. Plant height was measured as the distance from the ground to the first tassel branch. Ear diameter was measured at the mid portion of the ear using vernier caliper. Ear length was also measured from the bottom to the tip of the ear using a foot ruler. Measurements on ear diameter and length were taken from ten random samples. Silking date was determined as days from sowing until 50% of the plants had shed pollen or extruded silks. Data on grain yield were determined by weighing the ears harvested from two rows of each plot of the trial. The seed moisture content was recorded using electronic moisture tester. The grain yield of each entry was calculated using the formula below.

Wherein:

FW =Field Weight
MC=Moisture Content
CF=Correction Factor
AH=Area Harvested
CF= M-0.3(PS-SC)/SC
Where: PS=Perfect Star

Where: PS=Perfect Stand

SC=Stand Count at harvest 0.3=constant value

Table 1. Mean squares for yield and other agronomic traits of 45 maize entries.

Sources of Variation df			MEAN SQUARES				
		Yield	Plant Height	Silking Date	Ear Diameter	Ear Length	
Rep	2	12.310	25.413	16.563	0.007	1.783	
BlkAdj)	24	2.156	45.530	7.992	0.002	2.979	
Entries	44	3.015	148.927	7.558	0.003	4.216	
Entries (Adj)	44	3.132**	125.437**	3.7332ns	0.002ns	3.081ns	
Error CV(%)	64	1.549 17.30	64.690 4.10	3.933 3.60	0.002 1.600	2.425 14.20	

^{**=} significant differences at 1% level, ns= not significant

Statistical analysis Analysis of variance was performed for all the traits gathered using Alpha software program (CIMMYT Maize Program 1999). Genotypes were considered fixed effects. Adjusted means (if incomplete block effects were significant) or unadjusted means (if incomplete block effects were not significant) were used to estimate general and specific combining ability effects. Line x tester analysis was calculated using the adjusted means after the check entry was omitted based on the method described by Kempthorne (1957). General combining ability (GCA) and specific combining ability effects for grain yield were calculated based on the line x tester model.

Results and discussion

Field performance of crosses The mean squares for yield and other agronomic traits are presented in Table 1. Highly significant differences were noted in grain yield and plant height. No significant difference was observed in silking date, ear diameter, and ear length. The result implies that variability exists in yield and plant height among the entries. As shown in Table 2, the yield of the entries ranged from 2.79 to 6.88 t/ha with an average yield of 4.55 t/ha. The hybrid check (P30B29) had mean yield of 3.92 t/ha. Thirty two (32) entries yielded higher than the hybrid check with yield advantages that ranged from 1.28 to 73.437%. Among the 32 entries, three entries (entry no 1, 12, and 37) had yield potential over 6 t/ha with yield advantages greater than 60% over the hybrid check.

Significant differences in plant height were also observed among entries. The plant height of the entries ranged from 188.8 to 216.8 cm with an average mean of 220.7 cm. The hybrid check had plant height of 199.7 cm. No significant difference in silking date, ear diameter, and ear length was detected among entries evaluated.

Table 2. Grain yield and other agronomic traits of 45 maize crosses.

Crosses	Means1/					
	Grain Yield (t/ha)	Plant Height (cm)	Silking Date (cm)	Ear Diameter (cm)	Ear Length (cm)	
1. CL 04368 x CML 247	6.66	207.9	54.2	3.0	13.6	
2. CML 274 x CML 247	4.79	197.9	54.1	2.9	11.0	
3. CLRW x CML 247	2.92	204.4	55.2	3.0	9.3	
4. P22 C1-126 x CML 247	2.79	199.6	54.9	3.0	9.9	
5. P22 C1-29-13 x CML 247	3.05	202.4	53.3	3.0	11.9	
6. SMWL 010 x CML 247	4.58	198.1	55.0	3.0	10.7	
7. SMWL 010 x CML 254	5.68	203.7	54.6	3.0	13.4	
8. CML 147 x CML 254	4.29	207.6	55.5	3.0	11.8	
9. P22 C1-126 X CML 254	5.12	196.2	55.6	3.0	11.3	
10. CLRC 46 x CML 254	4.57	205.4	56.2	3.0	11.7	
11. CML 490 x CML 247	4.09	203.5	53.8	3.0	11.5	
12. CL 04368 x CML 254	6.64	214.2	52.2	3.0	11.5	
13. CML 274 x CML 254	4.09	197.4	53.4	3.0	12.4	
14. CML 176 x CML 247	5.40	209.7	53.4	3.0	12.4	
15. CLRCW 11 x CML 247	4.07	209.5	54.9	3.0	10.9	
16. CLFAW 11 x CML 247	5.29	211.2	58.0	3.0	10.1	
17. P22-C1- 24-13 x CML 247	4.51	192.9	58.5	2.9	8.3	
18. P22 C1-235 x CML 247	5.74	214.8	57.0	3.0	11.4	
19. P22 C1-235 x CML 254	4.35	207.4	56.0	3.0	12.0	
20. CLFAW 11 x CML 254	4.76	206.2	57.5	3.0	11.5	
21. CLRCW 11 x CML 254	4.43	194.2	56.0	3.0	12.3	
22. CML 176 x CML 254	3.86	213.1	57.2	3.0	10.7	
23. CML 490 x CML 254	3.89	216.8	57.2 57.9	3.0	14.0	
24. CL 06369 x CML 247	5.39	201.3	56.0	2.9	10.8	
25. CL 04374 x CML 247	2.73	187.3	56.2	2.9	11.1	
26. P22 C1-269 x CML 247	5.27	208.8	55.4	3.0	10.0	
27. CL 04374 x CML 254	4.77	209.5	55.3	3.0	9.2	
28. CL 04362x CML 247	5.82	210.4	56.6	3.0	10.6	
29. CL 04362x CML 254	4.00	188.8	56.5	3.0	10.0	
30. CML 407 x CML 254	5.83	198.2	58.0	3.0	9.6	
31. P22 C1-269 x CML 254	5.37	202.5	58.1	3.0	10.1	
32. CML 407 x CML 247	5.62	203.6	56.1	3.0	10.7	
33. CL 06369 x CML 254	3.72	190.9	55.6	3.0	11.3	
34. CML 268 x CML 247	3.67	198.1	55.1	3.0	10.2	
35. CML 268 x CML 254	3.75	191.0	54.9	3.0	11.1	
36. CML 147 x CML 247	3.19	206.9	55.7	2.9	9.1	
37. CML 476 x CML 254	6.80	201.8	56.3	3.0	10.2	
38. P22 C1-29-13 x CML 254	4.62	199.8	53.3	3.0	9.6	
39. P22 C1-29-13 x CML 254	3.38	205.1	55.6	3.0	11.1	
40. CML 264 x CML 254	3.30 4.32	205.1	55.6 57.2	3.0	11.1	
41. CML 476 x CML 247		205.3 194.8			11.5 11.0	
41. CML 476 x CML 247 42. CML 264 x CML 247	3.71 3.49		54.6	3.0	10.2	
43. CML 247 x CML 254	3.49 4.83	201.6	54.6 57.0	3.0	10.2	
44. CML 254 x CML 254		198.5		3.0		
44. CML 254 x CML 247 45. P30B29	5.00 3.97	203.3 197.7	56.0 55.5	3.0 3.1	10.8 11.7	
4J. FJUDZ9	J.81	191.1		ა. ו	11./	
MEAN	4.55	202.7	55.6	3.0	11.0	
LSD(α= 0.05)	2.03	13.1	-	-	-	
CV(%)	17.35	4.0	3.6	1.6	14.2	
	17.55	T.0	<u> </u>	1.0	17.4	

^{1/} average of three replications.

Line x tester analysis Among the five traits studied, only the grain yield was subjected to combining ability analysis. Table 3 shows the line x tester analysis for grain yield. Highly significant differences in grain yield were noted among crosses contributing 58% genetic variation of the total variation. No significant interaction effect was observed between tester x line. Similarly, no significant difference was observed between testers.

However, significant difference was noted among lines.

Mean value and estimates of GCA and SCA effects for grain yields of the inbred lines are presented in Table 4. The average grain yield of the 21 inbred lines crossed to tester CML 254 was 4.68 t/ha and 4.42 t/ha when crossed to tester CML 247. The mean grain yield

Table 3. Line x tester analysis for grain yield.

Source of Variations	df	SS	MS	F-test	P-value
Rep Crosses Lines (L) Testes (T) LxT	2 41 20 1 20	26.59 133.24 77.52 0.13 55.58	13.293 3.250 3.876 0.133 2.779	7.94 1.94 2.32 0.08 1.66	0.006 0.004 0.778 0.058
Error	82	137.27	1.674		

varied from 3.72 to 6.80 t/ha for testcrosses of CML 254 and from 2.72 to 6.66 t/ha CML 247 testcrosses. Six CML 254 and 8 CML 247 test crosses had significantly higher grain yield than the hybrids (CML 247 x CML 254 and its reciprocal cross) between the two testers (4.92 t/ha). The yield advantages of these hybrids over that of CML 247 x CML 254 varied from 4.07 to 38.21%.

Classifying inbred lines into heterotic groups In classifying inbred lines into heterotic groups, we followed the Menker's et al (2004) criteria with some modifications. The combining ability effects and mean grain yield of the inbred lines when crossed to flint and dent testers were used as the bases in classifying the lines into heterotic groups. Inbred lines showing positive SCA effect with dent tester (A) but having negative SCA effects with flint tester (B) and with test cross mean yields equal to or greater than the mean yield of the hybrid of testers were placed into the heterotic A group. Similarly, inbred lines displaying positive SCA effect with tester B but having negative SGA effects with tester A and with test cross mean yields equal to or greater than the mean yield of the hybrid of testers were put into the heterotic B group. Inbred lines exhibiting both positive SCA effects with both testers and with test cross mean yields equal to or greater than the mean yield of the hybrid of testers were assigned into the heterotic AB group.

Of the 21 inbred lines, only 9 lines had positive GCA effects for grain yield (Table 4). Three lines had positive GCA effects but only one line (CL 04368) had

significant GCA effect (0.70). In a recent study, this line was reported to be low N stress tolerant (Jaspe and Magulama 2007). Three inbred linesthat showed positive SCA effects with tester CML 254 and with test cross mean yield equal to or a greater than the mean yield of the CML 247 x CML 254 were placed into the CML 254 (A) heterotic group. Five inbred lines were placed into CML 247 (B) group since they had positive SCA effects with tester CML 247 with test cross mean yields higher than the mean of the CML 247 x CML 254. Further, 3 inbred lines were assigned to both AB group since they had positive GCA effects with higher mean yield is both test crosses than the CML 247 x CML 254. Ten inbred lines were unclassified since the mean yield was lower the mean yield of the hybrid of the two testers.

The results suggest that the inbred lines evaluated in this study interacted positively for grain yield with the genetic background of the two testers. The testers were able to classify 11 to 21 tested inbred lines into two heterotic groups based of SCA effects and test cross mean grain yield. The grouping was not related to the endosperm type of the inbred lines. As indicated by Messmer et al (1992), it is no longer possible to classify lines as flint or dent based on endosperm type alone because new generations of lines with mixed origin are becoming available and breeders are attempting to eliminate the weaknesses of the flint germplasm by introducing dent germplasm.

Table 4. Mean grain yield (t/ha), general and specific combining ability (GCA and SCA) effects, and heterotic group of 21 white maize inbred lines.

Lines	crosses	Testers CML 254 CML 247		Means	GCA Effects	SCA Effects Based on		Heterotic
		A Grp	B Grp			A	В	Group
1	CLRW 46	4.57	2.92	3.75	-0.268	0.232	-0.232	-
2	P22 C1-29-13	4.62	3.05	3.84	-0.238	0.218	-0.218	-
2 3	CL 04374	4.77	2.73	3.75	-0.266	0.297	-0.297	-
	CML 147	4.29	3.19	3.74	-0.269	0.140	-0.140	-
5	CLRCW 11	4.43	4.07	4.25	-0.099	0.017	-0.017	-
4 5 6 7	CML 264	4.32	3.49	3.91	-0.214	0.095	-0.095	-
7	CML 268	3.75	3.67	3.71	-0.279	-0.030	0.030	-
8 9	CML 490	3.89	4.09	3.99	-0.186	-0.077	0.077	-
9	P22 C1-24-13	3.38	4.51	3.95	-0.201	-0.232	0.232	-
10	CML 274	4.09	4.79	4.44	-0.036	-0.160	0.160	-
11	P22 C1-126	5.12	2.79	3.96	-0.198	0.345	-0.345	Α
12	SMWL 010	5.68	4.58	5.13	0.194	0.140	-0.140	Α
13	CML 476	6.80	3.71	5.26	0.236	0.472	-0.472	A
14	CL 04362	4.00	5.82	4.91	0.121	-0.347	0.347	В
15	CML 176	3.86	5.40	4.63	0.027	-0.300	0.300	В
16	CLFAW11	4.76	5.29	5.03	0.159	-0.132	0.132	B B B B
17	P22 CL235	4.35	5.74	5.05	0.166	-0.275	0.275	В
18	CL 06369	3.72	5.39	4.56	0.002	-0.322	0.322	В
19	CML 407	5.83	5.62	5.73	0.392	-0.008	0.008	AB
20	P22-C1-269	5.37	5.27	5.32	0.257	-0.027	0.027	AB
21	CL 04368	6.64	6.66	6.65	0.701	-0.470	0.470	AB
22	CML 247	4.83	-					
23	CML 254	-	5.00	0.07				
24	P30B29 (Check Hybrid)	4.60	-	3.97				
		4.68	4.42					

Summary and conclusion

Significant general and specific combining ability effects were detected among the inbred lines. Line CL 03468 was identified as good general combiner among the 21 inbred lines. Three crosses were noted to have good specific combining ability effects, namely: CL 03468 x CML 247, CL 03468 x CML 254, and CML 476 x CML 254. Of the 21 inbred lines tested, the tester inbred lines assigned the 11 inbred lines into two heterotic groups. Our findings further support the use of SCA effects and test crosses mean yield as major criteria for classifying inbred lines.

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