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Evaluation of Improved Maize Populations and Their Diallel Crosses for Yield

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ABSTRACT

Broadening the genetic base and increasing the yield potential of maize breeding populations are of prime importance to maize breeders. One potential source is the use of exotic germplasm by incorporating exotic sources into adapted sources. The objective of this study was to evaluate the breeding potential of ten maize populations for the hybrid breeding program. Ten breeding populations, diallel crosses among the populations, and nine check hybrids were evaluated in 2008, using an 8 × 8 triple lattice at three locations. Sources of variation for entries, populations, general combining ability (GCA) and specific combining ability (SCA) were highly significant. KS23(S)C5 had the highest positive significant GCA and variety effects of all the populations tested. Suwan1(S)C14 × KS23(S)C5 had the highest yield (8.27 Mg ha^{-1}) with high-parent heterosis of 14.23%. KS23(S)C5 was also among the parents of the other top three high-yielding crosses: KS23(S)C5 × KS24(S)C3 (8.09 Mg ha^{-1}), KS6(S)C4 × KS23(S)C5 (7.79 Mg ha^{-1}), and KS23(S)C5 × KS28(S)C2 (7.75 Mg ha^{-1}). From the results, KS6(S)C4 × KS28(S)C2 had the highest high-parent heterosis (17.17%) with a yield of 7.44 Mg ha^{-1}. KS23 was superior to the other introgressed exotic maize populations and it seemed to be a new potential source in crosses with Suwan1 and derivatives of Suwan1 for the hybrid maize breeding program.
Keywords: combining ability, heterosis, maize, population, yield

INTRODUCTION

Broadening the genetic base and increasing the yield potential of the maize breeding population are of prime importance to maize breeders (Eberhart, 1971; Holley and Goodman, 1988; Mungoma and Pollak, 1988). One potential source is the use of exotic germplasm by incorporating exotic sources into adapted sources. In a tropical breeding program, the potential use of exotic germplasm especially from temperate regions has received considerable interest from maize breeders. Its use has been limited primarily because of the adverse effects of the photoperiod mask for the desirable traits of exotic germplasm. Very early flowering, susceptibility to tropical

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diseases and severe inbreeding depression are major obstacles. Since 1978, in spite of these problems, the systematic evaluation and the incorporation of exotic germplasm have been undertaken as part of the maize breeding program at Kasetsart University. Several studies have reported the usefulness of incorporating exotic germplasm into a breeding program (Eberhart, 1971; Hallauer and Miranda, 1981; Holley and Goodman, 1988; Iglesias and Hallauer, 1989; Pollak *et al*., 1991). Diallel analysis of crosses among populations has been widely used to provide a preliminary analysis to determine the relative potential of populations as breeding populations in hybrid breeding program (Hallauer and Miranda, 1981). In general greater genetic diversity is related to greater heterotic values (Lonnquist and Gardner, 1961; Hallauer and Eberhart, 1966; Troyer and Hallauer, 1968). Moreover, Moll *et al*. (1965) reported that heterosis would increase, but only within a limited range of divergence. The objective of this study was to evaluate the breeding potential of ten maize populations for the hybrid breeding program.

MATERIALS AND METHODS

In 2007, a diallel set was produced among 10 populations. The populations represented a range of diverse germplasm developed by the maize breeding project of the National Corn and Sorghum Research Center (Suwan Farm), Kasetsart University. The 10 populations included in the diallel set were:

1. Suwan1(S)C14 is a population developed after 14 cycles of S_1 recurrent selection. Suwan1 is a downy-mildew-resistant version of Thai Composite 1. The resistance was incorporated from Philippine DMR 1 and Philippine DMR 5. Thai Composite 1 included the largest group of materials from several races collected on the Caribbean Islands, six collections from Mexico representing the elite race Tuxpeno, and material from Central America. Five collections were from South America and a few racial complexes were represented by Caribbean-Tuxpeno-India-USA.

2. Suwan3(S)C7 is a population developed after seven cycles of S_1 recurrent selection. Suwan3 was developed by intermating 30 S_1 lines of Suwan1(S)C8 and 20 S_1 lines of KC1(ME)C3. Suwan3 contains 20% of sub-tropical germplasm.

3. Suwan5(S)C6 is a population developed after six cycles of S_1 recurrent selection. Suwan5 was developed by intermating 60 full sib lines from five elite populations namely, Suwan1(S)C9, Caripeno DMR (S)C5, Thai Composite3(S)C5, Cupurico Flint Compuesto DMR (S)C2 and Amarillo Dentado (F)C5.

4. KS6(S)C4 is a population developed after four cycles of S_1 recurrent selection. KS6 was developed by intermating 40 S_1 lines of Caripeno DMR(S)C4, Amarillo Dentado DMR, Suwan DMR Source 11, and Suwan DMR Source 12.

5. KS23(S)C5 is a population developed after five cycles of S_1 recurrent selection. KS23 was a broad base synthetic developed by intermating 26 inbred lines which combined well with a strain of Suwan1. KS23 contains approximately 35% temperate germplasm and was designed to be a counterpart of Suwan1 in the hybrid breeding program.

6. KS24(S)C3 is a population developed after three cycles of S_1 recurrent selection. KS24 was developed by intermating strains of Suwan1 and Suwan3 that expressed a high combining ability with KS23.

7. KS26(S)C1 is a population developed after one cycle of S_1 recurrent selection. KS26 was developed by crossing collections of the Tuxpeno race and improved populations of the Corn Belt Dent race. KS26 was synthesized to provide a germplasm source which contained 50% of temperate germplasm.

8. KS27(S)C3 is a population devel-

oped after three cycles of S_1 recurrent selection. KS27 was developed by intermating strains of Caripeno DMR.

9. KS28(S)C2 is a population developed after two cycles of S_1 recurrent selection. KS28 was developed by crossing 16 non-Suwan1 inbred lines with Tuxpeno-1 Selection Sequia DMR.

10. KC15 is a population developed by crossing highland germplasm with temperate germplasm. KC15 was synthesized to provide a germplasm source that contained 100% exotic germplasm.

The 10 populations, 45 population crosses and nine hybrid checks were evaluated in an 8 × 8 triple lattice. In 2008, the plants were grown at three locations. Plant density was about 66,666 plants per hectare. The plots consisted of two rows each 5 m long, with 0.75 m between rows. Plots were overplanted and thinned to the desired plant density. Fertilizer was applied and weed control was practiced at each location based on recommendations for optimum yield production. Grain yield at 15% moisture content was estimated and expressed as Mg ha^{-1}. The efficiency of the lattice analysis relative to a randomized complete block analysis was minimal. Therefore, combined analysis of variance was computed with the unadjusted entry means from each location. The genetic information on the populations was obtained using "Analysis III" suggested by Gardner and Eberhart (1966).

RESULTS AND DISCUSSION

The combined analysis of the mean data showed significant differences among entries and significant entries by location interaction (Table 1). The population means per se ranged from 3.89 Mg ha^{-1} for KC15 to 7.24 Mg ha^{-1} for KS23(S)C5 (Table 2). The lowest-yielding population was the material which contained 100% exotic germplasm with the least selection during improvement. KC15 and KS26(S)C1 had negative significant variety effects, indicating that their yields were lower than the average population yield. The significantly positive values of variety effects demonstrated by KS23(S)C5, Suwan5(S)C6,

Table 1 Mean squares from Gardner and Eberhart (1966)'s population cross diallel Analysis III (Gardner and Eberhart, 1966) of yield from ten populations and their 45 diallel crosses tested at three locations in 2008.

Source of variation	df	Yield
		Mg ha^{-1}
Locations	2	715.37**
Locations × Rep.	6	1.71**
Entries	54	0.51**
Populations	9	0.87**
Populations vs Crosses	1	5.71**
Crosses	44	0.31**
General (GCA)	9	1.24**
Specific (SCA)	35	0.08**
Locations × Entries	108	0.84**
Residual	324	0.04
Total	494	3.97
C.V. (%)		10.4

Note: *, ** significant at P = 0.05 and 0.01, respectively.

Table 2 Yield (above diagonal) and specific combining ability effects (below diagonal) for the 45 population crosses, and yield (on diagonal), general combining ability, and variety effects for each of the ten populations per se tested at three locations in 2008.

Populations	SW 1 (S)C14	SW 3 (S)C7	SW 5 (S)C6	KS 6 (S)C4	KS 23 (S) C5	KS 24 (S) C3	KS 26 (S) C1	KS 27 (S) C3	KS 28 (S) C2	KC 15	General combining ability effects(g_i)	Variety effects (v_i)
	Mg ha^{-1}											
SW 1 (S) C14	<u>6.84</u>	7.27	7.54	7.46	8.27	6.87	7.25	7.93	7.59	6.55	0.29**	0.52**
SW 3 (S) C7	-0.28	<u>6.55</u>	7.15	7.33	7.59	7.19	7.25	7.65	7.13	6.59	0.09	0.23
SW 5 (S) C6	0.25	-0.17	<u>6.96</u>	6.84	7.47	7.49	7.17	7.27	7.48	6.49	0.07	0.64**
KS 6 (S) C4	0.05	0.12	-0.34*	<u>6.27</u>	7.79	7.22	6.59	7.18	7.44	6.19	-0.04	-0.05
KS 23 (S) C5	0.26	-0.22	-0.31*	0.12	<u>7.24</u>	8.09	7.58	7.50	7.75	6.83	0.56**	0.92**
KS 24 (S) C3	-0.59**	-0.07	0.26	0.09	0.36*	<u>6.67</u>	7.11	7.12	7.24	6.14	0.01	0.35*
KS 26 (S) C1	0.05	0.25	0.20	-0.27	0.12	0.19	<u>5.93</u>	7.23	6.95	5.23	-0.25**	-0.39*
KS 27 (S) C3	0.34*	0.26	-0.09	-0.07	-0.36*	-0.19	0.19	<u>6.46</u>	6.99	6.63	0.14*	0.14
KS 28 (S) C2	0.09	-0.17	0.21	0.28	-0.01	0.03	-0.01	-0.35*	<u>6.35</u>	6.19	0.05	0.03
KC 15	0.04	0.28	0.21	0.02	0.06	-0.09	-0.73**	0.28	-0.07	<u>3.89</u>	-0.94**	-2.43**

Note:

*, ** significant at $P = 0.05$ and 0.01, respectively.

LSD (0.05) for population cross yields is 1.38 Mg ha^{-1}.

SE (g_i) = 0.07

SE (S_{ij}) = 0.18

Suwan1(S)C14 and KS24(S)C3 indicated that they were promising breeding material for selecting desirable genotypes by recurrent selection. Significance at P = 0.05 and 0.01, is indicated below by * and **, respectively. KS23(S)C5 had the largest GCA effect (0.56**), indicating a high frequency of favorable alleles. The other populations with positive significant GCA effects were Suwan1(S)C14 (0.29**) and KS27(S)C3 (0.14*). KS26(S)C1 and KC 15 had negative significant GCA effects of –0.25** and –0.94**, respectively.

The individual cross yields ranged from 5.23 Mg ha^{-1} for KS26(S)C1 × KC15 to 8.27 Mg ha^{-1} for Suwan1(S)C14 × KS23(S)C5 (Table 2). The greater individual cross yields also included KS23(S)C5 × KS24(S)C3 (8.09 Mg ha^{-1}), Suwan1(S)C14 × KS27(S)C3 (7.93 Mg ha^{-1}), KS6(S)C4 × KS23(S)C5 (7.79 Mg ha^{-1}), and KS23(S)C5 × KS28(S)C2 (7.75 Mg ha^{-1}), respectively. There were no significant differences among the top five high yielding crosses. The three populations with positive GCA effects were included as parents of top-yielding crosses. A comparison among introgressed exotic germplasm populations (KS23(S)C5, KS26(S)C1, and KC15) in population crosses with Suwan1(100% tropical) which was a widely adapted tropical variety, indicated that KC15 (100% exotic) gave the lowest yielding cross. On the other hand, KS23(S)C5 (35% exotic) gave the highest yielding cross. The results might indicate that the proportion of exotic germplasm to be incorporated into adapted germplasm was important for increasing genetic diversity in the hybrid breeding program. Bridges and Gardner (1987) indicated that the optimum proportion of exotic germplasm to be incorporated differs from short-term and long-term selection goals, and also depends on the performance of the adapted and exotic germplasm. Two crosses had positive significant SCA effects: KS23(S)C5 × KS24(S)C3 (0.36*) and Suwan1(S)C14 × KS27(S)C3 (0.34*).

KS6(S)C4 × KS28(S)C2 had the highest high-parent heterosis (17.17 %) (Table2). The top four high-yielding crosses, (with the high-parent heterosis estimates in parentheses) were: Suwan1(S)C14 × KS27(S)C3 (15.94%), Suwan1(S)C14 × KS23(S)C3 (14.23%), KS23(S)C5 × KS24(S)C3 (11.74%), and KS6(S)C4 × KS23(S)C5 (7.60%). This study showed that exotic germplasm, especially from the temperate region, could be incorporated into adapted tropical germplasm to increase genetic diversity relating to the increment of yield potential of tropical maize. The research indicated that KS23 was superior to the other introgressed exotic maize populations. It seemed that KS23 was a new potential source in crosses with Suwan1 and derivatives of Suwan1 in the hybrid maize breeding program.

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