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Potential Lines and Hybrids Developed from Modified Reciprocal Recurrent Selection in Maize

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ABSTRACT

A single-cross hybrid is the ultimate commercial product from maize breeding programs. Modified reciprocal recurrent selection (MRRS) is an alternative selection method for inbred and hybrid development. The objectives of this study were to assess lines and hybrids developed from MRRS in Suwan1(S)C11 and KS6(S)C3 maize populations with inbred testers Ki 47 and Ki 46, respectively. Twenty-five S_4 lines, which corresponded to the 25 top-yielding testcrosses from 250 S_1 testcrosses with inbred tester in each C0 population, were used to produce 50 testcross hybrids with their inbred tester. Ten S_4 lines, which corresponded to the 10 top-yielding testcrosses, were also used in a factorial cross to make 100 interpopulation hybrids. The 150 hybrids and their 50 S_5 lines were evaluated separately at two locations. The results indicated that the 10 top-yielding hybrids were five from Suwan1(S)C11-S_4 × Ki 47, two from KS6(S)C3-S_4 × Ki 46 and three from interpopulation hybrids with significantly higher ($P < 0.05$) grain yield than the hybrid check, Suwan 3851, by two, one and two hybrids, respectively. In addition, three hybrids from Suwan1(S)C11-S_4 × Ki 47 had highly significant ($P < 0.01$) grain yield. The top 10 hybrids had similar values to the check for average days to 50% anthesis and silking, root and stalk lodging, foliar diseases and grain shelling, but had higher plant and ear heights. Parental lines of the top 10 hybrids were seven lines from Suwan1(S)C11 and four lines from KS6(S)C3. Their S_5 lines, which had yields as high as the inbred check Ki 47, were five and three lines, respectively. In addition, the lines were not different from the check in other agronomic traits, except for days to flowering and plant height. In conclusion, the MRRS program was effective for the development of potential lines and hybrids for further commercial hybrid production.

Keywords: modified reciprocal recurrent selection (MRRS), inbred tester, testcross, lines, hybrids

INTRODUCTION

Reciprocal recurrent selection (RRS) was originally proposed by Comstock *et al*. (1949) for improvement of commercial hybrids in diploid organisms. However, RRS is not as efficient for recovery of inbred lines as other methods of inbred development (Russell and Eberhart, 1975). Russell

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and Eberhart (1975) proposed a modified RRS (MRRS) as an alternative to RRS to overcome this limitation. For MRRS, inbred lines derived from the opposite populations are used as testers, instead of the population themselves. Lambert (1984) found a significant response for grain yield in population cross improved by MRRS. Landi and Frascaroli (1995) reported that heterosis of population cross was improved by MRRS, which was highly significant for grain yield and for sowing-silking interval. Menz Rademacher *et al*. (1999) also found the increase in grain yield of population cross was improved by MRRS. The objectives of this study were to evaluate lines and hybrids developed from MRRS in Suwan1(S)C11 and KS6(S)C3 maize populations, with inbred testers Ki 47 and Ki 46, respectively.

MATERIALS AND METHODS

Genetic material

Suwan1(S)C11 and KS6(S)C3 populations, designated as AC0 and BC0, with inbred testers Ki 47 and Ki 46, respectively, were used to initiate MRRS. Suwan1(S)C11 was developed from Thai Composite #1 DMR BC_3(S)C2 or Suwan1(S)C0 (a composite of 36 germplasm sources and two sources of downy mildew resistance with high yield, Philippine DMR 1 and 5), and was improved for grain yield and corn downy mildew resistance by 11 cycles of S_1 recurrent selection (Sriwatanapongse *et al*., 1993). KS 6 was developed to provide a population containing tropical germplasms which differed from Suwan 1. It was synthesized from 40 S_1 lines derived from four composite varieties. KS6(S)C3 was improved for grain yield and corn downy mildew resistance by three cycles of S_1 recurrent selection (Jampatong, 1994). Ki 46 is a commercial inbred line derived from Suwan1(S)C10 (Aekatasanawan *et al*., 2001a). Ki 47 is a commercial inbred line derived from KS6(S)C3 (Aekatasanawan *et al*., 2001b). Suwan 3851 is a commercial hybrid that was included in this study as a check; it is a single-cross hybrid obtained from the cross between Ki 46 and Ki 45. It was released to the public and private sectors in 1997 (Aekatasanawan *et al*., 1998).

For each C0 population, approximately 5,000 plants were grown and those that had good agronomic traits were selfed to give respective populations of AC0-S_1 and BC0-S_1, which were then crossed with the corresponding testers. In 2001, during the late rainy season, 250 C0 testcrosses (TC) for each population and six hybrids were evaluated at the National Corn and Sorghum Research Center (Suwan Farm). The entries were evaluated in a 16 × 16 simple lattice design using single-row plots, 5 m long with 0.75 m between rows and 0.25 m between hills. The progenies were selected for grain yield and other important traits, such as foliar diseases and root and stalk lodging. On the basis of the results of the testcross evaluations, 25 top-yielders of testcrosses in each group were identified and their 25 S_2 lines were recombined to form each C1 population. The corresponding S_4 lines of the testcrosses were used to produce 50 testcross hybrids (25 AC0-S_4 × Ki 47 and 25 BC0-S_4 × Ki 46). In addition, the corresponding S_4 lines of the 10 testcrosses having the top-yield ranking in each group were crossed in 10 AC0-S_4 × 10 BC0-S_4 to produce 100 interpopulation hybrids. The lines from AC0 and BC0 were used as female and male parents, respectively. The selected 25 S_4 lines developed from each population were generated to S_5.

Evaluation and field procedures

The 50 C0 testcross hybrids, 100 C0 interpopulation hybrids and six hybrids were evaluated in the late rainy season of 2002 at two locations, Suwan Farm and the Nakhon Sawan Field Crops Research Center (NSWFCRC). The two sites are located in northeastern and northern Thailand, respectively. The 156 entries were

evaluated in a 12 × 13 simple rectangular lattice design using two-row plots, 5 m long with 0.75 m between rows and 0.25 m between hills. The experiments were overplanted and thinned to one plant per hill. The 50 C0-S_5 lines and six inbred lines were evaluated in the same season and at the same locations as the hybrids. The 56 entries were evaluated in a 7 × 8 triple rectangular lattice design using two-row plots, 5 m long with 0.75 m between rows and 0.20 m between hills. Conventional fertilization and weed control practices were used at the recommended rates at each location for optimum grain production. All plots were hand-harvested with gleaning of dropped ears.

Data were collected from all experiments on a plot basis for: 1) the number of days to 50% anthesis and silking, based on the number of days from planting to 50% of plants shedding pollen and to 50% of plants with visible silks, respectively; 2) plant and ear heights, based on the distance in cm from the soil surface to the node of the flag leaf and to the highest ear-bearing node, respectively; 3) foliar diseases, based on a rating score (1-5) for important diseases, such as southern corn leaf blight (*Bipolaris maydis* (Nisik.) Shoemaker), northern corn leaf blight (*B. turcica* (Pass.) Shoemaker) and southern rust (*Puccinia polysora* Underw.), where 1 indicates no diseases and 5 indicates very heavy infection; 4) stalk lodging, based on % of plants broken at ear node or below; 5) root lodging, based on a rating score (1-5) of plants leaning 30° or more from vertical, where 1 indicates no plants leaning 30° and 5 indicates all plants leaning 30° or more; 6) grain shelling (%); and 7) grain yield, based on a conversion to kg ha^{-1} adjusted to 15% grain moisture.

Statistical analysis

The data collected for the nine traits were analyzed for each individual location according to a 12 × 13 simple rectangular lattice design for the C0 hybrids and a 7 × 8 triple rectangular lattice design for the C0 lines using PROC LATTICE of the SAS software package, version 9.0 (SAS Institute, 2002). The combined analyses of variance of data across the two locations were analyzed using adjusted entry means from the derived data at each location, using PROC GLM of SAS, version 9.0 (SAS Institute, 2002).

RESULTS AND DISCUSSION

Means for grain yield and other agronomic traits of the 10 top-yielding hybrids developed from C0 are shown in Table 1. The top 10 hybrids included both testcross hybrids and interpopulation hybrids. The testcross hybrids were predominant, especially testcross hybrids from Suwan1(S)C11-S_4 × Ki 47 indicating that superior lines developed from the improved populations of MRRS could be used immediately to produce hybrids with the inbred testers, if the testers are elite lines being used in commercial hybrid production (Horner *et al*., 1972; Russell *et al*., 1992; Menz Rademacher *et al*., 1999). Mean grain yield of the top 10 hybrids ranged from 6,873 to 7,790 kg ha^{-1} or 118 to 133% compared with the hybrid check, Suwan 3851. Grain yield of eight out of the top 10 hybrids was significantly different from the check. Three and two testcross hybrids from Suwan1(S)C11-S_4 × Ki 47 were significant at $P < 0.01$ and $P < 0.05$, respectively. One and two hybrids from KS6(S)C3-S_4 × Ki 46 and interpopulation hybrids, respectively, were significant at $P < 0.05$. Average days to 50% anthesis and silking, root and stalk lodging, foliar diseases and grain shelling of the top 10 hybrids were not different from the check. However, average plant and ear heights of the hybrids were significantly higher than the check at $P < 0.01$.

Lines which were components of the top 10 hybrids included seven lines from Suwan1(S)C11 and four lines from KS6(S)C3 (Table 2). Five lines from Suwan1(S)C11 and three lines from KS6(S)C3 had grain yields that were

Table 1 Means for grain yield and other agronomic traits of the 10 top-yielding hybrids developed from C0 compared with the hybrid check, Suwan 3851, from data combined over two locations in the late rainy season of 2002.

Entry[1]	Grain yield at 15% moist.	Relative to check	Days to 50%		Height		Lodging		Foliar dis.	Grain shell.
			Ant.	Silk.	Plant	Ear	Stalk	Root		
	kg ha^{-1}	%	——— d ———		——— cm ———		%	——— (1-5) ———		%
AC0-S_4-88 × Ki 47	7,790	133	56	56	223	119	1	1.2	3.1	80.57
AC0-S_4-72 × Ki 47	7,471	128	57	57	235	132	1	2.1	3.1	82.06
AC0-S_4-96 × Ki 47	7,410	127	57	57	224	111	0	1.9	3.1	83.12
AC0-S_3-180 × Ki 47	7,105	122	56	57	206	111	0	1.9	3.0	80.93
AC0-S_4-159 × BC0-S_4-250	7,074	121	57	57	229	115	1	1.9	3.4	81.75
BC0-S_4-90 × Ki 46	6,991	120	56	56	221	110	4	2.2	3.3	80.33
AC0-S_4-228 × Ki 47	6,927	119	56	56	221	111	3	1.8	3.2	81.94
AC0-S_4-204 × BC0-S_4-47	6,923	118	56	57	225	111	3	2.0	3.2	78.99
AC0-S_4-159 × BC0-S_4-47	6,878	118	56	57	222	107	12	1.3	3.2	80.40
BC0-S_4-296 × Ki 46	6,873	118	57	58	217	103	0	1.6	3.1	80.01
Mean	7,144	122	56	57	222	113	2	1.8	3.2	81.01
Hybrid checks										
KSX 4451	6,090	104	55	56	208	111	1	2.0	3.1	78.80
KSX 4452 (Suwan 4452)	7,618	130	56	57	206	115	0	1.5	2.9	81.27
KSX 4453	6,477	111	56	57	206	106	0	1.9	3.1	77.94
BIG 949	5,975	102	56	57	204	96	0	1.6	2.9	80.62
PIONEER 30A30	6,419	110	54	54	197	97	0	1.3	3.1	83.47
Suwan 3851 (Check)	5,845	100	55	56	193	101	2	1.9	3.2	79.20
Mean	6,404	110	55	56	202	104	1	1.7	3.1	80.22
CV (%)	8.99		1.04	1.12	3.15	3.97	135.94	15.48	6.40	1.42
LSD 0.05	1,047.70		1.16	1.26	13.42	8.43	4.72	0.57	0.40	2.23
LSD 0.01	1,383.20		1.53	1.66	17.72	11.13	6.23	0.76	0.53	2.94

[1] AC0 and BC0 = Suwan1(S)C11 and KS6(S)C3, respectively. Some S_3 lines were used if S_4 lines were not available.

not significantly different from the inbred check, Ki 47. Another line from Suwan1(S)C11 also had high yield that was not significantly different from Ki 46, the inbred tester derived from Suwan1(S)C10. The seven lines from Suwan1(S)C11 had grain yields that ranged from 1,054 to 3,693 kg ha^{-1} or 34 to 118% compared with the check. They also had agronomic traits, such as ear height, root and stalk lodging, foliar diseases and grain shelling, that were similar to the check, but had significantly more days to 50% anthesis and silking ($P < 0.01$) and higher plant height ($P < 0.05$). The four lines from KS6(S)C3 had grain yields that ranged from 948 to 2,786 kg ha^{-1} or 30 to 89% compared with the check. They had other agronomic traits similar to the check, with the exception of significantly more days to 50% silking ($P < 0.01$). In addition, other lines with yields as high as for the check were also obtained from the selection program (data not shown). The lines included 10 lines from Suwan1(S)C11 (1,952 to 2,909 kg ha^{-1}) and seven lines from KS6(S)C3 (1,982 to 3,280 kg ha^{-1}). The results revealed that the 25 S_4 lines for hybrid testing and the 25 S_5 lines for line testing per se from each C0 population were potential lines and hybrids for commercial hybrid production, because these lines were derived from the lines used for recombination to form each C1 population.

The performance and traits of the resulting hybrids and lines developed from the selection program indicated that potential lines and hybrids can be developed from MRRS for commercial hybrid production. MRRS is a useful recurrent selection scheme for supplementing line development (Hallauer and Miranda, 1988; Agrawal, 1998) and for hybrid production.

CONCLUSION

The MRRS program is effective for the

Table 2 Means for grain yield and other agronomic traits of the C0-S_5 lines, which were components of the 10 top-yielding hybrids, compared with the inbred check, Ki 47, from data combined over two locations in the late rainy season of 2002.

Entry[1]	Grain yield at 15% moist.	Relative to check	Days to 50%		Height		Lodging		Foliar dis.	Grain shell.
			Ant.	Silk.	Plant	Ear	Stalk	Root		
	kg ha^{-1}	%	——— d ———		——— cm ———		%	——— (1-5) ———		%
Suwan1(S)C11-S_4-180	3,693	118	62	63	145	72	2	1.7	3.3	83.13
Suwan1(S)C11-S_5-72	3,160	101	60	62	192	95	1	2.1	3.7	75.86
Suwan1(S)C11-S_5-159	2,785	89	60	62	158	66	3	1.4	3.4	74.49
Suwan1(S)C11-S_5-204	2,198	70	62	63	173	85	3	2.6	3.6	75.09
Suwan1(S)C11-S_5-96	2,053	66	62	64	162	59	5	2.1	3.8	78.01
Suwan1(S)C11-S_5-228	1,711	55	61	61	160	64	2	2.0	3.6	72.83
Suwan1(S)C11-S_5-88	1,054	34	62	65	163	83	3	1.5	3.6	68.95
Mean	2,379	76	61	63	165	75	3	1.9	3.6	75.48
KS6(S)C3-S_5-296	2,786	89	57	60	158	70	2	1.5	3.5	78.11
KS6(S)C3-S_5-90	2,287	73	60	62	168	81	1	1.7	3.2	77.43
KS6(S)C3-S_5-250	1,863	59	60	63	149	72	2	2.0	3.9	80.33
KS6(S)C3-S_5-47	948	30	60	64	147	62	1	1.8	3.9	56.24
Mean	1,971	63	59	62	155	71	1	1.7	3.6	73.03
Inbred checks										
Ki 44	2,374	76	58	59	118	53	2	1.2	3.8	81.76
Ki 45	2,380	76	60	61	119	61	4	2.0	3.6	83.66
Ki 46	2,970	95	56	56	141	56	0	1.3	3.7	77.93
Kei 0101	1,642	52	59	63	140	66	0	1.9	3.3	71.50
Ki 48	2,866	91	58	60	140	61	1	1.4	3.7	68.00
Ki 47 (Check)	3,134	100	56	56	142	70	7	1.4	3.7	81.14
Mean	2,561	82	58	59	133	61	2	1.5	3.6	77.33
CV (%)	34.13		2.42	2.54	6.41	8.84	141.89	15.44	5.88	6.50
LSD 0.05	1,322.80		2.88	3.13	19.83	12.38	10.23	0.56	0.43	9.74
LSD 0.01	1,761.20		3.83	4.17	26.40	16.48	13.62	0.75	0.57	12.97

[1] Some S_4 lines were used if S_5 lines were not available.

development of potential lines and hybrids for further commercial hybrid production.

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