# Fungicide Efficacy and Yield Responses to Fungicide Treatments Based on Predictions of Cercospora Leaf Spot of Sugar Beet[1]

**E.D. Kerr and A. Weiss**

*Professor, Panhandle Research and Extension Center, University of Nebraska, Scottsbluff, NE 69361-9655; and Associate Professor, Department of Agricultural Meteorology, University of Nebraska, Lincoln, NE 68583-0728, respectively.*

## ABSTRACT

**Number of hours of leaf wetness on sugar beet foliage and average leaf surface temperature during the period of leaf wetness were determined by a leaf wetness sensor and an infrared thermometer (LWS/IRT), respectively, connected to an automated weather station. Hours of relative humidity >90% and canopy air temperature were determined by a hygrothermograph (HYG). The two methods were compared for determination of daily infection values (DIVs) judged favorable, marginal, or unfavorable for Cercospora leaf spot development during late July and August of 1986 and 1987. Low levels of leaf spot severity (<1% of leaf area) adjacent to the weather station in 1986 fit favorably with infection predictions based on the LWS/IRT data. Leaf spot severity was <3% near the weather station in 1987 although favorable conditions for infection were indicated by both measuring systems. However, in an adjacent field sheltered on three sides, leaf spot severity developed to 50%. Fungicide application dates in 1986 based upon predictions by LWS/IRT data and first symptom appearance provided significantly (P=0.05) lower disease severity than a nontreated control in a plot area near the weather station. In 1987 one fungicide application following disease predictions based upon both the LWS/IRT and HYG systems provided control equal to three biweekly applications starting with first appearance of symptoms. Cercospora leaf spot infection predictions based upon weather data provide for effective timing of fungicide application in years of significant disease development and for avoidance of unnecessary use of fungicides when conditions are unfavorable for infection.**

[1]Published as Paper No. 9202, Journal Series, Nebraska Agricultural Research Division.

**Additional Key Words:** *Beta vulgaris* L., *Cercospora beticola* Sacc., leaf spot advisories, daily infection values

Cercospora leaf spot (*Cercospora beticola* Sacc.) is a common and destructive foliage disease of sugar beet (*Beta vulgaris* L.) and the closely related table beet, mangel, and Swiss chard. *C. beticola* also infects a wide range of weed species (Nyvall, 1989; Ruppel, 1986).

Cercospora leaf spot has been a serious production problem in some years in various areas of central United States, as well as sugar beet growing regions of Europe. Fungicides have been used for control of the disease since the 1920s and 1930s (LeClerg, 1935). In California, Cercospora leaf spot was not of economic importance in furrow irrigated sugar beet fields, but after growers turned to sprinkler irrigation, medium to severe epidemics occurred (Paulus, et al, 1971). The disease was particularly serious in eastern and central Nebraska in the l960s and fungicides were applied routinely in affected areas as the principal method of control. Spray schedules were initiated following detection of symptoms with applications repeated at regular intervals (Weihing and Finkner, 1968; Wysong, et al, 1968). Most fungicides registered for use on Cercospora leaf spot have provided satisfactory control. Cercospora leaf spot became a serious disease in some areas of the North Platte Valley of western Nebraska during the early 1980s. Growers adopted fungicide spray schedules similar to those used in eastern Nebraska as a preventive disease control program. Additional applications of fungicide were made assuming that the disease would increase in severity. In some years, disease did not progress as anticipated and the cost of fungicide application for leaf spot control was unnecessary. A system was needed for predicting the most efficient timing of fungicide application.

Pool and McKay (1916b) reported that a temperature of 27-32°C, with a minimum night temperature (preferably not below 16°C) was most favorable for conidial production and that a maximum relative humidity ranging above 60% for not less than 15-18 hr each day induced good growth of the fungus. Pool and McKay (1916a) also showed that penetration of the leaf by germinating conidia of *C. beticola* only occurred through open stomata, and consequently, infection occurred during the day. Furthermore, good stomatal opening was obtained at temperatures ranging from 21-32°C and stomata remained open during the day if relative humidity remained above 60% but usually closed if it was much below 50%. Their work assumed that plants are not drought stressed and thus, stomata remain open during the day.

More recently, Wallin and Loonan (1971) showed that duration of leaf wetness and air temperature influenced incubation period and disease severity. In several experiments, spore suspensions of *C. beticola* were sprayed on 3-wk-old seedlings in the 4-leaf stage; leaf wetness periods ranged from 10 to 72 hr after inoculation, and temperatures ranged from 10 to 29$^{o}$C. The number of spots produced after a 48 hr moist period was more than 30 times the number produced after a 24 hr moist period, and 29$^{o}$C was more favorable than lower temperatures for leaf spot development. Building on this effort, Shane and Teng (1984) investigated a broader range of temperature and moisture effects on infection. They combined their results with Wallin and Loonan's data to develop a table of daily infection values (DIVs). The range of DIVs is an arbitrary scale from 0 to 7 with 0 representing unfavorable conditions and 7 indicating optimum conditions for infection, respectively. They developed an advisory system where DIVs with a cumulative total of 7 or more on 2 consecutive days were considered favorable for infection, 6 was marginal, and less than 6 was unfavorable. Their data are based on relative humidity >90% and air temperature measured with a hygrothermograph (HYG). In 1986 and 1987 we modified their system using data collected from an automated weather station placed in a sugar beet field. In place of relative humidity and air temperature data (measured by a hygrothermograph), leaf wetness and canopy temperature were measured by a leaf wetness sensor (Weiss and Lukens, 1981) and an infrared thermometer. Predictions based on DIVs calculated with these sensors were used for a daily advisory for growers in 1987 after testing the system in 1986. For daily advisories, the leaf wetness and canopy temperature system was more convenient than the HYG system because the automated weather station could be accessed via a telephone line, which was not possible with the HYG system (Weiss and Kerr, 1989).

The objectives of this research were to compare relative humidity and air temperature vs leaf wetness and canopy temperature in determining DIVs; leaf spot severity after occurrence of favorable DIVs; and times of fungicide application based upon DIVs vs the conventional grower practice of spraying when the first leaf spots are observed.

## MATERIALS AND METHODS

Fungicide efficacy field tests conducted in the North Platte Valley during 1983-85 provided a preliminary comparison of leaf spot severity ratings to occurrences of high relative humidity and/or warm night temperatures. The tests were located on farms with histories of severe leaf spot disease. The

1983 and 1984 tests near Scottsbluff and Bridgeport, respectively, were both within 5 km of National Weather Service observer stations, from which minimum daily temperatures were obtained for July through September. The 1985 test near Bridgeport was equipped with a hygrothermograph at canopy level and DIVs were calculated for the same time period by the method of Shane and Teng (1984). The most effective fungicide treatment was selected for comparison to a nontreated control to indicate the effect of leaf spot severity on root yield. Fungicide data were chosen from one of seven treatments in 1983 and 1984 and from one of 14 treatments in 1985. Fungicide treatments, rates applied, and statistical methods are described in Table 1. Though benomyl fungicide was included among the treatments in those tests, resistance of *C. beticola* to benzimidazoles reported in other sugar beet production regions (Ruppel and Scott, 1974; Georgopoulos and Dovas, 1973) had not yet been a problem in western Nebraska. Fungicides were applied on 3, 17 August and 9 September 1983; 31 July, 15, 24 August and 10 September 1984; and on 8, 26 August and 9 September 1985. Sugar beet roots were harvested 12 October 1983, 10 October 1984, and 2 October 1985.

Experimental areas for 1986 and 1987 were located on a farm near Lyman, NE, about 8 km south of the North Platte River. These areas had a history of severe Cercospora leaf spot on sugar beet during the early 1980s. The soil was McCook loam with <1% slope. Fields were furrow-irrigated with surface water. A 2-yr rotation of corn and sugar beets had been used in recent years. Sugar beet variety MonoHy 55, moderately resistant to *C. beticola*, was grown in row spacings of 56 cm and the plants were hand-thinned to approximately 23 cm in-row spacing in both years.

In 1986, the experimental area was sheltered 100 m to the north by trees and 45 m to the west by corn. In 1987 trees were 100 m to the north and corn 50 m to the southeast.

An automated weather station was placed in the center of the experimental areas on 10 July 1986 and 1 July 1987 following final ditching for furrow irrigation. There were no disease symptoms a week after installing the weather station so it is assumed weather conditions had not been favorable for infection prior to installation. Initial symptoms of Cercospora leaf spot are seldom observed in the North Platte Valley before mid-July. Parameters measured every 5 min included: leaf wetness (Weiss and Lukens, 1981), air temperature, relative humidity (Phys Chem PCRC-11 relative humidity sensor, N.Y., N.Y.), and precipitation. Canopy temperature was measured every 15 min with an infrared thermometer (Model 4000, Everest Interscience, Inc., Tustin, CA) facing south at a height of 3 m and at a zenith angle of approximately 25 degrees. The leaf wetness sensor was placed in the top 10% of canopy height and changed in response to changes in canopy height. Hourly averages were calculated and stored for later transmission to a central computer. Both values of DIVs were calculated for 24 hr periods, from noon to noon, encompassing uninterrupted leaf wetness periods that occurred during the night. More details on this instrumentation are given in Weiss and Kerr (1989).

In addition, a HYG was placed in a louvered instrument shelter set on the soil surface beside the automated weather station to record air temperature and relative humidity. These data were collected and processed at weekly intervals on a daily noon to noon basis.

The DIVs based on the number of hours of leaf wetness and the canopy temperature during the periods of leaf wetness were compared to DIVs calculated from hours of relative humidity >90% and air temperature during these periods as recorded by the HYG.

Leaf spot occurrence was monitored approximately three times per week in a plot adjacent to the weather instruments. The severity percentage was determined by inspecting 20 randomly selected plants for average number of spots per leaf per plant and converting those values to an estimated percent of leaf area affected. Progress of disease severity was compared to dates of marginal and favorable DIVs.

Plots were established near the weather station in 1986 and 1987 to determine the relative success of controlling Cercospora leaf spot with fungicide application dates based on DIVs calculated from the automated weather station data versus appearance of visible symptoms (conventional method used by growers) of the disease. A randomized complete block design with six replications was used and each plot consisted of three rows 7.6 m long (56 cm between rows). In 1986, application dates were 24 July following two successive DIVs totaling 8, and on 9 August following the detection of first leaf spot symptoms in the plot area (severity = 0.07% leaf area). No treatment was made for hygrothermograph data. Triphenyl tin hydroxide (TPTH) fungicide was applied at 0.339 kg ai/ha with a backpack-type Solo sprayer with a fan type nozzle at a pressure of 138 kPa in 187 L of water/ha. Leaf spot ratings and root harvest were done on 25 September. Roots were hand-harvested from a 6 m length of the center row. Clean root weight and percentage sugar were determined by the Western Sugar Company. Statistical interpretation of data was by analysis of variance and single degree of freedom orthogonal comparisons of means.

The 1987 fungicide test utilized the same procedures as in 1986 except application date treatments were changed and treatments were replicated five times. Treatments were 1) nontreated control; 2) applications following the first 2-day cumulative DIV $\geq 7$ based on leaf wetness sensor/infrared thermometer (LWS/IRT) data, 27 July; 3) first leaf spot symptom appearance (severity = 0.074% leaf area), 27 July, and repeated 14 and 28 August; and 4) application following the first 2-day cumulative DIV $\geq 7$ based on HYG data, 7 August. Treatment 4) was delayed a few days because of extremely wet field conditions. A hailstorm on 4 September destroyed some of the older leaves and the leaf spot severity ratings on 29 September were based on the remaining mature leaves. Sugar beet roots were hand-harvested from a 4.6 m length of the center row of each plot.

**Table 1.** Preliminary Cercospora leaf spot fungicide studies[†] relating the number of nights with temperatures or daily infection values favorable for infection to disease severity, fungicide control, and root yields for 1983, 1984, and 1985.

| No. nights favoring infection | Fungicide and rate (kg ai/ha) | Leaf spot rating No. of spots (% severity) | | Fresh root yield (t/ha) |
|---|---|---|---|---|
| **1983** | | | 13 Sept. | |
| 21 d (19 July-19 August)[‡] | Benomyl + mancozeb (0.28+1.33) | | 5 (0.2) | 58.64 |
| | Control | | 173 (7.0) | 47.26 |
| | F[¶] | | 75.83 ** | 5.21 * |
| **1984** | | 24 Aug. | 10 Sept. | |
| 21 d (19 July-24 August)[‡] | Triphenyl tin hydroxide | 28 (1.2) | 38 (1.5) | 41.08 |
| | Control | 56 (2.3) | 101 (4.0) | 36.90 |
| | F | 1.60 NS | 7.36 ** | 1.48 NS |
| **1985** | | 9 Sept. | 23 Sept. | |
| 5 d (30 July-2 August, and 15 August)[§] | Mancozeb (1.79) | .25 (0.01) | 1.00 (0.04) | 31.25 |
| | Control | 2.00 (0.08) | 4.00 (0.16) | 28.08 |
| | F | 0.73 NS | 1.08 NS | 1.01 NS |

[†]Comparison of the most effective fungicide used in a field test to a nontreated control.
[‡]Nights with low temperatures $\geq 16.7^{\circ}C$ judged favorable for infection.
[§]Favorable nights with daily infection values $\geq 7$ totaled over two consecutive days (Shane and Teng, 1984).
[¶]F test values for single degree of freedom orthogonal comparison of means;
*, **, and NS indicate significance at $P<0.05$, $P<0.01$, and not significant, respectively. F values for leaf spot ratings are based on the number of spots per leaf.

## RESULTS AND DISCUSSION

Prior to the automated weather station experiments, the fungicide efficacy tests were based upon several applications at intervals of approximately 10-14 days. In the 1983-1985 series of fungicide trials, leaf spot was maintained at low levels by repeated fungicide applications over a period of 6-8 wk (Table 1). In both 1983 and 1984 there were 21 days of temperatures favorable (warm nights) for infection occurring over 4-5 wk (late July through August). In 1983, root yields were 11 t/ha greater in the fungicide-treated plots than in the nontreated controls where leaf spot was rated at 7% severity based on spot counts in mid-September. In 1984, leaf spot was only moderately severe (2.3 and 4%, respectively, in control plots on 24 August and 10 September) and fungicidal control did not result in a significantly greater root yield or sugar content. The 1985 data showed a very low severity of leaf spot (0.16% in control plots in mid to late September) following only one series of four favorable DIVs at the end of July plus one more on 15 August. Initial leaf spots were observed during the first week of August and did not develop further because of unfavorable environmental conditions.

These observations indicate that conditions during certain years are favorable for development of severe Cercospora leaf spot in the semiarid climate of western Nebraska and that yields can be reduced significantly. These data encouraged further field research utilizing automated weather stations to form a basis for predicting favorable times for infection and for application of fungicides.

LWS/IRT data were compared to HYG temperature and relative humidity (>90%) data for determination of DIVs during mid-July through August in 1986 and 1987. The DIVs for the 1986 comparison were presented by Weiss and Kerr (1989). They calculated four marginal and two favorable DIVs from HYG data but none from leaf wetness and infrared temperature data from 11-27 August. The average daily duration of relative humidity >90% was 1.9 hr longer than the average period of leaf wetness (13.8 and 11.9 hr, respectively). The average air temperature measured by the HYG was 2.2°C higher than the canopy temperature (17.8 and 15.6°C, respectively) determined during the periods of high relative humidity and leaf wetness, respectively.

By contrast, in 1987 (Table 2) 8 days of marginal and favorable DIVs were calculated from the number of hours duration of leaf wetness and infrared canopy temperature compared to 10 days calculated from HYG data on relative humidity >90% and air temperature. The average daily duration of relative humidity >90% was 11.7 hr compared to 15.6 hr of leaf wetness. Average air temperature measured by the HYG was 18.4°C and the average infrared canopy temperature was 17.5°C during periods of high relative humidity and leaf

**Table 2.** A comparison of leaf wetness and canopy temperatures (as measured by a leaf wetness sensor and an infrared thermometer) with relative humidity (RH) and air temperatures (as measured by a hygrothermograph) for determination of daily infection values (DIVs) for *Cercospora beticola* on sugar beet at Lyman, NE, 1987.

| | Leaf wetness and canopy temperature | | | Hygrothermograph RH and air temperature | | |
|---|---|---|---|---|---|---|
| Date (noon to noon) | Duration of leaf wetness (hr) | Mean canopy temperature (C) | DIV | Duration of >90% RH (hr) | Mean air temperature during >90% RH (C) | DIV |
| 22-23 July | 18 | 16.1 | 1 | 16 | 19.6 | 4 |
| 23-24 July | 16 | 19.7 | 4 | 9 | 21.3 | 2† |
| 24-25 July | 12 | 20.3 | 3‡ | 2 | 17.8 | 0 |
| 25-26 July | 15 | 18.3 | 4‡ | 7 | 19.2 | 2 |
| 26-27 July | 15 | 17.4 | 3‡ | 14 | 21.2 | 4† |
| 27-28 July | 15 | 16.9 | 1 | 8 | 17.8 | 0 |
| 28-29 July | 16 | 18.9 | 4 | 11 | 17.6 | 3 |
| 29-30 July | 18 | 21.3 | 5‡ | 13 | 19.1 | 3† |
| 30-31 July | 20 | 20.3 | 5‡ | 16 | 19.4 | 4‡ |
| 31 July-1 Aug. | 17 | 18.9 | 4‡ | 10 | 17.3 | 2† |
| 1-2 August | 15 | 17.1 | 3‡ | 12 | 17.1 | 2 |
| 2-3 August | 14 | 17.8 | 3† | 8 | 17.4 | 2 |
| 3-4 August | 19 | 16.3 | 1 | 9 | 12.9 | 0 |
| 4-5 August | 16 | 16.1 | 0 | 16 | 19.2 | 4 |
| 5-6 August | 14 | 18.2 | 3 | 7 | 19.2 | 2† |
| 6-7 August | 14 | 15.7 | 0 | 18 | 19.0 | 4† |
| 7-8 August | 21 | 15.8 | 2 | 18 | 18.0 | 5‡ |
| 8-9 August | 17 | 13.4 | 0 | 14 | 16.6 | 1† |
| 9-10 August | 12 | 15.4 | 0 | 12 | 17.9 | 3 |
| 10-11 August | 8 | 15.2 | 0 | 14 | 19.8 | 3† |
| Cumulative favorable and marginal | | | 8 | | | 9 |

†Sum of two consecutive DIVs = 6 and judged marginal for infection.
‡Sum of two consecutive DIVs = 7 or more and judged favorable for infection.

wetness, respectively. Favorable and marginal conditions for infection occurred at various times from 23 July to 11 August, 1987 approximately 3 wk earlier than in 1986.

Distribution of periods favorable for infection are shown in Table 2. The DIVs calculated from the LWS/IRT indicate two multiday periods favorable for infection while the DIVs calculated from the HYG data indicates three 1-day periods and two multiday periods favorable for infection. From 27 July until 3 August the two methods to calculate DIVs are in relative agreement. From 5-9 August, the HYG data indicate DIVs marginal or favorable for infection while the LWS/IRT data indicate DIVs unfavorable for infection.

In 1986, data also displayed similar characteristics between the two measuring systems (Weiss and Kerr, 1989); the LWS/IRT data showed DIVs appearing in consecutive groups, i.e., 2-day cumulative DIVs of 2, 4 and 2 on 11, 12 and 13 August, respectively, and 4 and 4 on 19 and 20 August, respectively. The HYG data took on an oscillating nature, i.e., favorable cumulative DIVs on 12 and 13 August, but marginal DIVs on 17 and 18 July, 17, 19, 25 and 26 August. The LWS/IRT measuring system was more conservative than the HYG system for making inputs in DIVs. Because there have been few comparisons of these two systems, prediction needs confirmation from field observations. In 1986 leaf spot symptoms were first detected at a 0.05% severity on 4 August. Perhaps this indicates a relationship of initial infection to the marginal DIVs on 17 and 18 July based on HYG data. The severity level remained below 0.1% until 29 August, then gradually increased to 0.64% by 8 September. The low level of disease development was a slow response to the two favorable and four marginal DIVs occurring from 12 to 26 August based upon HYG data, but no increase in disease was predicted based upon the LWS/IRT data.

**Table 3.** A comparison of Cercospora leaf spot development in the weather data collection area and in nearby field sheltered with trees and corn field windbreaks and supporting a higher initial inoculum level, 1987.

| | Percent leaf spot severity† | |
|---|---|---|
| Date | Experimental area | Adjacent field |
| 22 July | 0.00 | -- |
| 31 July | 0.01 | 1.66 |
| 6 August | 0.04 | 4.02 |
| 14 August | 0.27 | 9.56 |
| 20 August | 1.27 | 18.44 |
| 24 August | 2.55 | 20.68 |
| 28 August | 0.93 | 37.96 |
| 31 August | 0.75 | 41.48 |
| 3 September | -- | 50.00 |

†Percent severity is mean rating of 20 plants selected at random in a 10 x 10m area.

In 1987 (Table 2) during the period of 23 July to 11 August meteorological conditions were favorable for infection as indicated by both the LWS/IRT and HYG measuring systems. During this period, leaf spot severity showed an increase from zero to a maximum of only 0.27% (Table 3). In the following 2 wk, leaf spot severity increased to 2.55% even without marginal or favorable conditions. The increase in disease severity may have been due to expansion of established infections. The 2.55%

severity was a peak rating for a single date that was based on inclusion of a few randomly selected plants that were 12% severity and not represented in later rating dates. Nevertheless, those plants indicated a dramatic increase from zero disease severity recorded for 23 July. Although both measuring systems indicated favorable microclimate conditions during 1987, the low carry-over of inoculum from the previous season likely accounted for low leaf spot severity.

In a field 300 m from the weather station, the same sugar beet cultivar as grown in the experimental field was sheltered by corn on the north side and trees along a drainage ditch on the east and south side; this area also had a slightly higher inoculum level (as determined by disease severity in adjoining sugar beets the previous year). Leaf spot severity developed in that field to 10% by 14 August, to 21% by 24 August, and to 50% by 3 September (Table 3). Leaf spot severity in the weather station area peaked at only 2.55% on 24 August. These observations indicate the significance of local variation; large differences in infection occurred between small distances because of differing microclimates and/or levels of inoculum. The rapid increase in leaf spot severity in the nearby field followed predictions of increased infection indicated by the two measuring systems (Table 2). Under favorable conditions conidia may be produced from new infections within 10 days (Lamey et al.., 1982). Thus, a warm August may be favorable for rapid disease development.

The advisory system developed by Shane and Teng (1984), based on meteorological conditions necessary for initial infection, makes no assumption about the levels of initial inoculum although they point out that inoculum available for infection is an equally important consideration. Thus, meteorological conditions may be favorable, but infection may not occur if inoculum pressures are low.

In the semiarid conditions of the North Platte Valley, leaves usually remain wet for long periods of time because of frequent irrigation, but the limiting meteorological factor often is the canopy temperature.

Fungicide applications to field plots near the weather stations were designed to compare season-long disease control and yield of sugar beets with different dates of application based on leaf spot prediction information. In 1986, fungicide application dates were based on a single favorable day (24 July) calculated by the LWS/IRT system, and on 9 August based on the time of first symptom appearance in the plot area. Unfortunately, the 9 August application was a 5 day delay because of wet field conditions from irrigation. Comparisons of preharvest leaf spot severity ratings are reported in Table 4. Leaf spot symptoms developed slowly the remainder of the season but the disease ratings were significantly lower following the 24 July (LWS/IRT system) fungicide application than for the 9

**Table 4.** Single degree of freedom orthogonal comparisons of means of Cercospora leaf spot severity ratings following fungicide application on dates based on DIVs calculated from the leaf wetness sensor and infrared thermometer (LWS/IRT) favorable for infection and by first symptom appearance (FSA) in the field, 1986.

| Application date comparisons[†] | No. spots/leaf x proportion of leaves infected[‡] | Sum of squares |
|---|---|---|
| Control vs LWS/IRT and FSA | 3.37 vs 2.19 | 5.52 NS |
| LWS/IRT vs FSA | 0.15 vs 4.23 | 50.02* |
| | | (Error mean square = 7.73) |

*, NS indicate significant at $P = 0.05$ and not significant, respectively.
[†]Application dates based on LWS/IRT and FSA were 24 July and 9 August, respectively.
[‡]Means of six replications.

**Table 5.** Single degree of freedom orthogonal comparisons of means of Cercospora leaf spot severity ratings following fungicide application on dates based on the sum of two consecutive DIVs calculated from data from the leaf wetness sensor and infrared thermometer (LWS/IRT) and from RH>90% and air temperatures from hygrothermograph (HYG) data, and three applications at 2 week intervals starting with first symptom appearance in the field, 1987.

| Application date comparisons[†] | Severity ratings[‡] | Sum of squares |
|---|---|---|
| Control vs all fungicide treatments | 2.70 vs 0.63 | 16.017** |
| LWS/IRT and HYG vs symptom appearance | 0.65 vs 0.60 | 0.0008 NS |
| LWS/IRT vs HYG | 0.60 vs 0.70 | 0.025 NS |
| | | Error mean square = 0.840 |

**, NS indicate significant at P = 0.01 and not significant, respectively.
[†]Application dates based on LWS/IRT and HYG data were on 27 July and 7 August, respectively. Applications following first symptom appearance were 27 July, 14 August, and 28 August.
[‡]Severity ratings are percent of leaves infected and means of five replications.

August (first symptom) application. The 5-day lag for the 9 August application may have contributed in part to the higher disease rating. Although the 24 July application provided excellent control of leaf spot (ratings of 0.15 vs 3.37 in the nontreated control based on number of spots/leaf x proportion of leaves infected), the low maximum level of disease in the plot area did not result in significant differences in sugar yield among treatments.

In 1987, fungicide application dates were based on the LWS/IRT system, the HYG system, and "first symptom appearance." Since LWS/IRT and HYG data indicated favorable conditions over a short time, only a single fungicide application was made. For the "first symptom appearance," applications were repeated twice at 14-day intervals, which is rarely necessary in western Nebraska but used in this case for full-season protection. Preharvest leaf spot severity rating comparisons are shown in Table 5. Leaf spot severity was low throughout all treatments, but the nontreated control was rated significantly higher than all fungicide treatments collectively; 2.70 and 0.63% of leaves were infected, respectively. There were no significant differences in leaf spot severity among fungicide application dates; 0.60, 0.60, and 0.70% of leaves were infected for "first symptom appearance," LWS/IRT and HYG, respectively. The two extra applications of fungicide on the "first symptom" treatment provided no added benefit in disease control. There were no significant differences in sugar yield, and would not be expected at such low disease severity. In the fungicide tests conducted in 1983 to 1985 significant yield losses were obtained in fields with mid- September leaf spot severities of 7% (Table 1).

During 1986 and 1987, when these field investigations were conducted, Cercospora leaf spot was a minimal problem in most of the North Platte Valley. In 1986, the HYG data predicted favorable and marginal periods for infection during August while the LWS/IRT system predicted none. The 1987 data from both systems indicated more disease development than actually occurred in the open field around the instrument location. However, both systems accurately predicted increased disease incidence in a nearby field that had greater protection from air movement and an additional source of moisture from a drainage ditch along one side of this field (Table 3). The advantage of the LWS/IRT system is the ability to get decision making information to a grower in a timely manner compared to the HYG approach, although accurate measurement of environmental parameters is the primary issue. However, compared to a traditional HYG-approach, automated weather stations also can be fitted with relative humidity and temperature sensors which can be placed in the canopy. Although the two types of data may occasionally vary in DIVs, each is useful for prediction of infection and to provide advisories to growers. Thus, growers with fields in areas with conditions favorable for disease development would have benefited from the leaf spot advisory in late July and early August of 1987. Growers who were surveyed to estimate the usefulness of predictions in their management of leaf spot in disease-intense areas have indicated that spray advisories have been a valuable service (Weiss and Kerr, 1989).

Until recently, Cercospora leaf spot was not generally of economic importance in what is now the major sugar beet production area of western Nebraska. Based on our measurements, meteorological conditions favorable for infection occurred on nights with canopy temperatures greater than 16.7$^{o}$C, as leaf wetness was not limiting. Scheduling irrigations for cooler periods may be one method to ameliorate the effects of this disease.

## ACKNOWLEDGEMENTS

We wish to thank Jerry Schmidt for his assistance in setting up and programming the weather station and Lynne Landon for technical assistance. We also thank Don Lind for providing a field location for the study, for his excellent cooperation in conduct of the study, and his special attention to care of the sugar beet crop. Partial funding for this research was supplied by the Western Sugar Company—Grower Joint Research Committee, Inc.

## LITERATURE CITED

Georgopoulos, S. G., and C. Dovas. 1973. A serious outbreak of strains of *Cercospora beticola* resistant to benzimidazole fungicides in Northern Greece. Plant Dis. Rep. 57:321-324.

Lamey, H. A., A. W. Cattanach, and W. M. Bugbee. 1982. Cercospora leaf spot of sugarbeet. Cir. PP-764, Coop. Ext. Ser., N. D. State Univ.

LeClerg, E. L. 1935. Dusting and spraying experiments for the control of sugar beet leaf spot in southern Minnesota. Phytopathology 25:234-243.

Nyvall, R. F. 1989. Field Crop Diseases Handbook. Van Nostrand Reinhold, New York, New York. 817 pp.

Paulus, A. O., O. A. Harvey, J. Nelson, F. Shibuya, and A. H. Holland. 1971. Control of Cercospora leaf spot of sugarbeet under sprinkler irrigation. Plant Dis. Rep. 55:449-452.

Pool, V. W., and M. B. McKay. 1916a. Relation of stomatal movement to infection by *Cercospora beticola*. J. Agric. Res. 5:1011- 1038.

Pool, V. W., and M. B. McKay. 1916b. Climatic conditions as related to *Cercospora beticola*. J. Agric. Res. 6:21-60.

Ruppel, E. G. 1986. Foliar diseases caused by fungi: Cercospora leaf spot. *In* E. D. Whitney and J. E. Duffus (eds.). Compendium of Beet Diseases and Insects. APS Press, St. Paul, Minnesota. 76 pp.

Shane, W. W., and P. S. Teng. 1984. *Cercospora beticola* infection prediction model presented. Sugar Producer 10:14-15, 19.

Wallin, J. R., and D. V. Loonan. 1971. Effect of leaf wetness duration and air temperature on *Cercospora beticola* infection of sugar beet. Phytopathology 61:546-549.

Weihing, J. L. and R. E. Finkner. 1968. Fungicidal control of sugar beet leaf spot. Sta. Bull. 502, Univ. Nebr. Agric. Expt. Sta., Lincoln, Nebraska. 14 pp.

Weiss, A., and E. D. Kerr. 1989. Evaluating the use of pest management information by growers: an example using Cercospora leaf spot of sugar beet. Appl. Agric. Res. 4:168-172.

Weiss, A., and D. L. Lukens. 1981. Electronic circuit for detecting leaf wetness and comparison of two sensors. Plant Dis. 65:41-43.

Wysong, D. S., M. L. Schuster, R. E. Finkner, and E. D. Kerr. 1968. Chemical control of Cercospora leaf spot of sugarbeets in Nebraska, 1965. J. Am. Soc. Sugar Beet Technol. 15:221-227.