BREEDING TROPICAL CORN FOR DROUGHT TOLERANCE

S. Edme and R. N. Gallaher[1]

ABSTRACT

Improving tropical maize (*Zea mays* L.) tolerance for drought stress was initiated in 1991 in a fullsib recurrent selection program. This breeding program was initiated to compare two selection environments and to improve the yield stability of tropical maize under the north Florida drought-prone environments. Rainfed and irrigated plots were used to evaluate 140 fullsib families, along with four checks in a 12 X 12 partially balanced lattice design with four replications. Relative grain yield, plant and ear height leaf area, flower delay, canopy temperature, tassel weight, and drought index were used to select the fullsibs for the recombination phase. Yield reductions, ranging from 2 to 40% in the stress site, were mild due to appreciable rainfall. High variability existed among the fullsibs tested for grain yield. Irrigated grain yield ranged from 3987 to 8039 kg ha^{-1}, and rainfed grain yield from 3066 to 7124 kg ha^{-1}. A 15% selection pressure resulted in the advancement of 21 fullsibs from either site to the recombination process.

INTRODUCTION

Tropical and temperate maize (*Zea mays* L.) yields are both affected by drought resulting from irregular rainfall distribution and low water-holding capacity of soils, as in north Florida. Tropical maize is, however, mostly associated with low-input environments, characterized by water and temperature stresses, among others (Boyer, 1982). Improving tolerance for drought stress is imperative for tropical maize improvement and is a growing concern for multiple cropping and conservatino tillage sustainable agriculture. In north central Florida, low moisture retention by the soil makes even a short period of drought a constraint to grain production, particularly if the stress coincides with flowering time (Claasen and Shaw, 1970; Robins and Domingo, 1953). Observed variation in susceptibility to water stress among genotypes suggests that the trait can be improved (Fischer et al., 1983; Jensen, 1971).

[1]Dcpartment of Agronomy. University of Florida, Gainesville, FL32611.

Conflicting results exist as to the choice of best selection environment to be used for greater yield in low-yielding sites. Falconer (1981) suggested selecting in stress conditions while Daday et al. (1973) indicated that selection for yield is more effective under favorable conditions because of greater genetic variance and heritability. The most relevant criteria in breeding corn for drought tolerance were found to be anthesis-to-silking interval, canopy temperature at flowering, leaf area loss, and relative grain yield (Fischer et al., 1983).

This breeding program was initiated to improve the grain yield stability of tropical corn in Florida under drought conditions, to compare synthetics developed under rainfed and irrigated environments for drought resistance, and to develop synthetics as possible sources of drought resistance for future breeding programs. This paper presents the first year evaluation of the fullsib families for selection and subsequent recombination

MATERIALS AND METHODS

The first of the two cycles of fullsib recurrent selection was conducted at Green Acres Agronomy Farm of the University of Florida, Gainesville, Florida in 1991. The experimental site was an area dominated by Arenic and Grossarenic Paleudults soil types (Soil Survey Staff, 1984).

Plant materials

The 140 fullsib families derived from a set of 199 fullsibs under selection for high yield with Florida, Costa Kica, The Dominican Republic, and CIMMYT corn materials involved in their making (R.N. Gallaher, personal communication). Four checks were included in the 1991 evaluation: a temperate hybrid (Pioneer Brand P3320), the tropical hybrid (DeKalb Brand DeKalbXL 678-C, and two tropical Florida synthetics developed by Dr. R.N. Gallaher.

The 144 entries were planted on 21 March 1991 in a 12 X 12 partially balanced lattice design with four rep1ications. This initial evaluation trial was designated to measure the variation in a number of plant characters associated with drought-resistant mechanisms among the 140 fullsib families: leaf area, plant height and ear height, anthesis-to-silking interval, yield, drought intensity and index, and canopy temperature at flowering. Drought index was calculated as follows: S = (1-Y/Yp) / (1-X/Xp), where Y=yield under stress, Yp=irrigated yield, and X and Xp are the respective average yields over all fullsibs under stress and nonstress conditions. The drought intensity is defined by the term (1-X / Xp).

The trial was conducted under two different soil water regimes: sprinkler-irrigated and rainfed. Plot size was a single row 3 m long and 0.76 wide, and hills were hand-planted. The sites were managed for maximum production.

RESULTS AND DISCUSSION

Anthesis-to-silking interval

Days to anthesis and silking were affected less in the rainfed site compared with the irrigated site. High variability existed for the anthesis-to-silking interval when both sites were compared (Fig. 1). Delays of 3 to 5 days were observed under the rainfed conditions, with 4 to 5 days more common. Under the irrigated condition, the fullsibs had a range of 2 to 5 days of delay, but the majority had 2 to 3 days of delay.

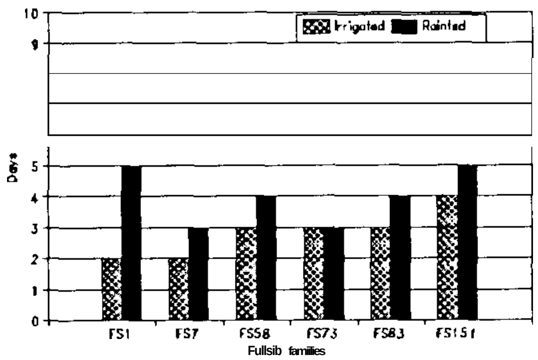

Fig. 1. Anthesis-silking intervals for six of the fullsib families.

Yield

High variability existed for yield in both rainfed and irrigated experiments (Table 1). The grain yields ranged from 3066 to 7124 kg ha^{-1} for the rainfed site and from 3987 to 8039 kg ha^{-1} for the irrigated site. Reductions or increases were observed for some of the fullsib families when their mean performance was compared in both conditions (Fig, 2). Good rainfall (687.6 mm) associated with a better soil moisture retention in the rainfed site resulted in a mild stress (a total of 20 drought-days of which only five occurred at pre-anthesis). Consequently, some higher mean grain yields were registered in the stress environment. Pre-anthesis stress adaptation might also have been a factor.

Table 1. Significance for the traits tested under irrigated and rainfed conditions.

Traits	Rainfed	Irrigated
Yield	***	***
Plant height	***	***
Ear height	***	***
Leaf area	ns	ns
Canopy temperature	ns	
Tassel weight	***	
Index	***	

*** significant at the 0.0001 level
ns nonsignificant at the 0.05 level
· no measurement taken

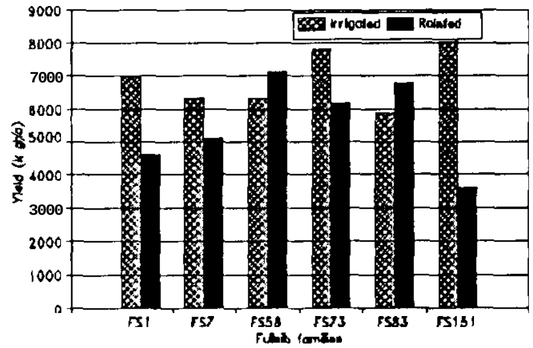

Fig. 2. Grain yield of six of the fullsibs in the rainfed and irrigated sites.

Plant and ear height

High variability also existed among the fullsib families for plant and ear height (Table 1). Plant heights were from 1.95 to 2.46 m in the irrigated site and from 1.00 to 2.45 m for the rainfed site. Reductions in ear height were also observed in the rainfed experiment. Ear height ranged from 0.97 to 1.47 m in the irrigated site and from 0.52 to 1 2 7 m in the rainfed site.

Leaf area and tassel weight

No significant differences were obtained for leaf area or other leaf traits in either site. The water stress was not severe enough to show differences among the fullsib families for leaf characteristics. Neither was a significant difference observed for canopy temperature. Frequent cloudy days at the flowering stage made this measurement difficult.

Tassel weight was found to be significant among the fullsib families grown in the rainfed site. The weight ranged from 2.67 to 6.84 g. Selection was practiced for reduced tassel weight in the rainfed site only.

Drought intensity and index

The drought intensities calculated for yield, plant height, and ear height were 020, 039, and 0.41, respectively (Table 2). A drought index based on relative yield was used for the final ranking of the families with respect to drought (Table 3). Some families had both high drought index and high yield potential. Twenty-one families with drought index greater than 1.00 were selected for the recombination phase.

CONCLUSION

High variability existed among the fullsib families for yield, tassel weight, plant and ear height, and drought index. A successful combination of a high yield potential and drought resistant traits from this breeding material should be possible for improved multiple cropping sustainable agricultural systems. The anthesis-to-silking interval was more affected than days to anthesis or to silking in response to the water regimes. Anthesis-to-silking intervals greater than live (5) days may result in incomplete pollination. Good rainfall and mild pre-anthesis stress might have explained the higher yields of some fullsib families in the rainfed conditions. Twenty-one fullsib families were selected from each site and crossed for recombination.

LITERATURE CITED

Royer, J.S. 1982. Plant productivity and environment. Science 218:443-448.

Claasen, M.M., and R.H. Shaw. 1970. Water deficit effects on corn. II. Grain components. Agron. J. 62:652-655.

Daday, H.P., E. Biner, A. Grassia, and J.W. Peak. 1973. Effect of environment on heritability and predicted selection response in Medicago sativa. Heredity 31:293-296.

Falconer, D.S. 1981. Introduction to Quantitative Genetics. Longman, New York

Fischer, K.S., E.C. Johnson, and G.O. Edmeades. 1983. Breeding and selection for drought resistance in tropical maize. International Maize and Wheat Improvement Centre. CIMMYT, Mexico, Mexico.

Jensen, S.D. 1971. Drought tolerance in US maize. Agric. Water Management 7:223.

Robins, J.S., and C. Domingo. 1953. Some effects of severe moisture deficits at specific growth stage in corn. Agron. J. 45:618-621.

Soil Survey Staff. 1984. Official series description of the Arredondo series. United States Government Printing Office. Washington, DC.

Table 2. Drought intensities based on grain yield, plant height and ear height in rainfed and irrigated conditions among the 140 fullsib families.

Traits	Drought intensity†
Yield	020
Plant height	039
Ear height	0.41

† Drought intensity= (1-X / Xp), where X = average over fullsibs under rainfed, and Xp = average of fullsibs under irrigated conditions.

Table 3. Drought index based on relative grain yield of rainfed to irrigated conditions among six fullsib families.

Families	Drought index (S)†
1	1.68
73	1.04
151	2.50
7	0.97
58	0.55
83	0.66

† S = (1-Y/Yp) / (1-X/Xp), where Y = yield under stress, Yp = irigated yield, and X and Xp are the respective average yields over all fullsibs under stress and nonstress conditions.