Use of Leaf Temperature to Measure the Effect of Brown Stem Rot and Soil Moisture Stress and Its Relation to Yields of Soybeans

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ABSTRACT

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Soybean cultivars susceptible to brown stem rot and tested in soil infested with high and low levels of the causal fungus (*Phialophora gregata*) showed significant differences in leaf temperature minus air temperature (DT) with different degrees of moisture stress. Significant differences in DT occurred between 11:00 A.M. and 4:00 P.M. for five consecutive days during the R6–R7 growth stages on plants with higher levels of stem browning, with both moisture-stressed and nonstressed treatments showing the higher temperature. Plants exposed to a high level of inoculum in combination with moisture stress had higher DT values and had significantly lower yields than other treatments. However, neither moisture stress in combination with a low inoculum level nor low or high inoculum levels in environments without moisture stress resulted in reduced yields. Higher values of DT were consistently associated with increased levels of moisture stress but not with increased stem browning. Although differences in percentage of stem browning among treatments were observed, the differences were not always significant. DT was significantly, negatively correlated ($r = -0.79$) with yield but was not significantly correlated with stem browning and level of inoculum. DT provided a convenient indication of soybean yield reduction caused by a combination of moisture stress and severe *Phialophora gregata* infection.

Additional key word: interactions

Brown stem rot (BSR), caused by *Phialophora gregata* (Allington & Chamberlain) Gams, has been reported to cause variable yield losses on soybeans (*Glycine max* (L.) Merr.) (1). One reason for such variability may be environmental factors. The importance of the physical environment relative to BSR development and its effect on yield is not fully understood. Adequate moisture for normal plant growth early in the season and moisture deficiency late in the season were speculated to favor BSR development (9) and subsequent yield reduction (10). Intuitively, diseased plants would be expected to be under moisture stress, but this has not been adequately documented. Ertl and Fehr (3) reported that BSR did not reduce yields of soybeans planted in widely spaced hill plots, where moisture stress was presumably less of a factor than in row plots. Critical monitoring of soybean plants for stress, caused either by disease or moisture stress or both, has been suggested (6,13). Tachibana and Hatfield (12) reported the effectiveness of thermocouples used in conjunction with the Campbell CR21X data logger as a means of monitoring leaf temperature. Monitoring leaf and air temperatures as an indication of plant stress is based on the fact that, in diseased plants, water uptake and transport tends to lag behind transpiration, which reduces the plants' evaporative cooling ability. This effect leads to elevated leaf temperature (2,7,8,13). Tu and Tan (13) reported that *Phaseolus* plants with root rot were warmer than plants without the disease when soil moisture was adequate for normal plant growth in the greenhouse.

This investigation was initiated to determine the relationships between DT, BSR, and yield in soybeans.

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MATERIALS AND METHODS

Two susceptible soybean cultivars, Pella and Cumberland, with similar maturities were grown in hill plots. The plots were arranged in a three-way split-plot design in a sandy loam soil at the Hinds Irrigation Research Center at Ames, IA, in 1985. Plots were spaced 1 m apart, and 10 seeds per plot were hand-sown with a corn jab-planter (5). Fertilizer (0-15-15) was incorporated at 168 kg/ha before planting. Water was applied by a trickle-irrigation system. Plots were irrigated at 2- to 3-day intervals to maximize plant development before soil moisture stress was initiated at the R6–R8 stages (4). On part of the field area, an automated movable weather shelter was used to control rainfall after the R6 stage. Soybeans had been tested for reactions to BSR in the experimental sites the previous 2 yr; consequently, the soil was fumigated with metam-sodium (Vapam) to reduce preexisting *P. gregata* inoculum. Plots outside the weather shelter (not fumigated) were included to simulate the conditions in the natural agroecosystem. All plots were hand-cultivated before planting. High and low inoculum levels were achieved by incorporating each with 30 gal (v/v) of infested and noninfested straw of the susceptible cultivar Lakota into a 113-m^2 area. Additional *P. gregata* inoculum (2.5×10^7 spores per plot) was introduced into the soil with high-inoculum-level treatments at the R3 stage to ensure the development of a high level of BSR. Two levels of moisture stress were attained by applying irrigation water as needed to all nonstressed plots and by withholding irrigation water and precipitation during the R6–R8 growth stages under the weather shelter. Moisture stress outside the weather shelter was achieved by withholding the irrigation water but not rainfall during the R6–R8 growth stages.

Thermocouples made by the Research and Technical Assistance Group (RTAG) at the Iowa State University were used to measure leaf and air temperatures. Thermocouples were attached on the abaxial sides of fully expanded leaves and were all positioned at comparable stem nodes and orientation to the sun. Balsa wood strips ($1.2 \times 12.0 \times 0.15$ cm) and rubber bands supported the thermocouples on the leaves. The thermocouples were moved to new, fully expanded leaves at intervals of 5–7 days. Soil water potentials were measured with gypsum moisture blocks placed at a depth of 30 cm at the center of each plot.

A Campbell CR21X data logger was programmed to collect leaf and air temperatures every 60 sec and to summarize average DT for final storage every 60 min. DT data were obtained for a period of 65 days. Data retrieval was achieved either through a telephone and modem or by downloading data from a

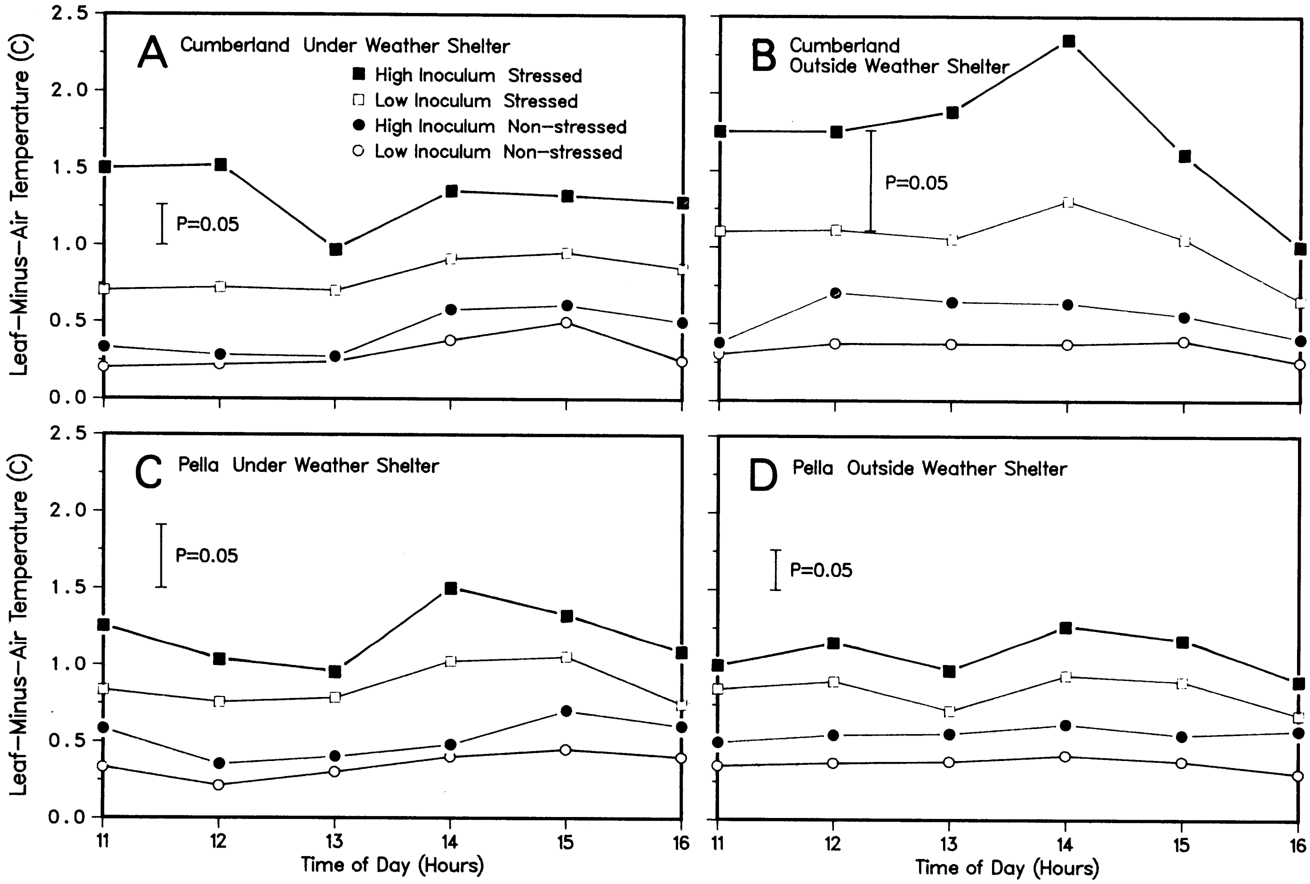

Fig. 1. Leaf-minus-air temperature differentials (DT) recorded during 5 days of stress at the R6–R7 growth stages in high and low inoculum levels for cultivars **(A and B)** Cumberland and **(C and D)** Pella, grown under and outside a weather shelter.

64K-byte storage module to an Osborne PC system with a 20-megabyte hard-disk drive. Ten days after physiological maturity, plants were harvested and checked for BSR incidence (percentage plants with symptoms) and severity (percentage stem discoloration) (11). After threshing, the seed was dried to a uniform moisture content of 13% and weighed.

Table 1. Percent disease incidence and severity caused by *Phialophora gregata*, differential temperature (DT)[a], and yield of soybeans grown under two moisture levels and two levels of inoculum under and out of the movable weather shelter at Hinds Farm, IA, 1985

Moisture levels	Inoculum levels	Disease (%) Incidence US[b]	Incidence OS	Severity US	Severity OS	DT US	DT OS	Yield (g/plot) US	Yield (g/plot) OS
Stress	High	100	94	76	62	1.17	1.38	271	251
Stress	Low	65	88	43	63	0.85	0.96	298	263
No stress	High	100	99	92	78	0.50	0.58	294	293
No stress	Low	90	92	74	66	0.33	0.34	309	293
LSD (0.05)		11	9	9	8	0.28	0.35	23	21

[a] DT = leaf minus ambient temperature expressed in degrees Celsius. Soil water potentials (bars) were −2.98 and −0.25 for stressed and nonstressed treatments, respectively.
[b] US = under shelter and OS = out of shelter.

RESULTS

Mean hourly DT temperature data taken over most of the 65-day period generally indicated that there was little or no difference in DT associated with level of inoculum. However, there was a period of five consecutive days when marked differences did occur at certain hours. During this time, the plants were in the R6 and R7 stages of growth. Stress in the low-moisture plots was severe, as indicated by seasonal mean soil water potential (bars) of −2.98 and −3.11, respectively, for the stressed plots under and away from the shelter, compared with comparable values of −0.25 and −0.28 in the nonstressed plots. Leaf temperatures ranged from 25 to 28 and from 24 to 29 C under and away from the shelter, respectively, while the air temperature ranged from 23 to 27 C. The differences in DT during these days were most evident in the late morning and through the afternoon (11:00 A.M. through 4:00 P.M.).

Individual analysis of variance (using data averaged over the 5-day period for each hour) for each cultivar showed that there was significant variation in DT associated with the four combinations of inoculum level and moisture stress for both the Cumberland and Pella cultivars (Fig. 1).

DTs for moisture-stressed Cumberland and Pella grown at the high inoculum level under the shelter averaged 1.52 and 1.50 C, respectively, and DTs outside the shelter averaged 2.35 and 1.30 C, respectively. Corresponding DTs for plants in the nonstressed plots were 0.5 C both under and outside the shelter.

When weather-shelter data for the two cultivars were combined (Table 1), DTs for the moisture stress treatments averaged 0.60 C higher than for the nonstressed treatments and 0.25 C higher at the high level of inoculum. Outside the shelter, the moisture-stressed treatments for the two cultivars averaged 0.71 C higher than the nonstressed plots and the high inoculum level averaged 0.33 C higher than the low level. Under the shelter, disease severity (as measured by percent stem browning) in plots with the high level of inoculum exceeded the low level by 33% when moisture stress was applied vs. 18% in nonstressed plots. Disease severity under conditions of high

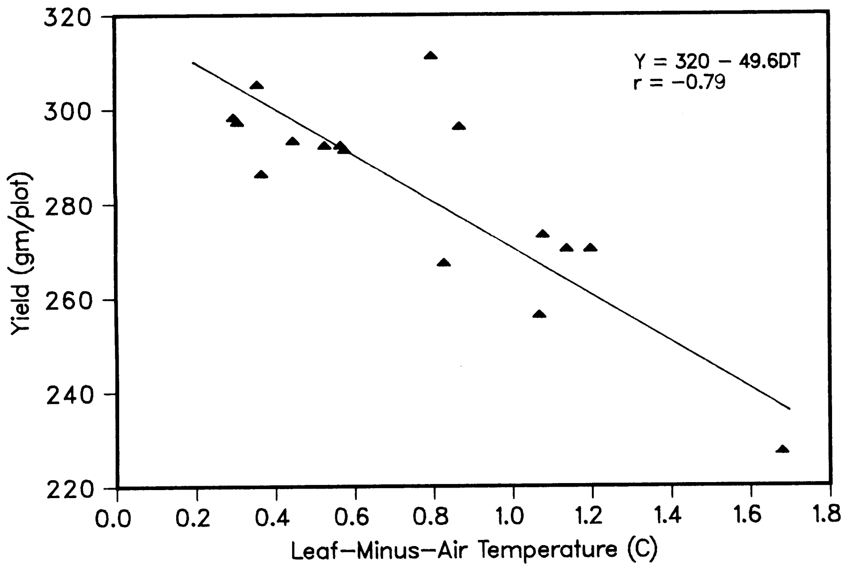

Fig. 2. Relationship between leaf-minus-air temperature differential (DT) and yield (g/plot) for combined data.

inoculum and adequate soil moisture was significantly higher than under the conditions of any of the other treatments. The high level of inoculum resulted in 100% disease incidence in both stressed and nonstressed plots, and the high inoculum level yielded significantly less than the low level under moisture stress.

Outside the shelter, significant differences in disease severity (16%) occurred only between the high-level plots that were moisture-stressed and nonstressed (Table 1). Significant differences in disease incidence were obtained between high level in nonstressed plots (99%) and low level in stressed plots (88%). Moisture-stressed treatments had significantly lower yield than the nonstressed treatments, but no significant yield differences occurred within either the stressed or nonstressed treatments.

When the data for the entire experiment were pooled, a significant linear relationship between yield and DT was evident ($r = -0.79$). DT accounted for 62% of the variation in yield (Fig. 2). For every one-degree (C) increase in DT, there was a corresponding 15% yield reduction. Percent stem browning accounted for only 23% of the variation in yield. The correlation coefficients between yield and percentage of stem browning and between DT and percentage of stem browning were −0.48 and 0.13, respectively; neither was significant.

DISCUSSION

Our results indicate that BSR significantly reduced yields of susceptible soybean cultivars when moisture was limited during growth stages R6–R8. The difference between leaf and air temperatures (DT) is influenced by both moisture stress and inoculum level and, in our trials, was significantly greater at high levels of inoculum in moisture-stressed plants than in nonstressed plants. This is in agreement with Tu and Tan (13), who found that diseased bean plants grown under moisture stress had much greater leaf-minus-air temperature differences than did healthy plants. In our study, the observed differences in disease severity did not result in significant yield differences except under the moisture-stressed conditions. The combination of level of inoculum and moisture stress resulted in higher DT values and significantly lower yields.

There was a strong negative correlation between DT and yield, and DT was a better predictor of yield than either disease severity or incidence. The effect of BSR per se remains unknown because sharply contrasting disease levels were not achieved in this study. The data indicate, however, that greater DT differences and increased percentage of stem browning occur with higher levels of *P. gregata* infestation.

Our results showed that the relationship between BSR and yield may differ substantially with variation in moisture conditions. The potential importance of this relationship should not be overlooked during the evaluation of soybean lines for BSR resistance and yield.

ACKNOWLEDGMENT

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LITERATURE CITED

1. Abel, G. M. 1977. Brown stem rot of soybean-*Cephalosporium gregatum*. Rev. Plant Pathol. 56:1065-1077.
2. Ehrler, W. L., Idso, S. B., Jackson, R. D., and Reginato, R. J. 1978. Diurnal changes in plant water potential and canopy temperature of wheat as affected by drought. Agron. J. 70:999-1004.
3. Ertl, D. S., and Fehr, W. R. 1983. Simultaneous selection for yield and resistance to brown stem rot of soybean in hill plots. Crop Sci. 23:680-682.
4. Fehr, R., Caviness, C. E., Burmood, D. T., and Pennington, J. S. 1971. Stages of development description for soybeans, *Glycine max* (L.) Merrill. Crop Sci. 11:929-931.
5. Garland, M. L., and Fehr, W. R. 1981. Selection for agronomic characters in hill and row plots of soybeans. Crop Sci. 21:591-595.
6. Idso, S. B., Reginato, R. J., Reicosky, D. C., and Hatfield, J. L. 1981. Determining soil-induced plant water potential depression in alfalfa by means of infrared thermometry. Agron. J. 73:826-830.
7. Jackson, R. D. 1986. Remote sensing of biotic and abiotic plant stress. Annu. Rev. Phytopathol. 24:265-287.
8. Jackson, R. D., Idso, S. B., Reginato, R. J., and Pinter, P. J., Jr. 1981. Canopy temperature as a crop water stress indicator. Water Resource Res. 17:1133-1138.
9. Otazu, V., Epstein, A. H., and Tachibana, H. 1981. Water stress effects on the development of brown stem rot of soybeans. (Abstr.) Phytopathology 71:247.
10. Tachibana, H. 1982. Prescribed resistant cultivars for controlling brown stem rot of soybean and managing resistant genes. Plant Dis. 66:271-274.
11. Tachibana, H., and Card, L. C. 1979. Field evaluation of soybeans resistant to brown stem rot. Plant Dis. Rep. 63:1042-1045.
12. Tachibana, H., and Hatfield, J. D. 1985. Measurement of moisture stress differences between brown stem rot diseased and healthy soybeans. (Abstr.) Phytopathology 75:1295.
13. Tu, J. C., and Tan, C. S. 1985. Infrared thermometry for determination of root rot severity in beans. Phytopathology 75:840-844.