Canopy Structure and Irrigation Influence White Mold Disease and Microclimate of Dry Edible Beans

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ABSTRACT

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The severity of white mold of dry edible beans caused by *Sclerotinia sclerotiorum* was greatly influenced by the structure of the plant canopy and by the amount and frequency of irrigation. The more frequently irrigated cultivar Great Northern Tara developed the most dense canopy and the less frequently irrigated cultivar Aurora had the most open canopy. The most dense canopy was the coolest, wettest, and had the highest severity of disease whereas the most open canopy was the warmest, driest, and had a very low incidence of white mold. This suggests that the severity of white mold was associated with differences in the microclimate of the plant canopy, so that at least partial control of white mold can be obtained through planting cultivars with open canopy structures, avoiding excessive irrigation, and other practices which modify the microclimate to create less favorable conditions for white mold development. Severely diseased plants were several degrees warmer than those with little or no disease. Crop temperature, as obtained through aerial surveillance techniques, may therefore be useful for detecting and delineating areas of white mold in fields of dry edible beans.

Additional key words: *Whetzelinia sclerotiorum*, *Phaseolus vulgaris*, disease control, remote sensing, plant stress, crop temperature, microclimate modification.

White mold of dry edible beans (*Phaseolus vulgaris* L.) caused by *Sclerotinia sclerotiorum* (Lib.) d By. [= *Whetzelinia sclerotiorum* (Lib.) Korf and Dumont (9)] causes severe losses in the bean crop (8). The semi-arid climate in the Great Plains region, where the majority of dry edible beans are grown (western Nebraska and eastern Colorado), is unfavorable for white mold development (12). Rotem and Palti (13) suggested that irrigation can provide favorable conditions for disease even though the macroclimate is unfavorable. They (10) stated that dew, irrigation, and foliage density are primary factors determining the incidence and severity of disease in a semi-arid climate. Detailed information associating the microclimate with the incidence and development of white mold is lacking.

The purposes of this investigation were (i) to establish whether or not bean canopy structure and irrigation affect the microclimate of dry edible beans, (ii) to determine the influence of canopy structure and irrigation on the incidence and severity of white mold, and (iii) to evaluate the potential for detecting areas of diseased plants with crop temperature measurements.

Preliminary results of certain aspects of this study have been reported earlier (2).

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MATERIALS AND METHODS

Two indeterminate dry bean cultivars Great Northern (GN) Tara (with a dense luxuriant canopy) and Aurora (a small white type with an open upright growth habit) were planted in Tripp very fine sandy loam near Scottsbluff, Nebraska (40° 51′ N, 103° 41′ W; 1,225 m above m.s.l.) on 5 June 1974 and 1975. A between-row spacing of 56 cm was used in 18 × 18 m plots. Within-row spacings for GN Tara and Aurora were 10 and 4 cm, respectively.

Two furrow-irrigation treatments were applied to each cultivar. In 1974 about 48 cm of water were applied in five applications at 6- to 8-day intervals to THI (Tara high rate of irrigation) and AHI (Aurora high rate of irrigation) plots. To the other plots (TLI and ALI = low rate of irrigation of Tar and Aurora, respectively) about 19 cm of water were applied in three applications at 8- to 15-day intervals in 1974. In 1975 THI and AHI received 50 cm of water in nine applications at 5-day intervals and TLI and ALI received 29 cm of water in five applications at 10-day intervals.

Plant and meterological measurements were made during August and early September. Air temperature within canopies was measured with 0.051-cm diameter (24-gauge) copper-constantan thermocouples set with epoxy cement in 2-cm-long pieces of teflon rod (6 mm outside diameter). To obtain a better spatial average of temperature three thermocouples were wired in parallel and placed 10 cm above the soil surface. Dew sensors (6) were located at the 10-cm height. One sensor was used in each plot in 1974 and two in 1975. A reading of 1.0 means that the dew sensor was entirely wet and a reading of 0.0 indicates a dry sensor. Difficulty was encountered in retaining stable calibration of the dew sensors so that the magnitudes of dew sensor readings are only semiquantitative.

Thermcouple and dew sensor output voltages were recorded every 7 min in 1974 and every 15 min in 1975 with an automatic data logger. Voltages were converted to parametric form with a series of computer programs. Converted data were averaged for 30-min periods and plotted with a Calcomp Model 750 plotter (California Computer Products, Inc., Anaheim, CA 92801).

The temperature of the plant canopy, primarily the peripheral leaves, was measured hourly every 2 or 3 days from mid-morning to late afternoon with an infrared (IR) therometer (Barnes Model IT3, Barnes Engineering Co., Stamford, CT 06904). The IR thermometer was aimed from atop a 2.5-m ladder at an angle of about 30 degrees. The viewed area was approximately 125-150 cm^2 and contained very little exposed soil because of the viewing angle and the nearly complete canopy cover.

The leaf area index (LAI), the total leaf area divided by the soil surface area, of each plot was obtained during the period from 22 July to 26 August, 1975. Two 0.5 × 0.5 m

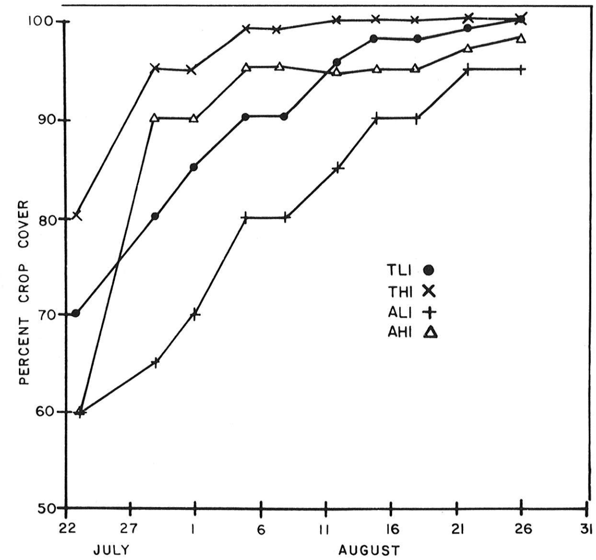

Fig. 1. Estimated percentage of soil surfaces covered by leaf canopy in dry edible bean plots in 1975. The abbreviations TLI, THI, ALI, and AHI stand for Tara low rate of irrigation, Tara high rate of irrigation, Aurora low rate of irrigation and Aurora high rate of irrigation, respectively.

TABLE 1. Leaf area index of Great Northern Tara and Aurora dry edible bean cultivars under high and low rates of irrigation in 1975

	Leaf area index[a]			
	Great Northern Tara		Aurora	
Date	High rate of irrigation[b]	Low rate of irrigation[c]	High rate of irrigation[b]	Low rate of irrigation[c]
22 July 75	2.64	1.79	1.79	1.85
29 July 75	3.76	1.83	2.86	1.89
5 Aug 75	3.56	3.12	2.93	2.24
12 Aug 75	5.16	3.09	3.56	3.41
19 Aug 75	6.34	4.34	4.82	3.33
26 Aug 75	3.54	4.66	4.00	4.23

[a]The total leaf area divided by the soil surface area.
[b]50 cm of water applied in nine applications at 5-day intervals.
[c]29 cm of water applied in five applications at 10-day intervals

TABLE 2. Severity of white mold (*Sclerotinia sclerotiorum*) of Great Northern Tara and Aurora dry edible bean cultivars under high and low rates of irrigation in 1974 and 1975

	Percent white mold[a]			
	Great Northern Tara		Aurora	
Date	High rate of irrigation[b]	Low rate of irrigation[c]	High rate of irrigation[b]	Low rate of irrigation[c]
3 Sept 74	38	18	4	0
6 Sept 75	61	17	4	0

[a]Percent of stems and foliage showing symptoms of white mold as estimated in five random 2-m samples.
[b]Forty-eight cm of water applied in five applications at 6- to 8-day intervals in 1974 and 50 cm of water in nine applications at 5-day intervals in 1975.
[c]Nineteen cm of water applied in three applications at 8- to 15-day intervals in 1974 and 29 cm of water in five applications at 10-day intervals in 1975.

samples were taken from each plot at weekly intervals. The total area of the leaves in each sample was measured with a Lambda Model LI-3100 area meter (Lambda Instruments Corp., Lincoln, NE 68504). During this same time period the percentage of the ground covered by the plant canopy was visually estimated every 3-5 days. No estimates of percent cover or LAI measurements were made in 1974. Disease severity readings were made as plants neared maturity on 3 September 1974 and 6 September 1975. The severity readings indicate the percentage of stems and foliage showing symptoms of white mold. Five random 2-m row samples were taken in each plot.

RESULTS

Plant canopy characteristics.—Plots of THI had much greater LAI values beginning from the date of the initial measurements and continuing through 19 August (Table 1). The rather dramatic decrease in LAI between 19 August and 26 August reflects the loss of leaves due to white mold. This drastic reduction was not observed in any other plot. The ALI plot generally had the lowest LAI values. Only minor differences in LAI were observed between the TLI and AHI plots.

The THI plot had substantially greater crop cover than the other plots from the initial day of measurement (22 July 1975) and maintained nearly complete crop cover after 27 July (Fig. 1). At the other extreme, crop cover never was complete in the ALI plot. The AHI plot had slightly more crop cover than the TLI plot until 11 August. After that date the TLI canopy cover was complete while the AHI plot remained at about 95% cover (Fig. 1).

Severity of white mold.—Apothecia, the initial inoculum source, were observed during the 1st wk of August. White mold symptoms were found in mid-August after the beans had flowered and begun to set pods. The highest severity of disease, 38% in 1974 and 61% in 1975 was observed in the THI plot whereas no disease occurred in the AHI plot in either year (Table 2). Moderate disease severity, 17-18%, was detected in the TLI plot while low severity, 4%, was found in the AHI plot.

Canopy air temperature.—Early in August, before complete crop cover, differences between plots in air temperature at the 10-cm height were minor although the ALI plot was approximately 1 C warmer than the other plots (Fig. 2). All plots had been irrigated shortly before measurements were made so no plant-moisture stress should have occurred on 2 and 3 August, 1974 when the canopy air temperature was measured. During the

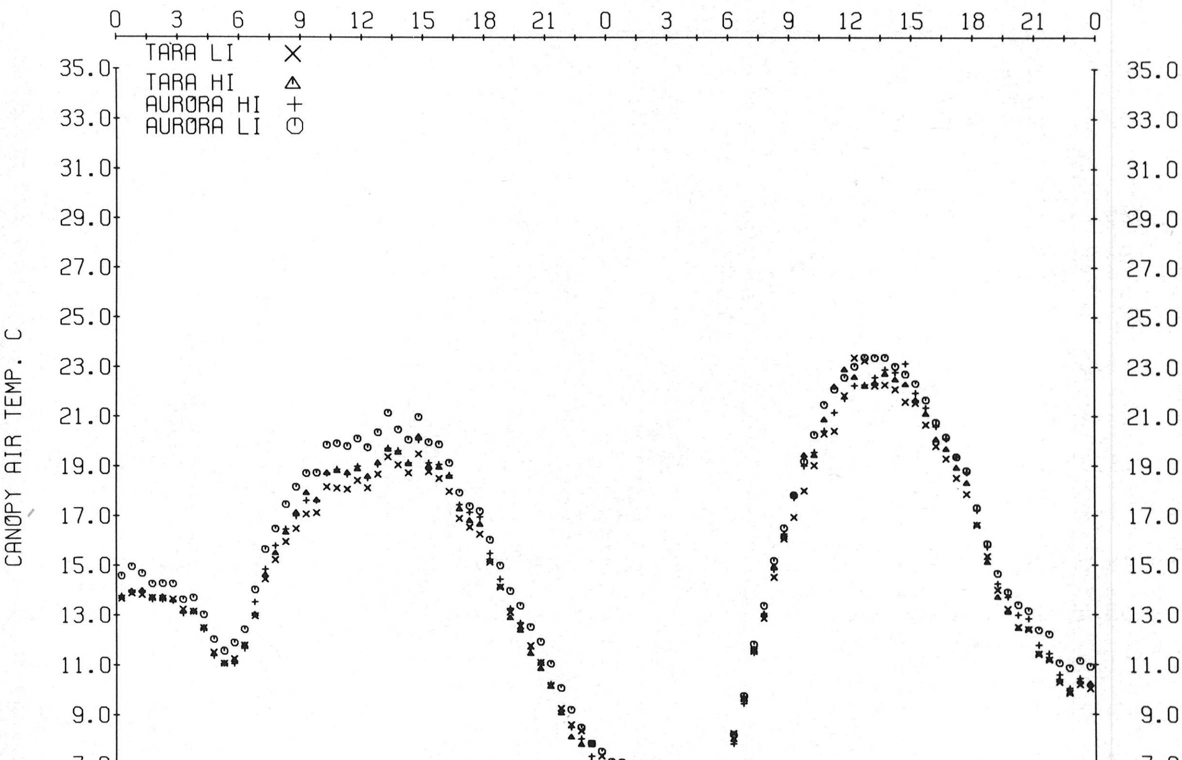

Fig. 2. Daily patterns of air temperature at 10 cm above the soil surface within four different plots of dry edible beans on 2, 3 August 1974 at Scottsbluff, NE. The abbreviations LI and HI stand for low and high rates of irrigation, respectively.

daytime on 9 August 1975 the heavily irrigated plots were as much as 7 to 8 C cooler than the less frequently irrigated plots (Fig. 3). Irrigation of all plots was begun on 8 August and completed on 9 August. It appears that plants in the less frequently irrigated plots were under moisture stress. Those in the heavily irrigated plots were not. Energy which would have been used by transpiration in nonstressed plants was used to heat the air in the TLI and ALI plots. By 10 August, plants in the TLI and ALI plots had sufficiently recovered from the stress to reduce daytime air temperature differences to 3 or 4 C. During the night, temperature differences between plots were negligible. By 23 and 24 August 1975 temperature differences between the THI, TLI, and AHI were small but the ALI plot was still 2-3 C warmer than any other plot (Fig. 4).

Canopy wetness.—Leaf wetness (dew sensors wetness) on 7, 8 August (Fig. 5) and 17,18 August (Fig. 6) 1974 are given as examples of leaf wetness patterns observed during 2 yr of study. The following general observations were made from the dew sensor measurements: (i) conditions favorable for condensation of water on the sensors was observed in each plot during almost every night of the study but the duration from night to night varied from 2 or 3 hr to more than 11 or 12 hr; (ii) the duration of dew was often 30 to 60 min longer and the amount of moisture was generally greatest in the THI plot; (iii) the duration of dew was generally shortest and of the least amount in the ALI plot (on some days no dew was observed in this plot); (iv) through mid- and late August more moisture was formed and the duration was slightly longer on sensors in the heavily irrigated plots; and (v) furrow irrigation sometimes extended the length of time the sensors remained wet (see THI data on 7 August, for example).

Plant canopy temperature.—Infrared thermometer measurements in 1975 showed no consistent differences in the plant canopy temperatures until about 25 August. Beginning then and continuing until 5 September, the THI canopy was consistently 1-5 C warmer than the TLI canopy. Differences were greatest near midday when solar radiation fluxes are greatest. The AHI canopy during the 25 August to 5 September period was less than 2 C warmer than the ALI plot.

DISCUSSION

The different amounts of white mold observed between the four bean plots could be attributed to one or both of the following factors: (i) GN Tara was genetically more susceptible to white mold than the Aurora cultivar or (ii) the microclimate, as influenced by irrigation treatment

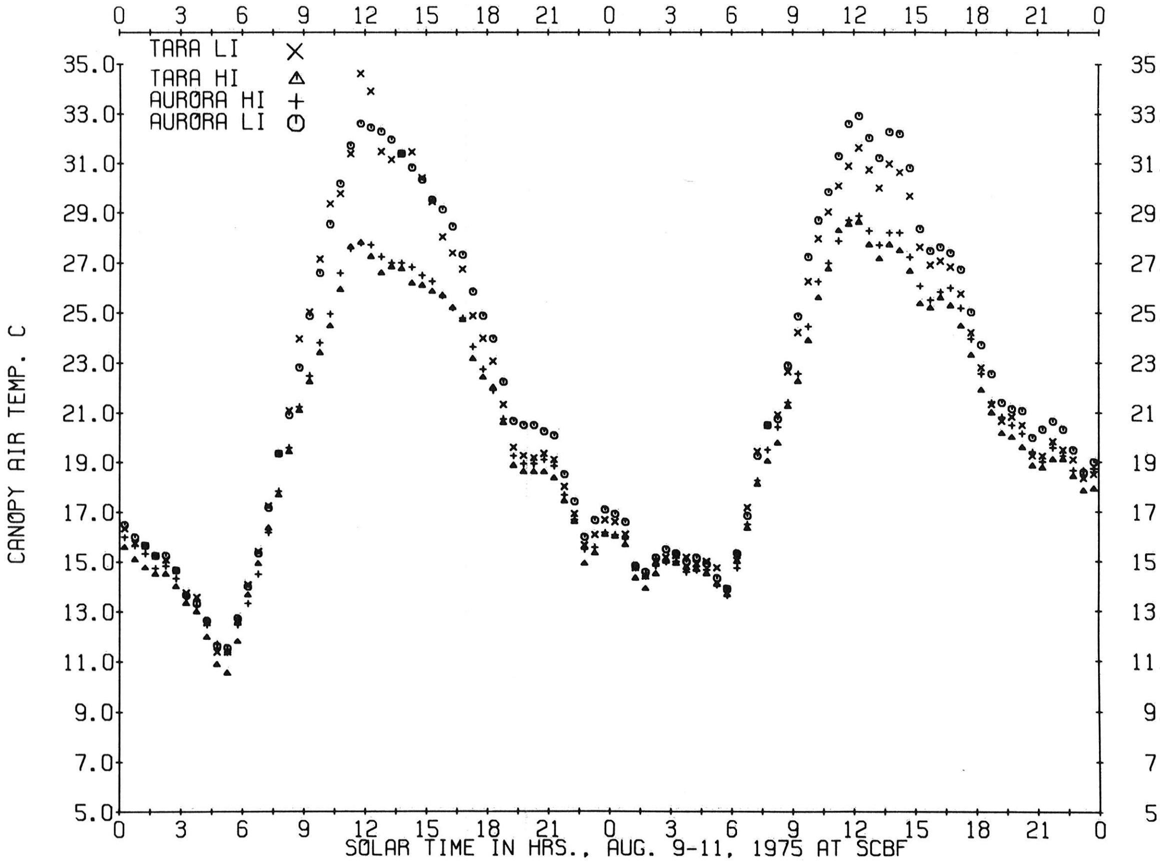

Fig. 3. Daily patterns of air temperature at 10 cm above the soil surface within four different plots of dry edible beans on 9, 10 August 1975 at Scottsbluff, NE. The abbreviations LI and HI stand for low and high rates of irrigation, respectively.

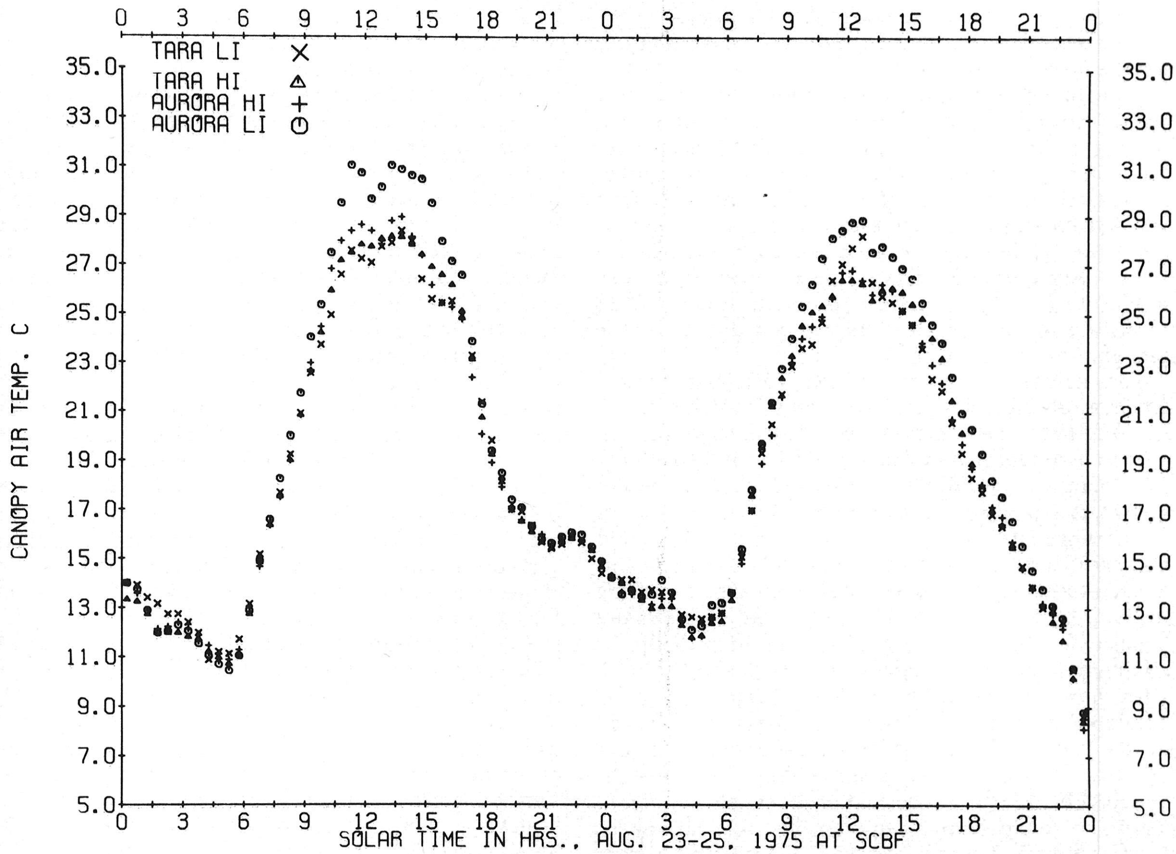

Fig. 4. Daily patterns of air temperature at 10 cm above the soil surface within four different plots of dry edible beans on 23, 24 August 1975 at Scottsbluff, NE. The abbreviations LI and HI stand for low and high rates of irrigation, respectively.

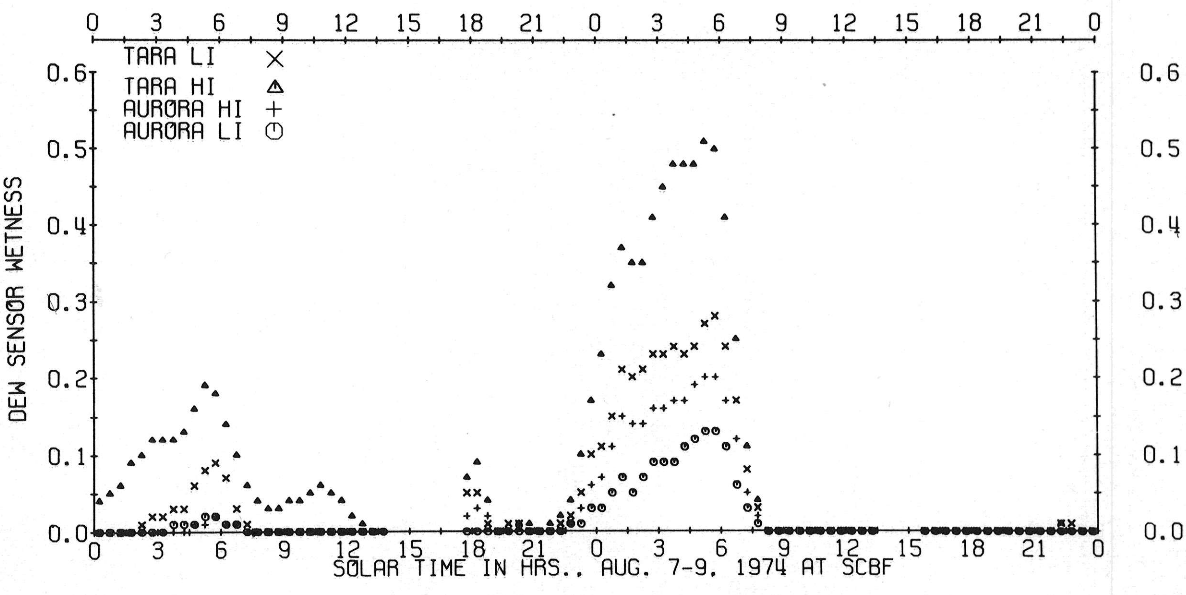

Fig. 5. Daily patterns of leaf wetness, as estimated by the amount of moisture collecting on a dew sensor (6), in four dry edible bean plots on 7, 8 August 1974 at Scottsbluff, NE. The abbreviations LI and HI are low and high rates of irrigation, respectively. (Reading of 1.0 = fully wet sensor; 0.0 = completely dry sensor.)

and canopy structure, was favorable for disease in the Tara plots, particularly THI, but was unfavorable for disease in the Aurora plots.

Cultivars of the Great Northern and Aurora type were equally susceptible to *S. sclerotiorum* at a within-row spacing of 30.5 cm, while at a spacing of 4.5 cm Aurora was tolerant and the Great Northern cultivars were susceptible (5). In a 1977 white mold nursery, GN Tara and Aurora grown at a within-row spacing of 22.5 cm did not differ significantly in disease severity (Steadman and Kania, *unpublished*). This evidence, combined with results of Coyne et al. (3), suggests that the lower amount of disease in the Aurora plots was not due to genetic tolerance in that cultivar.

The dense canopy within the THI plot created temperature and moisture conditions favorable for *S. sclerotiorum*. The maximum temperature for *S. sclerotiorum* reported by Abawi and Grogan (1) was 30 C. Steadman (*unpublished*) also found that ascospore germination and senescent blossom colonization did not occur above 30 C. Temperature within the THI plot did not exceed 30 C, while within the ALI canopy this temperature often was exceeded for several hours during the day. Leaf wetness was also of greatest duration and intensity in the THI plot but was less than the 16 hr minimum reported by Abawi and Grogan (1) for *S. sclerotiorum* infection in New York. Since white mold development did occur at leaf wetness duration of 11 to 12 hr, the Nebraska isolate of *S. sclerotiorum* may be less sensitive to water stress than the New York isolate. Sclerotia of the two isolates have been shown to differ in matric water potential requirements for carpogenic germination (7). The low severity of disease in the Aurora plots could have resulted from inadequate leaf wetness duration and high temperatures. In addition, the significant reduction of inoculum (apothecia) levels in the Aurora plots, when compared to the Tara plots reported by Schwartz (14), could have contributed to the disease differences. Since *S. sclerotiorum* populations were similar in all plots at the start of the growing season, inoculum differences are likely due to the influence of plant canopy and irrigation on soil moisture and temperature prerequisites for sclerotial germination.

The canopy structure appears to have been more important in determining the severity of infection than the level of irrigation, since the TLI plot had more disease than the AHI plot. Within a given cultivar, however, increased furrow irrigation caused increased disease.

Control of white mold in dry edible beans has not been accomplished through the breeding of cultivars which possess genetic resistance or disease avoidance characteristics nor has the use of fungicides been effective. A breeding and selection program designed to incorporate disease avoidance and genetic resistance into new cultivars is currently underway in Nebraska (4). As shown in this study, some reduction of white mold can be obtained through cultural practices, such as reducing the amount or frequency of irrigation or planting cultivars with open canopy structures, which modify the microclimate and create an environment which is less favorable for white mold development.

Even with adequate soil moisture, plants infected by *S. sclerotiorum* wilted, thus implying a decrease in transpiration rates. Under these conditions, some of the solar radiation, which would have been utilized in transpiration, was absorbed by the diseased plants and caused an increase in plant temperatures of 1 to 5 C. Further evidence that diseased plants were warmer than healthy plants was obtained by Blad, Gardner, and Pike (*unpublished*) through measurements made over THI and TLI plots on 2 and 3 September 1977. For example, they observed that near solar noon on 2 September 1977, the temperature of heavily diseased plants (>50% severity) was about 29 C, that of moderately diseased

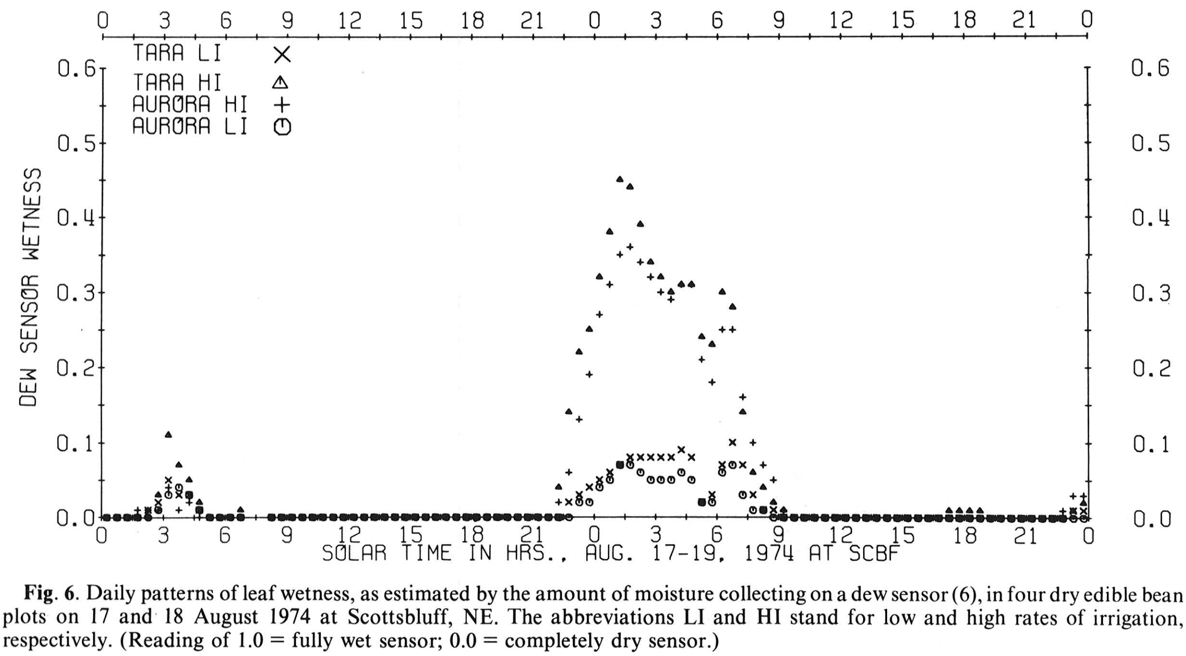

Fig. 6. Daily patterns of leaf wetness, as estimated by the amount of moisture collecting on a dew sensor (6), in four dry edible bean plots on 17 and 18 August 1974 at Scottsbluff, NE. The abbreviations LI and HI stand for low and high rates of irrigation, respectively. (Reading of 1.0 = fully wet sensor; 0.0 = completely dry sensor.)

plants (~ 20% severity) was about 26 C, and the temperature of healthy plants was about 24 C.

The availability of multispectral scanners to provide surface temperature measurements from airborne or satellite platforms offers the potential for surveying large acreages to detect white mold damage before the bean crop reaches maturity. Such crop temperature data, when used in conjunction with aerial photography or with visible or near-infrared imagery, already successfully used to detect white mold in peanuts (11) and bacterial blight in field beans (15), may be used to detect and evaluate the severity of disease in agricultural crops.

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