Maydica 51 (2006): 255-262

SELECTING AMONG AVAILABLE, ELITE TROPICAL MAIZE INBREDS FOR USE IN LONG-TERM TEMPERATE BREEDING[1]

P.T. Nelson, M.P. Jines, M.M. Goodman*

Department of Crop Science, North Carolina State University, Raleigh, NC 27607-7620, USA

Received May 20, 2005

ABSTRACT - The narrowness of the temperate maize (*Zea mays* L.) germplasm base has long been recognized, and there are many available, elite tropical lines that might be used to profitably broaden it. However, there are few comparative yield-trial data by which to choose which line(s) might be most useful. As the investment required for using a tropical line in a temperate breeding program is large, line-choice is critical. Here we report the results of testing a group of potentially-useful tropical lines in topcrosses grown in North Carolina. Results for 50%-exotic topcrosses and for 25%-exotic topcrosses are compared, and the 50%-exotic topcrosses with a broad-based tester (here, LH132.LH51) appear to be most efficient for initial screening. In addition, virtually all crosses suggested that any superior tropical line could be used equally well with either Stiff Stalk or non-Stiff Stalk germplasm. Of the 22 lines tested, CML258 and Tzi9 appear to be the most promising, if yield improvement is a major criterion. None of the lines appeared to have serious lodging, maturity or moisture problems in either 25% or 50%-tropical crosses.

KEY WORDS: Maize breeding; Tropical inbreds; Line-choice; Incorporation; Topcrosses.

INTRODUCTION

Use of public tropical lines for U.S. commercial maize (*Zea mays* L.) breeding is either undocumented or non-existent. A possible exception is the old Cuban line A6, which was still being used in tropical hybrids over 40 years after its development by DEL VALLE (1952). A major reason for the under-utilization of this valuable germplasm source is the sparse amount of yield-trial data available for most tropical lines. Effective evaluation of tropical, unadapted maize is costly and time-consuming in the U.S. corn-belt, where most temperate maize breeding is done. Thus, temperate maize breeding programs have shown minimal interest in such lines.

Many tropical lines have been available for over 15 years from the International Maize and Wheat Improvement Center (CIMMYT), the North Central Regional Plant Introduction Station (NCRPIS), or Jim Brewbaker in Hawaii. Potentially-useful tropical lines have also been released from IITA (International Institute of Tropical Agriculture; KIM *et al.*, 1987), the Suwan station in Thailand (CHUTKAEW, 1997), and South Africa, among others. Although substantial amounts of disease and insect resistance data exist (BREWBAKER *et al.*, 1989), very little comparative yield-trial data from either temperate or tropical areas have been published with which to make among-line choices, with the exception of work by HAN *et al.* (1991) and VASAL *et al.* (1992). CIMMYT alone has released hundreds of lines (SRINIVASAN, 2001), almost all of which are described as having "good general combining ability," but many have little readily-available data. Other sources of tropical lines and hybrids often have even less data. Much of the useful information on tropical hybrids and inbred lines is "word of mouth" or presented on slides or posters, often in meetings held in remote locations, rather than published in readily-available journals.

The maize breeding program at North Carolina State University has dealt extensively with tropical germplasm for nearly 25 years. NC State provides

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[1] This paper is dedicated to Dr. Donald N. Duvick who has served as an inspiration to the third author for over 45 years and whose leadership in the maize breeding and germplasm communities has been unmatched. The first and second authors are Pioneer Research Fellows whose stipends are a direct result of decisions made by Dr. Duvick while he was Vice-President of Research at Pioneer Hi-Bred International Inc.

* For correspondence (fax: +1 919 515 7959; e-mail: maize_resources@ncsu.edu).

an ideal environment for a long-term breeding program with tropical maize, given its southern location and its historical emphasis on maize breeding. We identified 22 all-tropical, public inbreds for screening and evaluation for use in our own breeding program and for potential use in GEM (Germplasm Enhancement of Maize), a public/private collaborative program designed to broaden the germplasm base of U.S. maize (SALHUANA *et al*., 1994; POLLAK AND SALHUANA, 1998, 2001; POLLAK, 2003). Our primary objective in conducting this study was to determine, in a yield-trial setting, which of these all-tropical lines might be most useful in a temperate breeding program. Additionally, we wanted to address three questions relative to testing procedures.

(1) Can tropical lines be directly topcrossed to a U.S. source, be tested in North Carolina, and yield useful comparative data?
(2) Do tropical lines need to be tested initially with both Stiff Stalk (SS) and non-Stiff Stalk (NSS) testers?
(3) Is testing topcrosses at the 25%-tropical level more informative than testing at the 50%-tropical level?

Data already exist that suggests (1) was correct (STUBER, 1978; GOODMAN *et al.,* 2000), but the materials involved in those studies had little past history of selection. There are varying results regarding question (2). MUNGOMA and POLLAK (1988), POLLAK *et al*. (1991), and GEADELMANN (1984) reported population × tester interaction among some tropical maize populations. HOLLAND and GOODMAN (1995) found the opposite in evaluation of tropical accessions. HOLLEY and GOODMAN (1988) also reported little heterotic interaction in evaluation of first generation, all-tropical, temperate-adapted lines. Note, however, that the aforementioned studies involved tropical populations, accessions, or temperate-adapted lines. Our study deals exclusively with all-tropical, unadapted inbred lines. Point (3) has not been addressed directly before.

Our reasons for conducting this study were the scarcity of usable, comparative yield-trial data from the tropics and the increasing reluctance of the private sector to share germplasm or information. Effective line selection is crucial for success in any breeding program, especially one that deals with unadapted, exotic germplasm. Until the available tropical material is screened, and the more promising lines identified, there is little chance of its effective use in a public breeding program.

MATERIALS AND METHODS

The 22 lines used and their sources are listed in Table 1. Most were included in the genetic diversity studies of LIU *et al.* (2003). These lines represent a sample of what were believed to be the best of the available, public, tropical inbred lines when the study started in 2000. They were chosen based on data presented at meetings such as the annual ASA-CSSA meetings, meetings and discussions at CIMMYT, a preliminary draft of a booklet by SRINIVASAN (2001), and conversations with maize breeders such as Hugo Cordova and S.K. Vasal at CIMMYT, Dave Smith and Glenn Robison at DeKalb, S.K. Kim at IITA, Takumi Izuno and Rick Ward at Pioneer, and Randy Holley at Syngenta. Each tropical line entered into 25% and 50%-tropical topcrosses in the following two ways. First, we crossed each tropical line to LH132.LH51 (basically, an improved B73.Mo17, developed and supplied to us by Holdens Foundation Seeds, now a part of Monsanto). This was formerly a widely-used hybrid, and one still in production. Such a hybrid represents a broad cross-section of U.S. maize (SMITH, 1988). Second, we crossed each tropical line to two U.S. inbreds, one representing SS germplasm (NC328) and one representing NSS germplasm (B97). After making the tropical inbred × U.S. inbred cross, we crossed the F_1 onto an appropriate tester; tropical × NC328 F_1s were crossed to FR615.FR697, a C103 sister-line cross representing NSS germplasm, and tropical × B97 F_1s were crossed to FR992.FR1064, a B73 sister-line cross representing SS germplasm (FR testers were supplied to us by Illinois Foundation Seeds). Thus, each of the 22 lines was represented in three topcrosses, a 50%-tropical topcross and two 25%-tropical topcrosses.

The tropical × temperate line crosses began in the summer of 2000 at Clayton, NC. Topcross seed was produced in the winter nursery in Homestead, Fl, in 2000 - 2001. Tester seed in the winter nursery was delay planted (3 to 12 days) to match line maturity.

A total of 66 crosses was grown at 4 North Carolina locations over three years (2001, 2002, and 2003). Plots were grown at Clayton, Lewiston, and Sandhills, NC, each year. Plots were grown at Plymouth, NC, in 2001 and 2002, but were lost to a hurricane in 2003. Thus, a total of 11 North Carolina environments were represented in the study. All crosses were grown together in lattice designs with three replications per location along with six commercial hybrid checks, Dekalb 687, Dekalb 697, Pioneer 3165, Pioneer 3223, Pioneer 32K61, and Pioneer 31G98. These commercial checks represent a broad range of maturities grown in North Carolina at the time the study was conducted. All crosses and checks were represented in 2002 and 2003. Experiments grown in 2001 included only three checks, DeKalb 687, Pioneer P3165 and P32K61, and (due to a vandalism incident in our nursery) did not include seven of the 66 topcrosses evaluated in 2002 and 2003: A6, CML254, CML264, and CML281 in topcrosses with FR992.FR1064 and CML264 and Ki44 in topcrosses with FR615.FR697. All plots were two-rows, 4.88 m in length measured from the center of the alley, with 1 m alleys between plots, and row spacing of 96.5 cm at all locations except Lewiston, NC, where row spacing was 91.4 cm. Plots were planted with 44 seeds/plot with a target plant density of 43,000 plants/ha at Clayton, Plymouth, and Sandhills, NC, and 45,000 plants/ha at Lewiston, NC. Data reported here are limited to yield, moisture percentage, ear height, plant height, percent erect plants at harvest, and days to anthesis (Table 2). Days to anthesis were recorded at Clayton, NC, only; all other data were collected at all locations.

TABLE 1 - *Lines used, germplasm sources, and seed sources.*

Line	Germplasm source	Seed source
A6	Cuban Flint	Pioneer
CML247	Pool 24 (Tuxpeño)	CIMMYT
CML254	Tuxpeño Sequia	CIMMYT
CML258	Pop. 21 (Tuxpeño)	CIMMYT
CML264	Pop. 21 (Tuxpeño)	CIMMYT
CML277	Pop. 43 (La Posta, Tuxpeño)	CIMMYT
CML281	Pop. 43 (La Posta, Tuxpeño)	CIMMYT
CML287	Pop. 24 (Antigua-Venezuela; Tuśon/Tuxpeño)	CIMMYT
Ki3	Suwan 1 (Thailand)	Pioneer
Ki9	Suwan 1 (Thailand)	DeKalb
Ki11	Suwan 1 (Thailand)	Pioneer
Ki14	Suwan 1 (Thailand)	Brewbaker
Ki43	Suwan 3 (Thailand)	DeKalb
Ki44	KS 6 (Suwan, Thailand)	DeKalb
KUI2007	Suwan 1; DeKalb version of Ki3	DeKalb
KUI2021	Suwan 1; DeKalb version of Ki9	Dekalb
Tzi8	TZB × TZSR	IITA
Tzi9	SIDS7734 × TZSR	IITA
Tzi10	Pop. 44 × TZSR	IITA
Tzi11	Mo17 × RPPSR	IITA
Tzi16	N28 × RPPTZSR-Y	IITA
Tzi25	$B73^2$ × (B73 × RPPSR-TZ)	IITA

The lines originally acquired from Dekalb, Pioneer, and IITA have been deposited with NCRPIS at Ames.

Statistical analysis was done using PROC GLM in SAS version 8.0 (SAS INSTITUTE INC., 1999). Years and environments were considered random and entries were considered fixed. Mean square error, degrees of freedom for error, and corresponding LSDs were calculated independently for 50%-tropical and 25%-tropical topcrosses. LSDs were calculated using a Satterthwaite approximation for degrees of freedom where necessary. Correlation analysis was done using Spearman's coefficient of rank correlation for comparison between broad-based, SS, and NSS testers and between years within and among testers. Four different selection truncation points were used for yield comparison among lines: lowest check, 90% of check mean, check mean - LSD, and tester mean + LSD.

RESULTS AND DISCUSSION

As expected, few of these experimental crosses performed well enough per se to merit much, if any, further attention, if yield alone were the primary objective. Typically, any experimental hybrid with a mean yield more than one LSD below the mean of the checks would be unlikely to lead to competitive lines unless the number of lines developed and tested was very large (>> 100), and the breeder very fortunate. However, because we were dealing with widely-varied, unadapted, tropical lines, no single-selection criterion seemed to provide adequate information about line performance. Therefore, we used four truncation points for yield comparisons: (1) lowest check, (2) 90% of check mean, (3) check mean - LSD, and (4) tester mean + LSD (Table 3). Using these selection criteria, several lines stood out across years and testers. CML258 and Tzi9 were consistently the two highest yielding lines, followed by Tzi8. Two other lines, CML277 and CML264, showed potential worth consideration, CML264 performing best in NSS topcrosses. The remaining 17 lines have little to offer as far as yield is concerned.

Only two of the 66 line × tester combinations lodged significantly more than the mean of the commercial checks (Table 2). About 42% of the line × tester combinations failed to differ significantly from the checks for ear and plant height. In the topcrosses involving B97, KUI2007 flowered 3 days earlier than the earliest check, Pioneer 32K61. None of the experimental crosses had grain moisture as low as Pioneer 31G98, which was also the highest-yielding entry.

For the purpose of initially screening 100%-tropical inbred lines, our results suggest that it is not necessary to topcross to both SS and NSS testers. Correlation analysis of topcross performance (averaged across three years and ranked by yield) gave rank correlation coefficients r = 0.46 and r = 0.44 for broad-based topcrosses vs. SS and NSS topcrosses, respectively (Table 4). Comparable correlation analysis of topcross performance from year to year on the same tester gave correlation rank coefficients ranging from r = 0.05 to r = 0.72, with the LH132.LH51 topcrosses being very much the most consistent across years (with $\bar{r} \approx 0.68$). The r-values for the FR992.1064 topcrosses were very low, making results obtained with this tester rather uninformative, although Tzi9 consistently made the selection cut-off on this tester. The r-values for FR615.FR697 topcrosses were higher, although one correlation was below 0.3 (Table 4). Correlation coefficients for line rank from year to year, averaged across all three testers, were slightly higher. In all cases correlation among years was highest between 2002 and 2003. This is somewhat surprising because 2002 was a drought year and 2003 was very wet.

TABLE 2 - *Means of tropical lines × U.S. testers; 50% and 25%-tropical topcrosses.*

Year 2003: Clayton, Lewiston, and Sandhills, N.C.
Year 2002: Clayton, Lewiston, Plymouth, and Sandhills, N.C.
Year 2001: Clayton, Lewiston, Plymouth, and Sandhills, N.C.

Pedigree	Yield t/ha	Mois %	Ear Ht (cm)	Plant Ht (cm)	EP[1] %	Anth Days
A6 × LH132.LH51	6.6	18.9	116	276	92	73
A6.B97 × FR992.FR1064	6.9	17.3	97	265	93	69
A6.NC328 × FR615.FR697	7.3	17.8	103	271	87	71
CML247 × LH132.LH51	6.9	19.8	100	256	92	72
CML247.B97 × FR992.FR1064	7.3	17.7	94	251	94	69
CML247.NC328 × FR615.FR697	7.2	18.2	95	260	95	71
CML254 × LH132.LH51	5.3	21.2	124	288	98	78
CML254.B97 × FR992.FR1064	6.9	17.7	95	258	96	70
CML254.NC328 × FR615.FR697	7.4	18.4	111	280	94	74
CML258 × LH132.LH51	7.9	19.0	114	281	95	75
CML258.B97 × FR992.FR1064	7.2	17.6	99	265	96	70
CML258.NC328 × FR615.FR697	7.9	17.5	101	273	94	72
CML264 × LH132.LH51	6.6	21.0	101	274	98	75
CML264.B97 × FR992.FR1064	7.3	17.6	89	253	98	70
CML264.NC328 × FR615.FR697	7.8	18.2	97	271	97	71
CML277 × LH132.LH51	7.5	19.9	104	272	95	74
CML277.B97 × FR992.FR1064	7.1	17.8	93	253	95	69
CML277.NC328 × FR615.FR697	7.7	18.3	97	267	92	70
CML281 × LH132.LH51	6.7	19.1	116	287	97	77
CML281.B97 × FR992.FR1064	7.2	17.3	97	264	97	69
CML281.NC328 × FR615.FR697	7.3	17.5	103	268	95	71
CML287 × LH132.LH51	6.9	20.3	121	295	93	75
CML287.B97 × FR992.FR1064	7.3	17.9	104	276	95	70
CML287.NC328 × FR615.FR697	7.4	18.2	107	278	94	71
Ki3 × LH132.LH51	6.7	19.5	87	243	97	69
Ki3.B97 × FR992.FR1064	6.7	17.6	82	243	93	68
Ki3.NC328 × FR615.FR697	6.8	18.4	88	255	95	69
Ki11 × LH132.LH51	6.7	18.9	103	270	95	72
Ki11.B97 × FR992.FR1064	7.2	17.2	95	256	95	68
Ki11.NC328 × FR615.FR697	7.4	17.5	100	267	94	70
Ki14 × LH132.LH51	6.5	18.7	104	262	97	73
Ki14.B97 × FR992.FR1064	7.0	17.2	92	253	93	69
Ki14.NC328 × FR615.FR697	7.1	18.3	101	267	93	70
Ki21 × LH132.LH51	7.2	18.2	107	265	89	72
Ki21.B97 × FR992.FR1064	7.2	17.3	95	251	92	69
Ki21.NC328 × FR615.FR697	6.9	17.1	94	257	91	68
Ki43 × LH132.LH51	7.3	19.7	99	261	96	71
Ki43.B97 × FR992.FR1064	7.1	17.6	91	255	95	69
Ki43.NC328 × FR615.FR697	7.4	17.9	96	265	95	70
Ki44 × LH132.LH51	6.6	19.0	98	256	98	71
Ki44.B97 × FR992.FR1064	6.9	17.5	90	252	95	69
Ki44.NC328 × FR615.FR697	7.2	17.8	99	267	94	71
KUI2007 × LH132.LH51	6.9	19.5	88	250	93	69
KUI2007.B97 × FR992.FR1064	7.0	17.3	86	248	93	66
KUI2007.NC328 × FR615.FR697	7.4	17.8	90	258	92	70
KUI2021 × LH132.LH51	7.2	19.0	111	275	88	72
KUI2021.B97 × FR992.FR1064	6.9	17.7	98	269	91	68
KUI2021.NC328 × FR615.FR697	7.2	17.9	102	271	89	70

TABLE 2 - *Continued.*

Pedigree		Yield t/ha	Mois %	Ear Ht (cm)	Plant Ht (cm)	EP[1] %	Anth Days
Tzi8 × LH132.LH51		7.5	20.1	104	271	96	72
Tzi8.B97 × FR992.FR1064		7.2	18.3	96	259	95	69
Tzi8.NC328 × FR615.FR697		7.7	18.6	99	268	95	70
Tzi9 × LH132.LH51		7.5	18.5	112	283	92	72
Tzi9.B97 × FR992.FR1064		7.6	17.1	100	264	92	70
Tzi9.NC328 × FR615.FR697		7.9	17.5	107	282	92	70
Tzi10 × LH132.LH51		6.0	18.9	117	286	98	75
Tzi10.B97 × FR992.FR1064		6.9	17.2	98	271	97	70
Tzi10.NC328 × FR615.FR697		7.4	18.1	100	275	95	71
Tzi11 × LH132.LH51		6.9	19.4	104	269	96	71
Tzi11.B97 × FR992.FR1064		7.1	17.6	94	261	96	69
Tzi11.NC328 × FR615.FR697		7.3	18.7	100	271	93	70
Tzi16 × LH132.LH51		7.3	17.6	104	276	94	71
Tzi16.B97 × FR992.FR1064		7.1	17.0	95	263	95	69
Tzi16.NC328 × FR615.FR697		7.6	17.0	101	272	92	71
Tzi25 × LH132.LH51		7.0	19.0	109	270	90	71
Tzi25.B97 × FR992.FR1064		7.1	17.5	93	255	95	69
Tzi25.NC328 × FR615.FR697		7.4	17.8	102	271	94	70
Means:	Experiment	7.1	18.3	100	266	94	71
	50%-Tropical	6.9	19.3	107	271	95	73
	25%-Tropical (SS)	7.1	17.5	94	258	95	69
	25%-Tropical (NSS)	7.4	17.9	100	269	93	70
DeKalb 687		8.4	17.4	95	256	95	71
DeKalb 697		8.9	17.8	97	264	90	70
Pioneer P3165		7.8	19.1	91	254	89	74
Pioneer P31G98		9.0	16.7	98	267	95	71
Pioneer P3223		8.9	17.4	103	260	89	73
Pioneer P32K61		8.0	17.0	82	258	96	69
Check Means		8.5	17.6	94	260	92	71
LSD*		0.3	0.6	3.9	5.1	3.8	0.9

[1] EP = Erect Plants (at harvest).
* Appropriate for comparison of experimental cross to mean of the commercial checks at $\alpha = .05$.

However, all locations had supplemental irrigation, which lessened the effects of drought in 2002.

Our results suggest that screening with a broad-based tester provides as good an indication of relative line performance as any single-tester method. Testing at the 50%-tropical level requires less time and fewer resources than testing at the 25%-tropical level. Given the large number of potential lines to be tested and the limited resources available, this screening procedure seems a reasonable one to pursue, while it might logically be followed by SS and NSS screening of the most promising lines. Our screening procedures for 100%-tropical, unadapted inbred lines will undoubtedly be done at the 50%-tropical level in the future, as there appears to be no need to have only 25%-tropical germplasm in topcross yield trials in North Carolina. These conclusions are consistent with results from other studies with all-tropical lines at NC State (Holley and Goodman, 1988; Holland and Goodman, 1995). Considerations other than yield, most likely disease or insect resistance, seed quality, or pollen production, will most likely determine how a temperate breeder might employ better tropical lines.

TABLE 3 - *Lines selected using four selection truncation points.*

Year	Truncation Point*	Tester LH132.LH51	FR992.FR1064	FR615.FR697
2001	1	CML258	————	CML258, Tzi8, Tzi9
2001	2	>6	>6	>6
2001	3	>6	>6	>6
2001	4	CML258	————	CML258, Tzi9
2002	1	————	————	Tzi9
2002	2	CML258	————	CML258, CML28, Tzi9
2002	3	————	————	————
2002	4	CML258, CML277, Ki43, Tzi8	————	CML258, CML264, CML281, KUI2007, Ki43, Tzi9
2003	1	CML258, Tzi16, Tzi8, Tzi9	CML247, Tzi9	CML258, CML264, CML277, CML287, Tzi8
2003	2	CML258, Tzi8, Tzi9	CML247, Tzi9	CML258, CML264, CML277, CML287, Tzi9
2003	3	Tzi9	————	————
2003	4	CML258, Tzi16, Tzi8, Tzi9	Tzi9	CML258, CML264, Tzi8
3 Year	1	CML258	————	CML258, CML264, Tzi9
3 Year	2	CML258	————	CML258, CML264, CML277, Tzi8, Tzi9
3 Year	3	————	————	————
3 Year	4	CML258, CML277, Ki43, Tzi16, Tzi8, Tzi9	Tzi9	CML258, CML264, CML277, Tzi16, Tzi8, Tzi9

* Truncation Points: (1) Lowest check, (2) 90% of check mean (3) check mean – LSD, (4) tester mean + LSD.
LSD calculations at α = .05.

TABLE 4 - *Spearman's coefficients of correlation for entries ranked by yield across testers and years.*

	LH132.LH51 vs FR992.FR1064	LH132.LH51 vs FR615.FR697	FR992.FR1064 vs FR615.FR697
Avg. Across Years	0.46	0.44	0.40
	2001 vs 2002	2001 vs 2003	2002 vs 2003
LH132.LH51	0.65	0.66	0.72
FR992.FR1064*	0.05	0.12	0.52
FR615.FR697**	0.28	0.61	0.60
Avg. Across Testers	0.59	0.67	0.80

For each comparison n = 22 except where noted.
* For comparisons involving FR992.FR1064 in 2001, n=18.
** For comparisons involving FR615.FR697 in 2001, n=20.

In topcrosses to a single, broad-based tester (50%-tropical), many of the problems (photoperiod related or otherwise) typically associated with growing unadapted tropical material in a temperate environment were lessened enough to allow effective line-evaluation. In order to run effective yield trials in North Carolina, flowering dates should be within a few days of the checks and grain moisture at harvest cannot be much higher than 28%. Lines evaluated on a single, broad-based tester certainly met these criteria. Among 50%-tropical topcrosses, days to flowering ranged from 69 to 78 with a mean of 72.8, about a day and a half later than the mean of the commercial checks. Mean grain moisture at harvest was 19.3%, the wettest (CML254) being 21.2%. Lodging resistance was quite good with only one line (KUI2021) lodging significantly more than the mean of the commercial checks. Mean ear and plant heights were 107 cm and 271 cm, respectively, significantly higher than the corresponding mean of the checks (α = .05).

Differences in mean yield, averaged over all years, were significant (p < .001) between the three types of topcrosses: LH132.LH51 at 6.9 t/ha, FR992.FR1064 at 7.1 t/ha, and FR615.FR697 at 7.4 t/ha. The lower yields observed in LH132.LH51 topcrosses come as no surprise, simply because of the higher percentage of unadapted tropical background in these crosses. Our previous experience using NSS vs. SS crosses with tropical material has been that the latter almost always yield better. The contradiction seen here is most likely attributed to the NC328 vs. B97 contribution in these crosses. NC328 is more adapted to North Carolina growing conditions and, therefore, it probably boosts yield in the NSS topcrosses, although further investigation would be necessary to draw any substantial conclusions.

CONCLUSION

Broadening the U.S. maize germplasm base is dependent on the incorporation of tropical germplasm. The pool of widely-available tropical hybrids and public inbred lines from the tropics is the most logical source of such germplasm, but the lack of available, comparative, yield-trial data on such lines has made effective line-choice difficult. Use of tropical germplasm in a temperate breeding program is costly and time-consuming; therefore, line-choice is critical. The task of evaluation and incorporation of such lines has fallen largely on the shoulders of public maize breeding programs. Given the large number of potentially-useful lines to be screened and the limited (and rapidly diminishing) resources available to public breeding programs, efficiency is key in effective evaluation.

Results presented here suggest that in North Carolina, initial screening of all-tropical materials can be done effectively at the 50%-tropical level with topcrosses to a single, broad-based U.S. tester. Furthermore, many of the problems commonly encountered when testing all-tropical material (namely photoperiod and disease issues) are lessened enough to allow effective evaluation when testing at the 50%-tropical level. In light of the large number of publicly-available tropical lines, and the finite resources available to public breeding programs, this screening method is likely the most efficient.

The relative success of all-tropical, temperate-adapted lines like NC296 and NC346 (Goodman, 1999; Tallury and Goodman, 1999) has demonstrated the yield potential in elite exotic sources, but such events are rare. However, these and other temperate-adapted, all-tropical lines, like NC298 and NC300, offer resistance against diseases that could affect today's narrowing U.S. germplasm base. Further progress will require continued commitment and long-term funding, as progress is slow. The release of NC296 required 15 years of development (Goodman, 1993), which is not atypical of line development using predominantly-exotic germplasm. The data presented here suggest that five of the 22 lines tested probably merit inclusion in such efforts: CML258, CML264, CML277, Tzi8, and Tzi9. Two lines, CML258 and Tzi9, appear to be the most promising.

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