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Characterizing Corn Hybrid Moisture Stress Sensitivity Using Canopy Temperature Measurements

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SHORT COMMUNICATION

Characterizing Corn Hybrid Moisture Stress Sensitivity Using Canopy Temperature Measurements

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The relationship between a canopy temperature stress indicator (TSI) and relative grain yields (RGY) was examined for five hybrids of corn (Zea maize L.). TSI is the midday difference in canopy temperature between a specific location and an area producing maximum yields for each hybrid. The results show that relative grain yields can be estimated to within ±8% if hybrid type is unknown or ±4% if hybrid type is known. The TSI relationship is a potentially important tool for screening drought response among hybrids.

Introduction

Several studies have demonstrated that moisture stress causes elevated canopy temperatures when compared to air temperature or the temperature of a nonstressed canopy (Idso et al., 1977; 1980; 1981a,b; Jackson et al., 1977; 1981; Gardner et al., 1981a,b; Diaz et al., 1983; Walker and Hatfield, 1979): Gardner et al., (1981a) showed that relative grain yield reductions are a function of canopy temperature for two hybrids of sorghum.

Mtui et al. (1981) showed that hybrid corn plants were consistently cooler than their inbred parents, and yielded higher. Irrigated plots had cooler midday canopy temperatures and higher yields than nonirrigated plots. Interestingly, there were midday canopy temperature differences between fully irrigated plots of the hybrids. The hybrid with the coolest midday canopy temperatures during the grain-fill period had the highest yields.

Relationships between canopy temperature, moisture stress, and grain yield are important to plant breeders, since remote measurements of canopy temperature can be made for a large number of hybrids in a short time. Kirkham et al. (1984) showed that canopy temperature measurements can be used to classify genotypes according to their drought resistance. The objective of this study is to examine the relationship between canopy temperature and grain yield for several hybrids of moisture stressed corn.

Materials and Methods

A field study was conducted in 1979 on 10×18 m plots at the University of Nebraska Sandhills Agricultural Laboratory (41°37′N; 100°50′W and 975 above msl), 70 km north of North Platte, NE. The experimental design consisted of two

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replications of five commercial corn hybrids which were planted in a completely randomized design. The five hybrids were: ACCO 3002, Golden Harvest 2457, Jacques 1033A, Prairie Valley 215, and Sakota TS-74. The crop was planted on 15 May at a rate of 64,000 plants/ha in north–south rows with a row spacing of 0.76 m.

The gradient irrigation system used is similar in design to the line source sprinkler system described by Hanks et al. (1976). During a gradient irrigation, applied water decreases in a linear pattern from the sprinkler line outward. All plots in this study received a gradient irrigation except during tasseling, when all plots were uniformly irrigated. The amount of water applied across a plot ranged from 0% to 100% of that needed to supplement precipitation so as to replace soil water lost by evapotranspiration.

A hail storm, with stones up to 30 mm in diameter, struck the experimental site on 16 July. Many emerged leaves were damaged, but stalk damage was minimal. The top 3–4 leaves emerged after this date. This damage altered the canopy and may have permitted our infrared thermometer (IRT) to view deeper into the canopy, especially under windy conditions, than would be the case for a non-damaged corn canopy. The temperature variability due to wind gusts was found to be approximately 0.5°C at midday. The effect of wind induced canopy temperature variability on relative temperature differences between plots was assumed to be negligible.

Beginning on 20 July, midday canopy temperatures were measured at 6 locations across each plot with a Telatemp Ag-42 infrared thermometer (IRT). Ten meters of row were sampled for grain yield from each of these locations at the end of the season. All canopy temperature measurements were made between 1200 and 1500 solar time with the infrared thermometer facing toward the south.

The temperature stress index (TSI) used in this study is defined as:

$$TSI = T_c - T_m,$$

where

T_c = midday canopy temperature (°C) of a specific plot location,

T_m = midday canopy temperature of the area having the highest grain yield for a specific hybrid.

TSI was summed for each plot between 20 July and 1 September.

Results and Discussion

Maximum grain yields ranged between 7969 kg ha^{-1} and 9659 kg ha^{-1} for the five hybrids. Consequently, yields were expressed on a relative basis using the maximum yield for each hybrid, so that hybrids could be more easily compared. Relative grain yield decreased with increasing values of TSI (Tables 1–2, Fig. 1). Regression analysis showed that a linear regression properly represents the data. Significant differences existed in the responses of the hybrids, however. R^2 values ranged between 0.82 and 0.92 depending on the hybrid. A single regression fit the combined data reasonably well. Note that the Pioneer 3780 hybrid grown at SAL in 1978 (Gardner et al. 1981b)

TABLE 1 Linear Regressions of Grain Yield (y) versus Canopy Temperature (T_c) for Each Hybrid and Combined Data, and F-Test at = 0.01 for Homogeneity of Regression[a]

Hybrid	Maximum Yields (kg/ha)	n	a (kg/ha)	b (kg/ha °C)	r^2	SEE
ACCO 3002	7969	12	41766.2	− 29.56	0.92	315.1
Golden Harvest 2457	9649	12	77415.1	− 60.56	0.94	374.7
Jacques 1033A	8362	12	66458.5	− 51.65	0.86	353.9
Prairie Valley 215	8902	12	61091.8	− 46.69	0.82	618.2
Sakota TS-74	8099	12	44601.6	− 33.83	0.82	654.6
Combined data		60	38334.4	27.18	0.51	953.9

[a] Homogeneity of regression: F value = 41.98, $F_{0.01}$ = 3.83.

responded almost identically to Jacques 1033A. Relative grain yields can be estimated with TSI measurements to within 4–8% depending on hybrid (Table 2).

Examination of the slopes of the relative grain yield versus TSI regressions (Table 2) shows a wide range in response to moisture stress for the different hybrids. Note that ACCO 3002 lost only 0.371% yield for each 1°C increase in TSI; yet Jacques 1033A lost 0.618% for each 1°C increase in TSI. This provides evidence that ACCO 3002 is more drought tolerant than Jacques 1033A and that the relative grain yield versus TSI relationship is an important tool for screening drought response among hybrids.

This differential hybrid response to moisture stress introduces an element of uncertainty into remote estimates of grain yield over large areas since information on hybrid type is not readily available. The combined regression for all hybrids (Table 2) shows that relative grain yields can be estimated to within ±8% if hybrid type is unknown or ±4% if hybrid type is known. Further research on other hybrids is needed to determine the maximum range in errors which may be expected in remote estimates of corn grain yield where hybrid type is unknown.

TABLE 2 Linear Regressions of Relative Grain Yield (%) versus Temperature Stress Index (TSI) for Each Hybrid and Combined Date, and F-Test at = 0.01 for Homogeneity of Regression[a]

Hybrid	n	a	b	r^2	SEE
ACCO 3002	12	99.7	− 0.371	0.92	4.0
Golden Harvest 2457	12	92.4	− 0.627	0.94	3.9
Jacques 1033A	12	99.3	− 0.618	0.86	4.7
Prairie Valley 215	12	98.9	− 0.524	0.82	6.9
SAKOTA TS-74	12	94.9	− 0.415	0.92	7.5
Pioneer 3901[b] (Gardner et al., 1981b)	28	94.9	− 0.555	0.92	4.1
Combined data	60	96.0	− 0.415	0.75	7.5

[a] Homogeneity of regression: F value = 47.90, $F_{0.01}$ = 3.83.
[b] Included for comparison.

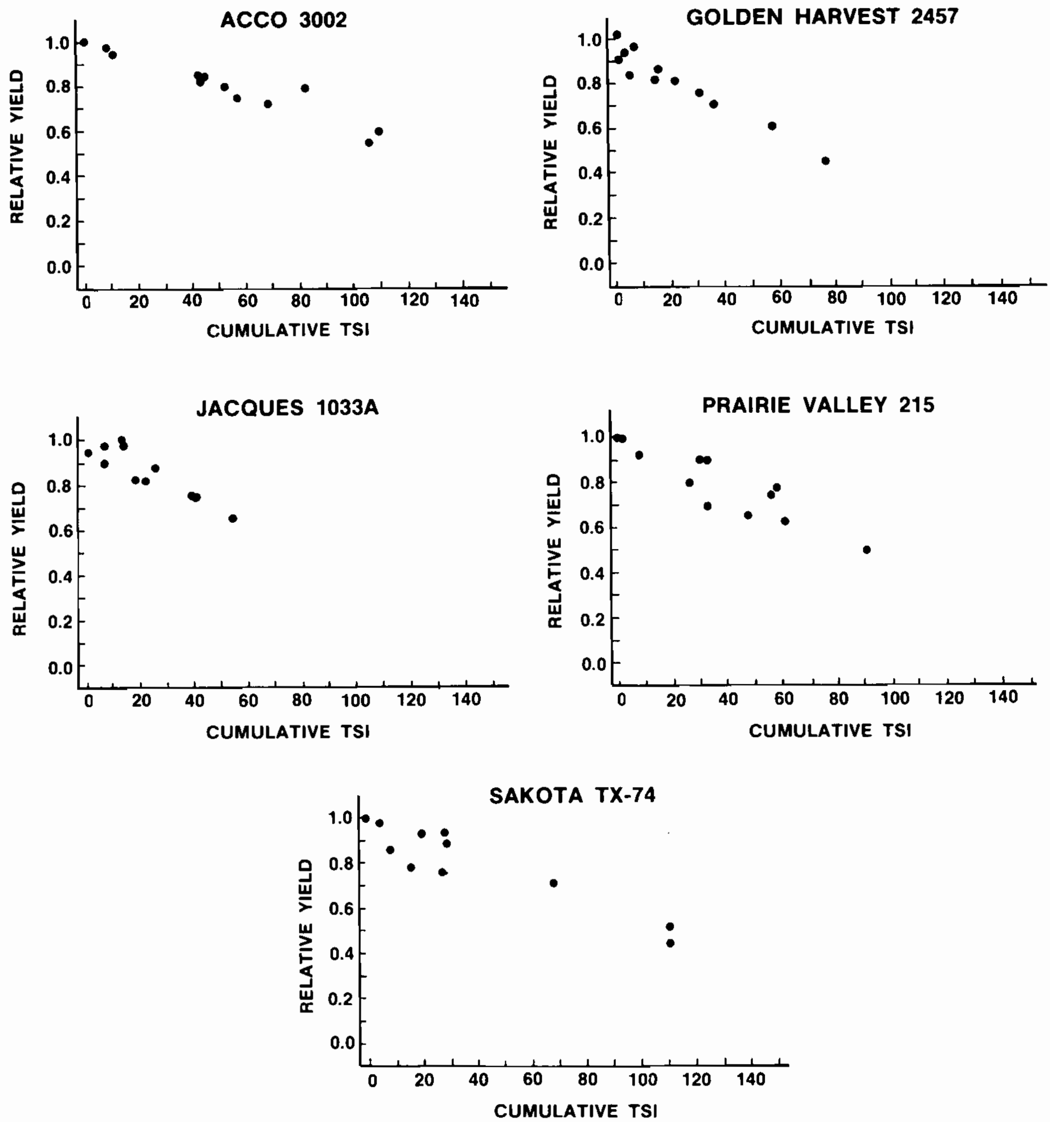

FIGURE 1. Relative grain yield versus cumulative temperature stress index (TSI) for 5 hybrids grown in 1979.

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