Improvement of the Maize Population "Elite Synthetic NT" for Soils with Low Nitrogen Content

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Abstract

The maize population 'Elite Synthetic NT' has been selected with the objective of improving its yield potential in soils with low nitrogen (N) availability. During the 1994/95 season, 144 half-sib families showing good male-female flowering synchrony were evaluated with and without N fertilizer at Sete Lagoas, MG. The experimental design utilized was a 12 x 12 lattice, with 5 m plots. The open-pollinated variety 'BR 106', selected in soils with high fertility, was used as a between block check. Mean ear weight for the selected families in N+ and N- environments averaged 4,511 kg/ha and 3,327 kg/ha, respectively. Yield reduction between environments averaged 27.14% for the selected families and 65.8% for BR 106. The results indicate that selection in N- environments is an efficient approach for developing genotypes with better performance in soils with low nitrogen content.

Nitrogen (N) availability is estimated to be the principal limiting factor in more than 20% of arable land (Lafitte and Edmeades, 1988). Nitrogen fertilizer application can overcome this limitation in many tropical regions, but the high risk resulting from high cost and uncertain economic return frequently deters farmers from using it. This has brought about an intensified search for technologies which can increase the efficiency of N use by plants (Furlani et al., 1985). For small-scale farmers in Brazil, improved N use efficiency is particularly important because there are no government fertilizer subsidies.

Increasing the N use efficiency of maize germplasm may reduce the effects of soil N deficiency on maize production. Superior genotypes may either be more efficient at N uptake or N utilization, or both. Traditional breeding programs commonly do not select under low N conditions because higher environmental variation reduces the heritability of grain yield (Blum, 1988). It is not clear whether selection in N limited environments is a better strategy to improve N use efficiency (Clark and Duncan, 1991).

Genetic variability for N use efficiency under low N was found for inbred lines (Balko and Russell, 1980) and tropical cultivars (Thiraporn et al., 1987; Lafitte and Edmeades, 1994a,b). Moll et al. (1987) observed in temperate maize germplasm that materials selected for N use efficiency had good yields at high N levels, but they could not be distinguished from unselected materials at low N levels. It has been suggested that selection efficiency can be increased in environments with low N levels by selecting for secondary characteristics, provided they are correlated with grain yield and less affected by the environment. For a breeding program, utilization of secondary characteristics is frequently limited due to the difficulty in measuring them with precision and rapidity (Beauchamp et al., 1976; Clark, 1982).

This study evaluates ear yield of half-sib families from Synthetic Elite NT under high and low N conditions and compares their performance with a commercial check entry. Synthetic Elite NT has been selected under low N conditions, whereas the check entry was developed in high fertility environments.

Material and Methods

Maize population Synthetic Elite NT was formed in 1987 from the 10 best inbred lines belonging to the breeding program of the National Center for Maize and Sorghum

Research (CNPMS). All possible crosses among lines were made and a balanced bulk of F_1 seed from each cross was recombined. In 1989 and 1990, a second and third recombination was carried out by planting a balanced bulk of seed from selected ears in isolation. During the third recombination, several plants were selfed and 400 S_1 ears were selected. Two cycles of recurrent selection were completed under high N conditions and the best 10% of the lines were recombined each time. A third cycle of selection was planted at a population density of 100,000 plants/ha and under low N conditions in 1993. A mixture of pollen from 50 tassels was taken each day and used to pollinate plants with good flowering synchrony (i.e., short anthesis-silking interval, or ASI).

The resulting 144 half-sib families were evaluated in two environments: on fertile soil (N+) and poor soil (N-) at Sete Lagoas-MG, Brazil (19° 28' S, 44° 15' W). The soil is classified as latosoil dark red, dystrophic and of clay texture. The field trials were planted during the rainy season using a 12 x 12 simple lattice experimental design. An intercalate check entry, BR 106, was planted in each block. In the N+ environment, 400 kg/ha of 4-14-8 (NPK) fertilizer was applied at planting and 60 kg/ha of N was side-dressed later in the season. No fertilizer was applied in the N- environment. Plots consisted of one 5 m row spaced 0.90 m between rows and 0.20 m between plants within rows. Water stress occurred during the 10 days around the flowering period. Ears were weighed from each plot. Percent moisture was measured and used to correct the weights to 14.5% moisture. Data for ear weight from both trials were analyzed using the procedures given by Cochran and Cox (1957).

Results and Discussion

Soils were analyzed for major nutrients (Table 1). The soil in the N- environment contained medium levels of Ca and P, a low level of K and a high level of Mg (based on recommended levels from Comissão, 1989). The level of organic matter suggested that N levels resulting from N mineralization might be high. However, only 25 kg/ha of N was available as NO_3 and NH_4 in the top 40 cm of the N- soil (data not shown). The N+ environment had adequate levels of all elements based on soil analyses and applied fertilizer.

Analysis of variance for ear weight showed highly significant (P£0.01) differences among half-sib families in both environments. Values for the coefficient of variation (CV, Table 2) were relatively high and similar for both environments; typical of trials grown under stress conditions (Blum, 1988; Parentoni et al., 1992; Machado et al., 1992; Gama et al., 1994). A lower coefficient of variation would normally be expected under unstressed, N+ conditions, so drought stress during flowering may have affected both environments and

Table 1. Chemical composition of the soils in environments with and without nitrogen. Sete Lagoas - MG, Brazil, 1994/95.

Soil depth	pH	Ca (eq.mg/100 cc)	Mg	K (ppm)	P (ppm)	O.M. (%)	NH_4 (ppm)	NO_3 (ppm)
Without nitrogen (N-)								
0-20 cm	6.2	3.69	1.04	34	7.5	3.18	1.72	3.26
20-40 cm	6.4	3.95	1.15	45	10.0	3.19	2.45	3.08
With nitrogen (N+)								
0-20 cm	6.4	6.65	0.63	194	42	2.56	-	-
20-40 cm	6.4	5.40	0.54	122	15	2.19	-	-

Table 2. Mean ear weight for the best 20% selected families and tester BR 106 in two environments; i.e., with (N+) and without (N-) nitrogen. Sete Lagoas - MG, Brazil, 1994/95.

Treatment	N+ (kg/ha)	Treatment	N- (kg/ha)
58	9000	58	5447
55	6812	91	5320
116	6749	141	5102
19	6697	31	5092
59	6661	16	4887
110	6649	55	4863
94	6566	71	4853
90	6418	47	4800
88	6405	50	4726
9	6396	90	4615
20	6328	99	4612
92	6195	129	4604
44	6154	125	4603
34	6114	77	4592
131	6051	144	4524
48	6018	21	4514
107	5967	116	4511
108	5933	88	4478
137	5908	9	4464
3	5898	20	4427
141	5884	62	4368
73	5880	34	4345
50	5847	142	4303
144	5688	97	4282
37	5673	114	4266
51	5659	69	4212
17	5648	87	4171
87	5602	48	4114
BR 106 (Tester)	5585	BR 106 (Tester)	1910
Selected Mean	4511	Selected Mean	3287
CV (%)	22.3	CV (%)	23.43
LSD (0.05)	183	LSD (0.05)	138

may have resulted in high and similar CVs in both environments.

Grain yield ranged from 2,380 to 9,000 kg/ha for the N+ environment and from 1,764 to 5,447 kg/ha for the N- environment. Yields of the 20% (28) best families in each environment are presented in Table 2. Thirteen families were selected in both environments. The mean performance of the selected families was very encouraging, considering their contrasting performance to check entry BR 106. Mean grain yield of the selected families in the N- environment (3,287 kg/ha) was 27% less than in the N+ environment (4,511 kg/ha), whereas the check entry reduced its yield by 66% from 5585 kg/ha under N+ conditions to 1910 kg/ha under N- conditions. All selections leading to BR 106 were conducted under N+ conditions (Santos et al., 1994), and this may be the reason for its poor performance under N- conditions.

The lower production costs associated with omitting fertilizer application probably compensated for the yield disadvantage of 1,224 kg/ha under N-, with the net benefit of N use efficient families presumably larger in the N- environment. Thus, sowing N use efficient germplasm like Synthetic Elite NT may be a viable production strategy for regions with predominantly small, low income, self-sufficient farms, especially when combined with minimal organic fertilizer application. Areas like the northeast region of Brazil, where yields range from 500 to 1,000 kg/ha at present, could profit from such germplasm. The results of this study confirm the existence of genetic variability for N use efficiency in maize, and are in agreement with the results presented by Balko and Russell (1980), Thiraporn et al. (1987), and Lafitte and Edmeades (1994a,b).

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