Influence of Primary Weather Variables on Sorghum Leaf Blight Severity in Southern Africa

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ABSTRACT

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A study was conducted on the effect of climatic factors (rainfall, minimum and maximum air temperature) on severity of leaf blight over several locations and years in southern Africa. The weather data used were from 2 wk before sowing to 3 wk after sowing. Temperature was the most important variable predicting disease severity after dough stage of the crop. High disease severities coincided with minimum temperatures between 14 and 16 C and mean temperatures of 20.8 to 22.2 C. Low severity at dough stage of the sorghum or absence of leaf blight was associated with minimum temperatures above 16 C from 2 wk before sowing to 3 wk after sowing. Discriminant analysis conducted using temperature from very early in the season correctly classified 88% of the cases into three disease severity categories: no, low, and medium-to-high disease. Therefore, primary weather variables, in particular air temperature, may be valuable predictors of disease severity early in the season. These results may be used to identify and map disease levels for large areas using past temperature data.

Additional keywords: disease prediction, *Exserohilum turcicum*, *Sorghum bicolor*.

Leaf blight caused by *Exserohilum turcicum* (Pass.) Leonard & Suggs is a cosmopolitan disease of sorghum (*Sorghum bicolor* (L.) Moench) (5), which can reduce yields (up to 45%), seed quality, and forage quantity and quality (15). Documentation on the distribution and the importance of the disease in southern Africa is incomplete.

The fungal pathogen may survive as mycelia, conidia, or chlamydospores in infected crop residues on the soil surface or in the soil (3,6,14). Diseased plant residues appear to be a more important source of infection than the conidia (14). Conidia probably are carried long distances by the wind and can result in secondary spread within and between fields (3). The abundance of inoculum in southern Africa is not documented nor is anything known about fitness differences among pathogen populations (10). Fitness is the ability of a leaf blight isolate to develop when conditions for development are optimal.

The climate during the sorghum growing season appears to have an influence on leaf blight disease development. Most of the work conducted on leaf blight has concentrated on maize (*Zea mays* L.). Meredith (13) observed that, on days following rain, conidia are released as the morning sun dries the foliage (that is, 40% are discharged between 0800 and 1200 hr). Benedict (1) reported that photoperiod, light, temperature, and rainfall influence disease progress. Berger (2) developed a system to forecast northern leaf blight based on the blight favorable hours (that is, the number of hours for which temperature is >15 C and relative humidity is >90%). During the growing season, disease development is encouraged by moderate temperatures (18–27 C) and heavy dews and hindered by dry conditions (7). In China, conidial production on diseased maize residue occurred at air temperatures of 10–35 C and the optimum was 15–20 C (14). In sweet corn, lesion development was negatively associated with photoperiod, light intensity, and leaf sugar content (11). Classification of areas by potential leaf blight risk would aid sorghum growers in making better management decisions such as the best time to sow and irrigate and what cultivars to sow to avoid disease risk, reducing potential losses and saving time and money. Classifying areas where disease is likely to be severe also would aid researchers to identify suitable sites for screening new cultivars for disease resistance.

The objective of this study was to determine whether data about climatic variables such as rainfall and temperatures (available through the Department of Meteorology within each country) could be used instead of data about soil moisture and soil temperature (which are not usually available) to predict disease severity. If any of these variables proved to be useful predictors or classifiers of leaf blight severity, future studies could be planned using these variables over more locations and on specific cultivars.

MATERIALS AND METHODS

Collection field data. Disease assessments were made for several years (1985 through 1988) at various sites in several of the countries in southern Africa: namely, Malawi, Swaziland, Tanzania, Zambia, and Zimbabwe. Several factors were noted: site and country, sowing date, and leaf blight severity. The severity of leaf blight (percentage of total leaf area affected) was scored initially on a scale of 0–100%. These scores then were reduced to three levels or categories: no disease = 0%; low disease = <20%; medium-to-high disease = ≥20%. Disease was recorded by location over several cultivars including standard susceptible checks (Red Swazi, Framida, and hybrid DC 99). Climatic data recorded by the Department of Meteorology within each country at stations nearest to the nurseries under study were used for these locations and years. In southern African countries, rainfall and temperature data are more reliable and consistent than other variables, and, therefore, they were used in this study.

Daily rainfall and maximum and minimum temperatures were collected for 16 observations (eight different sites with one or more years for each site). Weekly total rainfall and average weekly daily maximum and minimum temperatures were computed for each of the 5 wk from 2 wk before sowing to 3 wk after sowing. This time period was chosen in hopes of predicting disease severity early in the season.

Data analysis. An initial divisive classification analysis using the TWINSPAN computer program (9) was conducted to see if the observations could be separated or grouped based on the weather variables and, if so, if these groupings corresponded to disease severity. In addition, this analysis was used to see which, if any, climatic variables were of importance to the groupings.

Discriminant analysis (16) was conducted to classify the 16 observations into three disease levels or categories: 1 = no disease, 2 = low disease, 3 = medium-to-high disease for each location using the climatic variables. The BMDP statistical software was used for the analysis (4). The climatic variables and weekly time periods that were the most closely associated with disease level were selected by trying all reasonable subsets and choosing the one that gave the highest probability of correct classification using the least number of variables (8). The best variable subset determined by this procedure was used to derive the discriminant functions. Two methods were used to evaluate the discriminant functions by calculating error rates. The apparent error rate is the proportion of cases that are misclassified when all cases are used to compute the discriminant functions (12). The jack-knife or leave-one-out error rate is the proportion of cases misclassified when each case is omitted, in turn, from the discriminant function calculations and tested according to the discriminant functions computed from all other observations. Posterior probabilities of group membership for each observaton also were calculated. These comprise a measure of the confidence with which the discriminant functions classify each observation (4).

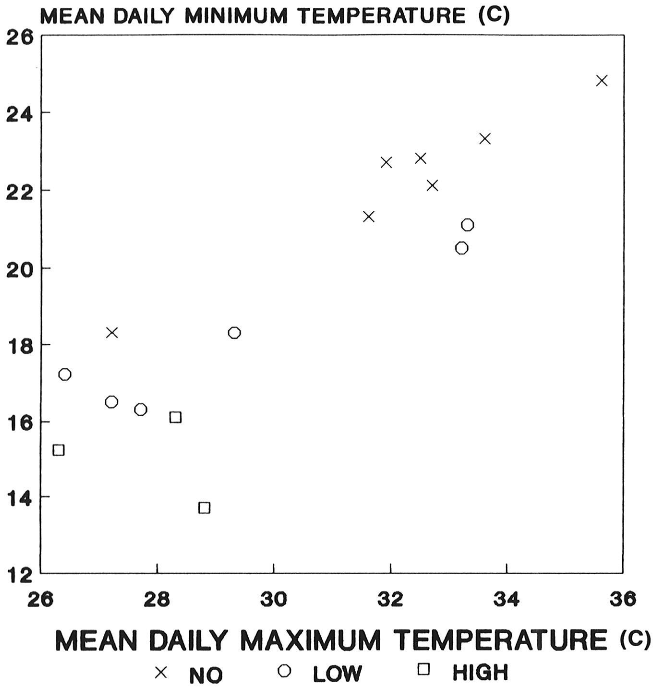

Fig. 1. Average daily maximum and minimum temperatures (C) and their relative disease levels for 16 observations over a 5-wk period (2 wk before to 3 wk after sowing) in southern Africa.

RESULTS

High incidence of leaf blight appeared to be associated with low temperatures; all three observations with high disease severity had mean minimum temperatures below 16.1 C, whereas the remaining 13 observations with no or low disease were associated with mean maximum and minimum temperatures above 26.4 and 16.1 C, respectively (Fig. 1). This observation was the first indication that temperature could be a useful predictor of leaf blight severity.

When climatic factors (average minimum and maximum temperature and total rainfall) were subjected to the TWINSPAN classification analysis, the observations generally separated out according to leaf blight severity. The three medium/high observations and one low observation immediately split off from the remaining group of mixed low and no disease. In most cases, minimum and maximum temperature had the most impact on the classification splits.

Selection of the best subset of variables for discriminant analysis resulted in two climatic variables of most importance: average daily maximum temperature for 1 wk (X_1) after sowing and average daily minimum temperature at 2 wk after sowing (X_2). The linear discriminant functions (D) based on these two variables can be written as:

$$D = -87.97 - 2.08(X_1) + 10.67(X_2) \text{ (group on level 1)}$$
$$D = -58.09 + 0.69(X_1) + 5.10(X_2) \text{ (group on level 2)}$$
$$D = -50.16 + 2.43(X_1) + 1.75(X_2) \text{ (group on level 3)}$$

Classification of each case based on these functions is given in Table 1. These functions also can be used to classify new cases into the disease level categories. The apparent error rate was 0, whereas the leave-one-out method misclassified two observations (=12%). No observations predicted disease levels more than one category off the actual level. Most (88%) of the posterior probabilities for correct group membership were >0.88 (Table 2). Two observations had posterior probabilities of 0.72 and 0.59; both were misclassified observations made with the jack-knife method.

DISCUSSION

The relationship between leaf blight severity and overall mean of daily minimum and maximum temperatures and average daily maximum temperature over a 5-wk period, for the 16 observations in the southern African region, showed that medium-to-high and low severity could occur at similar temperatures (Table 1, Fig. 1). However, low severity, or absence of leaf blight, was mostly associated with overall mean temperatures above 22 C and

TABLE 1. Average maximum, minimum, and overall temperatures (C), two discriminant analysis variables X_1 and X_2, and relative disease levels for 16 observations over a 5-wk period (2 wk before to 3 wk after sowing) in southern Africa

		Average temperatures			Discriminant variables		
Location, country	Date of sowing	Maximum	Minimum	Mean	X_1	X_2	Disease level
Kasinthula, Malawi	15 Dec. 1985	31.9	22.7	27.3	32.3	23.1	no
Kasinthula, Malawi	20 Jan. 1987	32.7	22.1	27.4	31.0	22.1	no
Kasinthula, Malawi	30 Nov. 1987	33.3	21.1	27.2	35.1	21.2	low
Malkerns, Swaziland	13 Dec. 1985	26.4	17.2	21.8	25.7	16.0	low
Malkerns, Swaziland	19 Nov. 1986	27.2	16.5	21.8	26.7	17.5	low
Ilonga, Tanzania	15 Feb. 1986	33.2	20.5	26.8	33.0	20.3	low
Ilonga, Tanzania	2 Feb. 1987	31.6	21.3	26.5	31.7	21.8	no
Henderson, Zimbabwe	4 Dec. 1985	26.3	15.3	20.8	27.8	16.7	high
Henderson, Zimbabwe	19 Nov. 1986	28.8	13.7	21.2	29.7	16.0	high
Henderson, Zimbabwe	10 Jan. 1988	28.3	16.1	22.2	28.4	16.4	high
Matopos, Zimbabwe	21 Dec. 1985	27.7	16.3	22.0	25.8	16.9	low
Ngabu, Malawi	15 Dec. 1986	33.6	23.3	28.5	33.4	23.9	no
Ngabu, Malawi	30 Dec. 1987	35.6	24.8	30.2	31.7	24.3	no
Ngabu, Malawi	21 Dec. 1984	32.5	22.8	27.6	31.9	22.5	no
Makoka, Malawi	5 Jan. 1987	27.2	18.3	22.7	26.5	19.0	no
Mt. Makulu, Zambia	11 Dec. 1987	29.3	18.3	23.8	29.0	16.6	low

TABLE 2. Actual and predicted classification[a] of 16 observations (locations and years) in southern Africa according to the severity level of sorghum leaf blight caused by *Exserohilum turcicum*, together with the posterior probability of group membership (*P*)

Location, country	Year	Disease level Actual	Prediction	*P*
Kasinthula, Malawi	1985–86	no	no	1.00
Kasinthula, Malawi	1986–87	no	no	0.99
Kasinthula, Malawi	1987–88	low	low	0.88
Malkerns, Swaziland	1985–86	low	low	0.72
Malkerns, Swaziland	1986–87	low	low	0.98
Ilonga, Tanzania	1985–86	low	low	0.93
Ilonga, Tanzania	1986–87	no	no	1.00
Henderson, Zimbabwe	1985–86	high	high	0.59
Henderson, Zimbabwe	1986–87	high	high	1.00
Henderson, Zimbabwe	1987–88	high	high	0.92
Matopos, Zimbabwe	1985–86	low	low	0.98
Ngabu, Malawi	1986–87	no	no	1.00
Ngabu, Malawi	1987–88	no	no	1.00
Ngabu, Malawi	1984–85	no	no	1.00
Makoka, Malawi	1986–87	no	no	0.92
Mt. Makulu, Zambia	1987–88	low	low	0.98

[a]Classification based on average maximum and minimum temperatures 2 wk before sowing to 3 wk after sowing (see Table 1).

minimum temperatures above 16 C. There were no locations represented in this study with mean temperatures between 23 and 25 C or below 20 C, maximum temperatures below 26 C, and minimum temperatures below 15 C. Locations with these temperatures need to be included in future studies. High and medium severities occurred at overall mean temperatures over a 16-wk period below 22 C, and low severities occurred at mean temperatures of 22–28 C and with mean maximum temperatures up to 33.5 C. These relatively long-term means correspond well with temperature ranges mentioned for sorghum leaf blight by Frederiksen (6) of 18–27 C. The China data for maize (range 10–35 C, optimum 15–20 C) covered a supplementary temperature range but also indicated that leaf blight can develop to temperatures up to 34 C. Our data agreed with the finding of Berger (2) regarding favorable temperatures (above 15 C), provided an upper limit was given (Fig. 1).

Our study investigated the use of easily obtained and measured weather variables to predict leaf blight severity. The various analyses (classification and discriminant) conducted on the data have shown that temperature was the most important variable in differentiating observations and in successfully classifying observations into disease level categories. The discriminant analysis correctly classified all of the observations.

Sowing dates were from 19 November to 15 February, and photoperiods were approximately between 11 and 13 hr. The variables photoperiod (short days) and light intensity (cloudiness during the rains) may have had a positive effect on leaf blight development (13). From Levy's findings (10) it appears to be necessary to study whether there are differences in fitness among pathogen populations in the region. It also may be necessary to study the effect of photoperiod and light intensity on fitness.

Rain was not as critical as temperature in classifying leaf blight level, probably because of specific association. At temperatures favorable for leaf blight development after rain, leaf wetness periods may have been long; whereas at high temperatures unfavorable for leaf blight development, leaf wetness may have been too short. Obviously, at favorable temperatures without leaf wetness, there would be no leaf blight development but also no or poor crop development. Further validation of the discriminant model is necessary by increasing the number of locations and years. Future studies should use a single susceptible sorghum or a limited number of sorghums grown over all sites along with the corresponding climatic data. Scoring on a cultivar basis instead of over all cultivars, as was done in this study, may be both more reliable and of better predictive value. However, even with the present data base, the predictive value was high.

In this study, we were interested in disease severity under dryland conditions, under which sorghum normally is grown. Originally, we had several observations of crops that received supplemental irrigation (*unpublished*). We found that, when these data were used in the discriminant analysis, the majority was misclassified, probably because irrigation affected soil temperature independently of air temperature. We believe that this needs further study and have excluded all observations with supplemental irrigation.

If the discriminant model continues to hold true after further validation using better scoring techniques on single cultivars, then leaf blight disease severity could be predicted for a location by the second week after sowing. At this time, highly affected areas could be resown to a different crop or measures could be taken to try and control the disease (high input farming). Areas of high risk might be identified, which would be beneficial to farmers as well as to researchers who could use such areas for screening new cultivars for leaf blight resistance or susceptibility. Potential disease levels for large areas could be identified and mapped using past temperature data. The most important aspect of this study is the implication that certain primary climatic variables, in particular air temperatures, may be valuable predictors of disease risk very early in the season. This could be of economic benefit to sorghum growers in southern Africa and possibly other parts of the world.

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