

Study of Maize Populations Contained Different Proportions of U.S. Corn Belt Germplasm

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ABSTRACT

The incorporation of exotic germplasm into tropical breeding materials can broaden and diversify the genetic base of the tropical maize, and also adding more desirable alleles. For effective utilization of the exotic germplasm, choice of exotic source and efficient method of incorporation of exotic germplasm into tropical material is needed. This study was conducted to assess a genetic potential and the effectiveness of different types of exotic germplasm introduced from U.S. Corn Belt in combination with tropical breeding materials. The results of the study implied: commercial hybrid was the most promising source to improve performance of the tropical inbred lines followed by Non-BSSS inbred lines and BSSS "Iowa Stiff Stalk Synthetic" inbred lines. Semi-exotic population with 50% exotic showed significantly lower grain yield, earlier days to silking and anthesis, lower grain moisture content and higher leaf disease infection than 25 and 12.5 % exotic. On the other hand, no significant difference was observed between 25 and 12.5 % exotic. Semi-exotic populations with 25 and 12.5 % commercial exotic hybrid also showed grain yield higher than the corresponding tropical population but were not statistically different to the best check variety "Suwan 1".

Key words: maize, exotic, germplasm, genetic diversity, population

INTRODUCTION

Commercial variety of major crops normally derived from intensive selection within only a small part of the total genetic resources available (Rasmusson and Phillips, 1997; Troyer, 1999). Normally, the most improved inbreds have been intermated and subsequently extracted for new improved inbred lines. By this breeding strategy, for short term, gain of selection appears to be high, and encourage continued breeding within narrow gene pool. For long term, on the other hand, this breeding strategy has led to a genetic gap where there is a large difference in the favorable gene frequency between the improved and unimproved

lines and narrowing of genetic diversity within elite gene pools which presumably reducing the potential of future progress of breeding program (Rasmusson and Phillips, 1997), and the associated problems of genetic vulnerability (Bridges and Gardner, 1987; Gouesnard *et al.*, 1996; Kraja *et al.*, 2000),

To increase the effectiveness of long term breeding program, maintaining and increasing an effective genetic diversity and adding more favorable alleles from other sources of germplasm are required. Exotic germplasm has been suggested as a source to increase genetic diversity and favorable alleles. In tropical area, potential resources of exotic germplasm can be temperate,

subtropical, or foreign tropical germplasm. There is a wide array of exotic germplasm available for breeding program. This exotic germplasm ranges from open-pollinated varieties, synthetics, inbred lines and hybrids.

Despite the usefulness of exotic germplasm to broaden the genetic diversity of adapted germplasm, many practical disadvantages also exist. In the tropical region, the difficulty in using exotic germplasm introduced from temperate and sub-tropical regions frequently caused by non adaptability of exotic germplasm *per se* and of it crosses with adapted sources was characterized by susceptibility to disease, insect, and heat, early flowering and senescence (Kim, 1990; Khehra *et al.*, 1986). The non adaptability of the material creates a problem in identifying superior genotypes.

Successful exploitation of exotic germplasm for improving the local germplasm required a systematic approach. Effective choosing source of germplasm, both adapted and exotic, and methods applied are very important (Hainzelin, 1998). The use of exotic germplasm in selection also requires an adaptation phase (Gouesnard *et al.*, 1996). The most common procedure has been to cross exotic with adapted germplasm (Holley and Goodman, 1988). Several generations of random mating, with or without mild selection, were recommended before the application of more stringent selection (Lonnquist, 1974; Hallauer, 1978; Hoffbeck *et al.*, 1995). Optimum proportion of exotic and adapted germplasm in the foundation population is another question needed to be considered (Dudley, 1982; Bridges and Gardner, 1987; Crossa and Gardner, 1987; Darsana and Samphantharak, 2004).

The objectives of the study were: 1) to evaluate the potential use of different types of exotic germplasm introduced from temperate region (U.S. Corn Belt) as sources of favorable alleles for improving the existing adapted maize inbred lines, 2) to determine the optimum proportion of exotic germplasm of certain region

for improving the local adapted population.

MATERIALS AND METHODS

Six tropical maize inbred lines namely Nei9008, Nei9202, AMATLCOHS 63-2-5-E-3-1-2, AMATLCOHS 170-2-3-2-1-1-B-3, Ag18, and Ki42 were chosen and intercrossed to four types of maize germplasm introduced from U.S. Corn Belt ($36^{\circ} - 45^{\circ}$ North). The four types of U.S. Corn Belt maize sources were defined as:

1. Commercial hybrids (H) consisted of 8 hybrids, namely D17117A, DK602, DK611, ISU#1, ISU#2, ISU#3, MITOS, SANTOS.
2. Open pollinated varieties (O) consisted of 5 varieties, namely BSSS(R)C6, Reid Yellow Dent, Krug, Lancaster, and Midland.
3. BSSS inbred lines (B), inbred lines generated from Stiff Stalk Synthetic developed by Iowa Experiment Station, consisted of 5 inbred lines, namely B73, B76, B79, B84 and B104.
4. Non-BSSS inbred lines (N), inbred lines which their background un-related to Stiff Stalk Synthetic, consisted of 4 inbred lines, namely B90, B91, B98, and B106.

To generate BC_0F_1 , crosses between the tropical inbred lines and the exotic groups were made in the following procedures: 1) Each of the six tropical inbred lines was crossed by bulked pollens of 5 to 7 plants from each exotic hybrid, 20 plants per tropical inbred lines. 2) Crosses between the tropical inbred lines and the open pollinated varieties (OPV) were made by collecting pollen samples from 25 plants of each variety and they were uniformly mixed before pollinated to each of tropical inbred lines, 20 plants per inbred line. The same procedures were applied with the BSSS and non-BSSS inbred lines.

In the following season, in order to generate BC_0S_1 and BC_1F_1 seeds, the BC_0F_1 plants were self pollinated and backcrossed to the corresponding tropical inbred lines. The BC_0S_2 was derived from selfing of the BC_0S_1 . The

BC₁F₁ was self pollinated to generate BC₁S₁. Simultaneously, the BC₁F₁ was backcrossed to corresponding tropical inbred lines to generate BC₂F₁.

For each exotic group, three semi-exotic populations containing 50, 25 and 12.5 % were generated. Details of procedure for the formation of the 50 % semi-exotic populations of each exotic group were as followed: (1) Twenty ears of each of the BC₀S₁ of the six combinations of each exotic group x 6 adapted inbred lines were selected to the total of 120 ears. (2) Equal number (10 seeds) of seeds were sampled from each of the 120 ears and uniformly bulked as foundation material. Since there were 4 exotic groups, the total of 4 semi-exotic (50 %) populations were obtained. (3) The bulked seeds were grown in 25 rows, conventional plant spacing (0.75 × 0.25 m) of 5-m long and approximately, total of 500 plants were obtained. (4) At the flowering stage, the 500 plants were recombined by half-sib mating procedure; half of the plant numbers were arranged as pollen sources and their bulked pollens were pollinated to the other half and vice versa. (5) At harvest, 50 desirable ears were selected. The same procedures were employed to generate 25 % and 12.5 % semi-exotic populations using BC₁S₁ and BC₂S₁ seeds as foundation materials, four types and three proportions of exotic sources. One additional population was generated by recombining the six corresponding tropical inbred lines, representing the tropical population (0 % exotic).

Four additional populations were included in order to facilitate experimental arrangement. Two of the four additional populations were Suwan 1 and Bisma. Suwan 1 is a widely adapted tropical population developed by Kasetsart University and Bisma is a tropical population widely adapted in Indonesia developed by Food Crops Research Center, Department of Agriculture Indonesia. The other two populations were newly formed populations. The 16 populations were evaluated in 4 × 4 lattice design with three replications.

Yield trials were conducted in the year 2003 at three locations: National Corn and Sorghum Research Center (Suwan Farm, Nakhon Ratchasima, Thailand) locating at 14°30' North, 101°30' East, 356 meter above sea level; Bangkok Seed Industry Research Farm (Salengparn, Saraburi, Thailand) locating at 14°30' North, 101°30' East, 40 meter above sea level; and PT. BISI Research Farm (Kediri, Indonesia) locating at 7°55' South, 112°01' East, 110 meter above sea level. Each plot consisted of six 5-m rows at Salengparn and Kediri, and 4.5-m rows at Suwan Farm. Plant spacing was 0.75 m between rows and 0.20 m within row. Plots were over-planted with 44 seeds per row and after two weeks, plants were thinned to 1 plant per hill or population size of 66,667 plant/ha. Standard cultural practices were followed at all locations. Data were recorded on, days to 50 % anthesis and silking, ear and plant height expressed in cm, leaf disease infection "Southern rust and leaf blight" (1 = highly resistance, 9 = highly susceptible), root lodged and stalk lodged expressed in percent plant lodged per plot, grain moisture content at harvest expressed in percent, and grain yield at 15 % moisture expressed in ton ha⁻¹.

The analysis of variance was done in two phases. First, population means over locations were computed by running individual location analyses, obtaining lattice adjusted and/or unadjusted means, and then by averaging those means over locations. For all traits, the following single degree of freedom comparisons (group comparisons) between means of population type were performed:

- 1) A vs H, O, B, N
- 2) H vs O, B, N
- 3) O vs B, N
- 4) B vs N

Where, A = adapted population; H, O, B and N were semi-exotic populations derived from U.S. Corn Belt hybrids, OPV's, BSSS, and Non-BSSS inbred lines, respectively.

Each population type consisted of three semi-exotic populations representing three proportions of exotic germplasm. In the second phase, effect of treatment (proportion of exotic germplasm) was analyzed. The later analyses were done based on simple randomized complete block design using unadjusted data and separated for each group of exotic sources. The populations and the location x treatment interaction sum of squares were partitioned into linear and non-linear orthogonal polynomials. All statistical computations used the MSTAT-C computer program (MSTAT-C, 1988).

RESULTS AND DISCUSSION

Diversity among the 16 populations clearly displayed as the treatment mean squares for all traits showed highly significant differences, except plant and ear height (Table 1). Highly significant location x treatment interaction implied the instability of all traits over locations, except plant and ear height. The variance of overall semi-exotic populations showed significant difference to the 0 % exotic population (A) for grain yield and moisture content and highly significant difference for days to anthesis and silking. Among type of exotic sources, for grain yield, comparison between variance of A vs H, O, B and N showed significant difference, and between variance of H vs O, B and N and between variance of O vs B and N showed highly significant difference. On the other hand, no significant difference was noted between variance of B vs N. In addition, significant difference was also found for leaf disease infection between variance of O vs B and N.

Among types of exotic source (Table 2), population contained exotic germplasm of type-H (commercial hybrids) showed the highest mean grain yield, followed by population containing exotic germplasm of type-N (Non-BSSS inbred lines), and type-B (BSSS inbred lines). The lowest mean grain yield was found in semi-exotic

population containing exotic germplasm of type-O (open-pollinated variety). Type-H also showed mean grain yield similar to the population with 0 % exotic germplasm (tape-A). These phenomena indicated that the hybrids were the most promising sources to improve performance of the tropical inbred lines followed by Non-BSSS and BSSS inbred lines. The type-H exotic source is commercial hybrid which, theoretically, accumulates more desirable alleles than other sources, since this type of germplasm has already experienced of inbreeding and intense selection during inbred line development and hybrid evaluation. The type-N and type-B were also promising sources, respectively. This result was in agreement with the result reported by Goodman (1999) which suggested that using exotic germplasm with history of inbreeding gave about 100-fold advantage over elite synthetic with no history of inbreeding. Types of germplasm showed no significant effects to the semi-exotic population performance for days to anthesis and silking, grain moisture content and leaf disease infection which indicated that, with the same region of adaptation of exotic sources, the different performances of semi-exotic populations were mostly caused by difference in accumulation of desirable alleles for grain yield.

Comparison among semi-exotic populations with different proportions of exotic germplasm of each type of exotic source showed that, in general, semi-exotic population with 50 % exotic showed significantly lower grain yield, earlier days to silking and anthesis, lower grain moisture content and higher leaf disease infection than those of 25 and 12.5 % exotic. On the other hand, between 25 and 12.5 % exotic, no significant difference was observed. However, semi-exotic populations with 25 and 12.5 % exotic type-H showed grain yield higher than the corresponding proportions of exotic of other types. The lowest grain yield of the 50 % exotic population than the 25 and 12.5 % revealed that with 50 % exotic, high

Table 1 Mean squares of yield and other desirable traits; a comparison between check and type of exotic sources, among type of exotic sources, combined across three locations.

Source of variation ^{1/}	Mean squares							
	d.f.	Grain yield	Days to anthesis	Days to silking	Grain moisture	Leaf disease	Plant height	Ear height
Locations	2	0.214	27.174	5.021	45.440**	110.271**	3136.302**	2463.611**
Replication within locations	6	0.378	5.417	3.847	3.941	1.368	73.840	43.292
Treatments	15	2.080**	16.363**	15.929**	34.591**	5.833**	133.266	73.444
A vs H, O, B, N	1	1.397*	7.704**	2.001**	15.099*	1.641	0.055	36.347
H, vs O, B, N	1	2.542**	0.001	0.694	0.713	1.778	15.384	0.174
O, vs B, N	1	2.250**	0.222	6.722	1.912	2.722**	10.478	7.094
B vs N	1	0.085	7.407	15.574	0.392	0.167	193.423	3.787
Location x Treatment	30	0.484**	4.603**	4.132**	2.364*	1.908**	113.522	89.874
Loc. X A vs H, O, B, N	2	1.168**	0.821	0.257	6.564	2.028	110.116	32.135
Loc. X H vs O, B, N	2	0.209	1.953	3.361	0.356	1.232	202.791	143.918
Loc. X O vs B, N	2	0.231	10.019**	4.500	4.331	0.686	165.234	39.324
Loc. X B vs N	2	0.390	6.130*	6.241*	0.892	0.722	2.456	141.745
Pooled error	90	0.213	1.787	1.632	1.297	0.650	94.000	64.210
Total	143							
CV (%)		8.31	2.61	2.41	5.1	13.77	4.91	7.73

* , ** Significant at 0.05 and 0.01 probability levels, respectively.
^{1/} A= local adapted (0%exotic) ; H, O, B and N are U.S. Corn Belt germplasm; hybrids, OPV's, BSSS and Non-BSSS inbred, respectively.

Table 2 Means of grain yield and other desirable traits, and responses due to proportion of exotic germplasm, averaged across three locations.

Type of exotic germplasm ¹⁾	Proportion of exotic germ.	Grain yield	Days to anthesis	Days to silking	Grain moisture	Leaf disease ²⁾
		--kg/ha--	-----day-----		---%---	---1-9---
H (F1 Hybrid)	50%	5.17b	50.3c	51.9c	19.7c	6.7a
	25%	5.97a	50.9b	52.7b	22.0b	5.4b
	12.5%	6.14a	52.2a	53.9a	24.1a	5.5b
	0%	5.91a	52.1a	53.4a	23.4a	5.7b
	Average ³⁾	5.76	51.1	52.8	21.9	5.9
Response:	Linear	**	**	**	**	**
	Quadratic	**				*
	Qubic		**	*	*	
O (Open pollinated var.)	50%	4.51c	50.3b	52.4c	19.5c	7.3a
	25%	5.55ab	50.4b	53.4b	22.0b	6.6a
	12.5%	5.45b	52.4a	54.3a	24.2a	5.7b
	0%	5.91a	52.1ab	53.4b	23.4ab	5.7b
	Average ³⁾	5.17	51.0	53.4	21.9	6.4
Response:	Linear	**	*	**	**	**
	Quadratic			*		
	Qubic					
B (BSSS Inbred line)	50%	5.02b	50.4c	52.1c	19.9c	6.9a
	25%	5.68a	51.6b	53.3b	22.4b	5.9b
	12.5%	5.75a	52.7a	54.6a	24.6a	5.2c
	0%	5.91a	52.1ab	53.4b	23.4b	5.7bc
	Average ³⁾	5.49	51.6	53.3	22.3	6.0
Response:	Linear	**	**	**	**	**
	Quadratic		*	**	**	**
	Qubic		*	**	**	*
N (Non-BSSS Inbred line)	50%	5.22b	49.0c	50.8c	19.8d	6.8a
	25%	5.69a	50.9b	51.7bc	22.2c	5.9ab
	12.5%	5.78a	52.6a	54.3a	24.4a	5.7b
	0%	5.91a	52.1a	53.4ab	23.4b	5.7b
	Average ³⁾	5.56	50.8	52.3	22.1	6.1
Response:	Linear	**	**	**	**	*
	Quadratic				**	
	Qubic			*	**	
SUWAN 1		6.24	52.2	54.3	24.6	5.0
SUWAN 2		4.93	48.1	50.4	20.4	5.3
BISMA		5.98	52.2	54.1	23.9	4.3
LSD (0.05)		0.43	1.3	2.0	5.1	0.8
CV (%)		8.31	2.6	2.4	1.1	13.8

*, ** ; significant at 0.05 and 0.01 probability levels, respectively.

1) A = 0% exotic germplasm; H,O, B and N are exotic germplasm from US corn Belt; Hybrids, OPV's BSSS and Non – BSSS inbred lines, respectively.

2) Leaf disease: 1 = highly resistance ; 9 = highly susceptible.

3) Average based upon 50, 25, and 12.5 % exotic only, 0% excluded.

amount of un-adapted alleles especially susceptible to disease and heat were presented and suppressed the effective function of desirable alleles as indicated by high leaf disease infection and premature death of the plant.

Significant nonlinear (quadratic) response among semi-exotic population means due to proportion of exotic germplasm was noted for grain yield in the populations containing exotic source of type-H, which indicated the curvilinear nature of the response (Table 2 and Figure 1). The curvilinear response also indicated that additional backcrosses to adapted germplasm would not achieve further significant increases in grain yield. The same result was also reported by Crossa and Gardner (1987). On the other hand, semi-exotic populations containing some other types of exotic, type-O, type-B and type-N, showed significant linear response due to proportion of exotic sources for grain yield, which indicated that additional backcrosses to tropical sources were required to lift the mean of this semi-exotic populations to the same level or exceed the adapted population. Albrech and Dudley (1987) also reported significant linear response when introgressing an exotic germplasm "South Africa Photoperiod

Insensitive Composite II" to U.S. Corn Belt maize population, RSSSC. The responses of mean population due to proportion of exotic germplasm for other traits mostly tended to show linear response (Table 2).

Commercial hybrids, inbred lines and open-pollinated varieties of the U.S. Corn Belt sources interact differently in response to the numbers of backcross. With improved sources (exotic hybrid), smaller numbers of backcross to the tropical recurrent parent were required to improve the performance of the tropical sources and open the chance to incorporate higher proportion of desirable alleles of exotic sources into the semi-exotic population. On the other hand, if less advanced exotic sources were used, more backcrosses to the tropical recurrent parent were required in order to eliminate the negative epistatic effect of un-adapted alleles and therefore, to decrease chance to add genetic diversity to the semi-exotic population.

CONCLUSION

Exotic germplasm with history of inbreeding and intensive selection for combining ability was the most promising source to improve

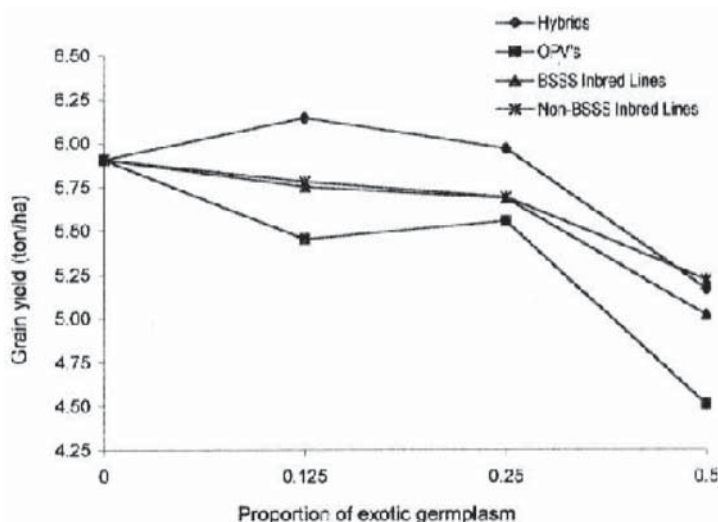


Figure 1 Changes in means of grain yield of semi-exotic population from different sources (types) and proportions of exotic germplasm, averaged across three locations.

the performance of the semi-exotic population. At least one backcross to the tropical recurrent parent was required to effectively incorporate the desirable and to eliminate the un-adapted alleles of exotic in semi-exotic population

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