Relationships Among Late Leafspot, Healthy Leaf Area Duration, Canopy Reflectance, and Pod Yield of Peanut

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ABSTRACT

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Experiments were conducted to investigate the relationships among disease severity, canopy reflectance, healthy leaf area duration, and pod yield of peanut. For Florunner, a cultivar susceptible to late leafspot (caused by *Cercosporidium personatum*), pod yield in 1988 and 1989 decreased as the duration of healthy leaf area (HAD) decreased. Several levels of cumulative stress from disease (estimated by the HAD) were obtained by periodic sprays of four rates of the fungicide chlorothalonil. Canopy reflectance at 800 nm decreased as disease severity and defoliation increased during the season. Regression of reflectance against green leaf area gave coefficients of determination (R^2) of 0.77 in 1988 and 0.95 in 1989 for Florunner and 0.87 in 1989 for Southern Runner. The pod yield of Florunner was reasonably predicted from HAD for all treatments except the untreated control. The prediction model was developed earlier by averaging the loss of pods that accompanied a delay in harvest of 78 crops of Florunner. The original model was then modified with a scaling factor for maturity of the crop at harvest. The yields predicted from HAD with the newly scaled model were within 11% of the actual yield of Florunner in 1988 and 1989. The yield predicted with the model for Southern Runner, a cultivar known to produce more foliage and to partition proportionately less photosynthate to the pods than Florunner, was overestimated by an average of 18%. Modification of the model parameters to account for the lower partitioning of photosynthate for Southern Runner brought the average predicted pod yields within 6% of the actual yields. The HAD-yield relationship may be used to estimate the relative, radiation-use efficiency of a peanut cultivar.

Additional keywords: *Arachis hypogaea*, leaf area index, multispectral radiometer.

Late leafspot, caused by the fungus, *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton, is the predominant foliar disease of peanut (*Arachis hypogaea* L.) in Florida. Late leafspot can cause severe defoliation and reduced pod yield (2,9,24). Without adequate disease control, over 50% of the yield may be lost (23,24). These losses have been attributed to a reduction in the leaf area index caused by leaf necrosis and defoliation. Reduction in light interception and canopy photosynthesis due to defoliation leads to decreased pod growth and increased pod loss (3,7,15–17,25).

Studies involving crop loss assessment often make use of the quantitative relationship between disease intensity and yield (12,20). Several crop loss prediction models based on disease severity have been developed (20). For certain crops such as wheat, potatoes, and peanut, yield has been related to the duration of healthy leaf area (27). This may be a more relevant parameter to utilize than the proportion of diseased tissue or disease incidence. Waggoner and Berger (26) proposed the concept of relating yield to healthy leaf area duration (HAD), which is the integral of healthy leaf area during the season, and to a related variable, healthy leaf area absorption (HAA), which is the amount of insolation absorbed by the healthy leaf area. They successfully demonstrated the concepts for crops such as peanut, potatoes, corn, and wheat. With data from previous studies, they showed that the simple concepts of HAD and HAA can be used to predict yield of manually defoliated and leafspot-defoliated peanut.

Bourgeois (6) tested the concepts of HAD and HAA to predict pod yield in the peanut cultivar Florunner. He found the concept acceptable only when the crop was treated with fungicides. Although Bourgeois (6) measured yield and HAD for five harvest dates in each of two seasons, he chose only the harvest date in each season that was the optimum for the sprayed treatments to test the relationship of HAD to yield. The unsprayed treatments with severe leafspot and defoliation had an earlier optimum harvest date, consequently his choices of harvest dates were biased against the unsprayed treatments. Bourgeois suggested that potential yield should have been used in the computations of predicted pod yield instead of the harvested yield, because time of harvest (in relation to crop maturity) affected harvestable yield. Measurements of healthy leaf area have been used for studies of crop loss in other pathosystems such as late blight of potato (19), take-all of winter wheat (10), and the combination of early blight, Verticillium wilt, and leafhopper damage in potato (13).

Measurement of leaf area is very tedious and often requires destructive sampling. An alternative approach to quantify disease intensity is through the use of radiometric techniques. Nutter (15) reported that the percentage of reflectance from a peanut crop canopy at a 800-nm wavelength provided a rapid and objective means to measure disease intensity. He suggested that this measurement may be representative of the amount of green leaf area (GLA). However, the leaf area index was not determined in that study. In other studies, researchers demonstrated the use of spectral radiometry to determine the severity of disease (21) and to estimate defoliation (11).

Florunner is a peanut cultivar that is susceptible to late leafspot. Florunner defoliates rapidly when leafspot becomes severe, and it replaces very few leaves. Pixley et al (16) reported that three peanut genotypes with resistance to late leafspot lost leaf area similar to Florunner but maintained a higher leaf area index because of sustained leaf production until maturity. One of the genotypes in their tests was later released as the cultivar Southern

Runner. Florunner partitions about 92% of its assimilate to pods during the reproductive growth stages. In contrast, Southern Runner only partitions about 80% of assimilate to pods (17).

The objectives of this study were to determine the relationships among disease severity, canopy reflectance, healthy leaf area duration, and pod yield and to find out if yield is simply determined by the duration of healthy leaf area.

MATERIALS AND METHODS

Field experiments. Field experiments were conducted during the peanut-growing seasons in 1988 and 1989 at the North Florida Research and Education Center, Marianna, Florida. Similar agronomic and cultural practices for peanut production were carried out for both seasons, except that no nematicide was used in 1988 because of the close proximity to a well. The nematicide aldicarb (2.35 kg ai ha^{-1}) was applied in 1989. Other cultural practices conformed to those recommended by extension specialists for growing peanuts in the area (14). Six-row plots were used; each row measured 6.1 m long with 0.91-m centers. Yield was determined from the center rows (rows 3 and 4) in each plot. Measurements of irradiation reflectance and leaf area index were made on rows 2 and 5. The 1988 peanut crop received irrigation from overhead sprinklers, whereas the 1989 peanut crop was irrigated with a center-pivot system. The amount of water from rainfall and irrigation and the daily temperatures during each season are shown in Figure 1.

During the 1988 cropping season, the susceptible cultivar, Florunner, was planted on 5 May in a randomized complete block design with four replications. To establish several classes of disease levels, spray treatments of chlorothalonil were used. Six treatments of fungicide were applied at 14-day intervals as follows: standard spray program initiated 35 days after planting (1.0× rate of chlorothalonil); an unsprayed control and four treatments initiated at 1% leafspot incidence (0.13×, 0.25×, 0.5×, and 1.0×, in which × is the recommended rate of 1.75 L/ha of chlorothalonil

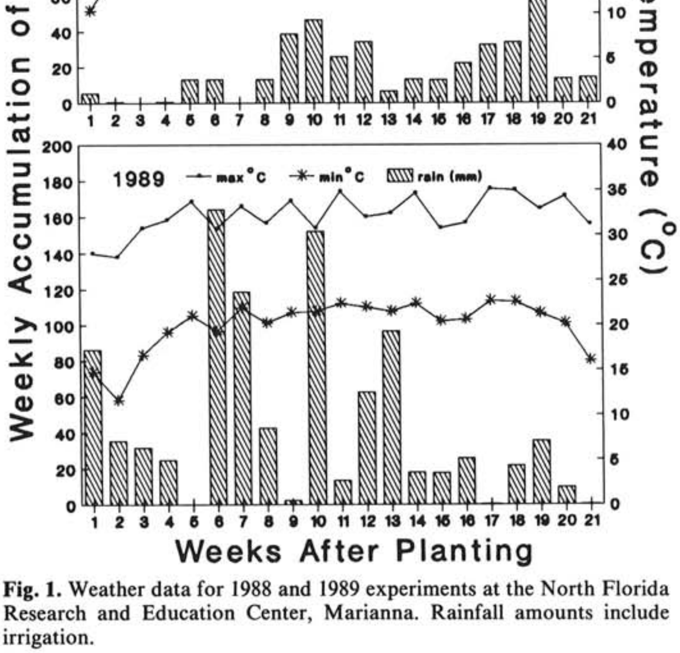

Fig. 1. Weather data for 1988 and 1989 experiments at the North Florida Research and Education Center, Marianna. Rainfall amounts include irrigation.

[720 g ai/L, flowable formulation]). Plants were inspected weekly to determine when 1% of the leaves had at least one leafspot (1% incidence). To ensure establishment of a late leafspot epidemic, inoculum was introduced by applying infested peanut plant debris 1 mo after peanuts were planted. Approximately 50 g of chopped peanut stems from the previous year's crop were scattered on the sixth row of each plot. The experimental areas for both years had not been planted with peanut for the two previous seasons. Fungicide applications were made both years by using a CO_2-powered, tractor-mounted sprayer equipped with three hollow cone (D2-45) nozzles per row at 2 kg/cm^2 of pressure.

Peanut plots were dug on 27 September 1988 by using a digger-shaker-inverter. After pods were dried in windrows for 3 days, they were harvested with a two-row combine and dried to 10% moisture content for determination of pod yields.

In the 1989 experiment, two cultivars were used: Florunner, a susceptible cultivar, and Southern Runner, a cultivar with moderate resistance to late leafspot. Both cultivars were planted on 15 May 1989 in a split-plot randomized complete block design with cultivars as main plots and fungicide treatments as subplots. Five fungicide treatments were applied on 14-day intervals as follows: standard treatment beginning 35 days after cultivars were planted; an unsprayed control; and three treatments initiated at 0.5% leafspot incidence (0.25×, 0.5×, 0.75×, in which × is the recommended rate of chlorothalonil). Plots of Florunner were harvested on 29 September 1989, and Southern Runner was harvested on 12 October 1989. Pod yield was determined as in the previous year.

Disease assessments. Disease assessments were made at 10- to 12-day intervals beginning 55 days after Florunner was planted in 1988 and 52 days after cultivars were planted in 1989. Severity of late leafspot was based on a combined measurement of percentage of necrotic area and percentage of defoliation (16). Visual assessment of percentage of necrotic area was estimated by using a standard leafspot diagram (22) and was based on a weighted average of three canopy layers (16). Percentage of defoliation was obtained by counting the number of nodes with missing leaflets and the total number of nodes on the stem of five randomly selected plants. Total disease severity was obtained by integrating visible disease (percentage of necrotic area) with defoliation by using the equation (18):

$$y_t = [(1 - d)y_v] + d \quad (1)$$

in which y_t represents total disease severity, y_v is the proportion of visible disease (percentage of necrotic area), and d is the proportion of defoliation. Severity values were logistically transformed (4) and subjected to analysis of variance for each assessment. The apparent infection rate was considered as the slope of the linear regression line of logit (Y) on time when time was the independent variable.

Radiometric measurements. The amount of sunlight reflected from peanut canopies was measured throughout the season at 10- to 12-day intervals. Percentage of reflectance at the 800-nm wavelength was monitored by using a handheld multispectral radiometer (Cropscan, Inc., Fargo, ND). Measurements of percentage of reflectance were taken from a height of approximately 1.9 m above the peanut canopy. The support pole of the radiometer sensor was leaned over the plots, and a bubble spirit level (attached to the main module) was used to ensure that the sensor was at a right angle to the plane of view. Sample readings from two inner rows in each plot were automatically averaged and recorded. Readings were made between 1100 and 1500 h EST.

Leaf area index and HAD. Leaf area index was measured eight times during the season for both years by using the method of Foster et al (8). Whole plants from 0.91-m lengths of row were harvested from rows 2 or 5 of each plot. The ratios of leaf mass to fraction leaf (specific leaf areas) were measured on single plants that had been separated from each 0.91-m (row length) sampling area. Leaf areas of the subsampled single plants were measured with a leaf area meter (Li-Cor, Inc., Lincoln, NE). The total dry weights (biomass) of plants in the sampling area (including the subsampled single plants) were determined. The leaf area index was calculated as specific leaf area × fraction of leaf × biomass.

GLA was computed based on the equation (26):

$$\mathrm{GLA}_i = (1 - y_i)L_i \quad (2)$$

in which y_i is the proportion of diseased or necrotic area and L_i is leaf area index of sample i. Percentage of reflectance at 800 nm was regressed against the GLA to determine the relationship.

HAD was calculated by using the equations given by Waggoner and Berger (26):

$$\mathrm{HAD} = \Sigma \{[(1 - y_i)L_i + (1 - y_{i-1})L_{i-1}]\,(t_i - t_{i-1})/2\} \quad (3)$$

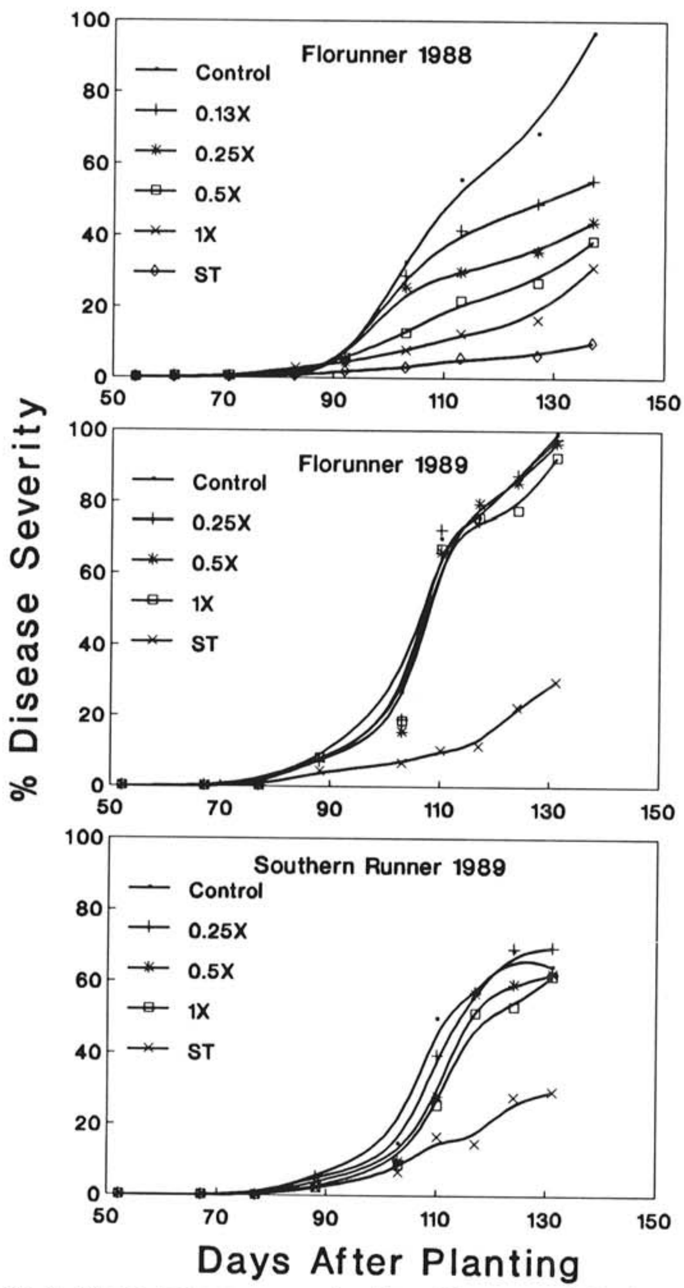

Fig. 2. Disease progress on peanut cultivars Florunner and Southern Runner. Disease severity levels were attained with fungicide dosages: ST = standard treatment; 1× rate of chlorothalonil applied beginning 35 days after cultivars were planted; 0.13×, 0.25×, 0.5×, 0.5×, 0.75×, and 1× rates were applied beginning at 1% disease incidence in 1988 and 0.5% disease incidence in 1989. Treatments were applied on 14-day intervals.

in which y_i, L_i, t_i are, respectively, the proportion of diseased area, the leaf area index, and the time of sampling in days. This model was developed for the relationship of yield to HAD, in which the loss of pods that occurred with any delay in harvest beyond optimum maturity was averaged over 78 crops of Florunner.

Predictions of pod yield with HAD were made for the original model by using the equation developed by Waggoner and Berger (26):

$$\mathrm{Yield}\ (\mathrm{g/m^2}) = 735{*}\exp\{-3.15{*}\exp[-0.00821{*}(\mathrm{HAD} - 93.71)]\} \quad (4)$$

A new model was developed for Florunner and Southern Runner in our study, because the original model was developed from a wide range of crop maturities at harvest, and we harvested at or near optimum maturity. The derivation of new HAD-yield models were accomplished with nonlinear, least squares regression by the software described by Berger (5). Predicted yield of harvested pods was statistically compared to actual yield by using Student's t test.

RESULTS

Disease progression. Early leafspot caused by *Cercospora arachidicola* Hori occurred early in the season both years. However, severity of early leafspot was negligible, and late leafspot quickly became the predominant disease. The disease progress curves for cultivars Florunner and Southern Runner are shown in Figure 2.

In 1988, the rate (r) of disease progress for the unsprayed control was 0.108 logits day^{-1} compared to the rate ($r = 0.04$) for the sprayed standard treatment. The standard treatment was initiated 35 days after the cultivar was planted, at which time the disease had not yet appeared. The epidemic rates for the other treatments in which spray was initiated at 1% disease incidence were 0.06 (0.13×), 0.06 (0.25×), 0.05 (0.5×), and 0.05 (1.0×).

In 1989, the rate of disease progress for untreated Florunner was $r = 0.15$, whereas the rate for the standard treatment was 0.05. The epidemic rates for treatments 0.25×, 0.5×, and 0.75× were 0.15, 0.14, and 0.12, respectively. Compared to untreated Florunner, the rate of disease progress for untreated Southern Runner was much less ($r = 0.09$). The standard treatment for Southern Runner had an epidemic rate of 0.05. The rates for the other treatments were slightly slower than the untreated control (0.08 each for the 0.25×, 0.5×, and 1.0× treatments).

Leaf area. The changes in leaf area index for Florunner in 1988 and 1989, and for Southern Runner in 1989 are presented in Figure 3. During the 1988 season, there were no differences in leaf area index of Florunner among the treatments until 100 days after the cultivar was planted. Plants receiving the standard treatment had a leaf area index of 3.8 at 113 days after being planted and 4.25 by 137 days after being planted. This was significantly higher ($P \leq 0.05$) than the leaf area index for the other treatments.

The peanut crop in 1989 attained a higher leaf area index than the crop in 1988. For both Florunner and Southern Runner, the differences in leaf area among treatments became evident after 88 days after the cultivars were planted. In 1989, plants of Florunner with the standard spray treatment reached a maximum leaf area index of 5.0 at 110 days after being planted. Plants of Southern Runner that received the standard treatment attained a maximum leaf area index of 6.1 at 103 days after being planted. Plants of Southern Runner that received the 0.75× treatment maintained a leaf area index of >2.0 until about 120 days after being planted. For all the other spray treatments and the unsprayed control, the leaf area index of both cultivars declined drastically over time in 1989 as late leafspot became severe. A leaf area index >2.0 was maintained up to harvest only on plots that received the standard spray treatment.

GLA and percentage of reflectance. Reflectance values for the Florunner crop at 800 nm were initially lower in 1988 than in

1989 (Fig. 4). The 1989 crop had better vegetative growth and greater leaf areas when leafspot was maintained at a low level. Percentage of reflectance values generally decreased as disease severity and defoliation increased during the season. For plots with the standard treatment, values remained relatively similar throughout the season. During 1989, reflectance of Florunner plots receiving the standard treatment was significantly different from the other five treatments at 114 days after the cultivar was planted. Percentage of reflectance for Southern Runner was higher than that of Florunner for all treatments. Curve fitting by using multiple regression indicated that the best fit between GLA and percentage of canopy reflectance for both cultivars was obtained by using the quadratic functions (Fig. 5). Coefficients of determination (R^2) were 0.77 in 1988 and 0.95 in 1989 for Florunner, and 0.87 in 1989 for Southern Runner.

HAD and pod yield. Greater HAD values were obtained in 1989 than in 1988, because both cultivars attained a higher leaf area index that year. Predictions of yield with the HAD model were very good for Florunner with good disease control (standard treatment) in 1988 and 1989 (Table 1). Deviations of predicted yield from actual yield were 6.1% in 1988 and 8.4% in 1989 for the standard treated plots. These varied from 1.9 to 23.2% for the 1.0×, 0.75×, and 0.5× treatments for Florunner. Greater deviations from predicted pod yields (40.9% in 1988 and 32.8% in 1989) were observed from plots that received no fungicide. Yields were underestimated by the general model. Because the scale parameter (−93.71 HAD) in the original model was for yield averaged over a range of maturities of the crops at harvest, a new scale parameter was developed. The new scale parameter (−55.47 HAD) was derived by nonlinear curve fitting (5) to predict

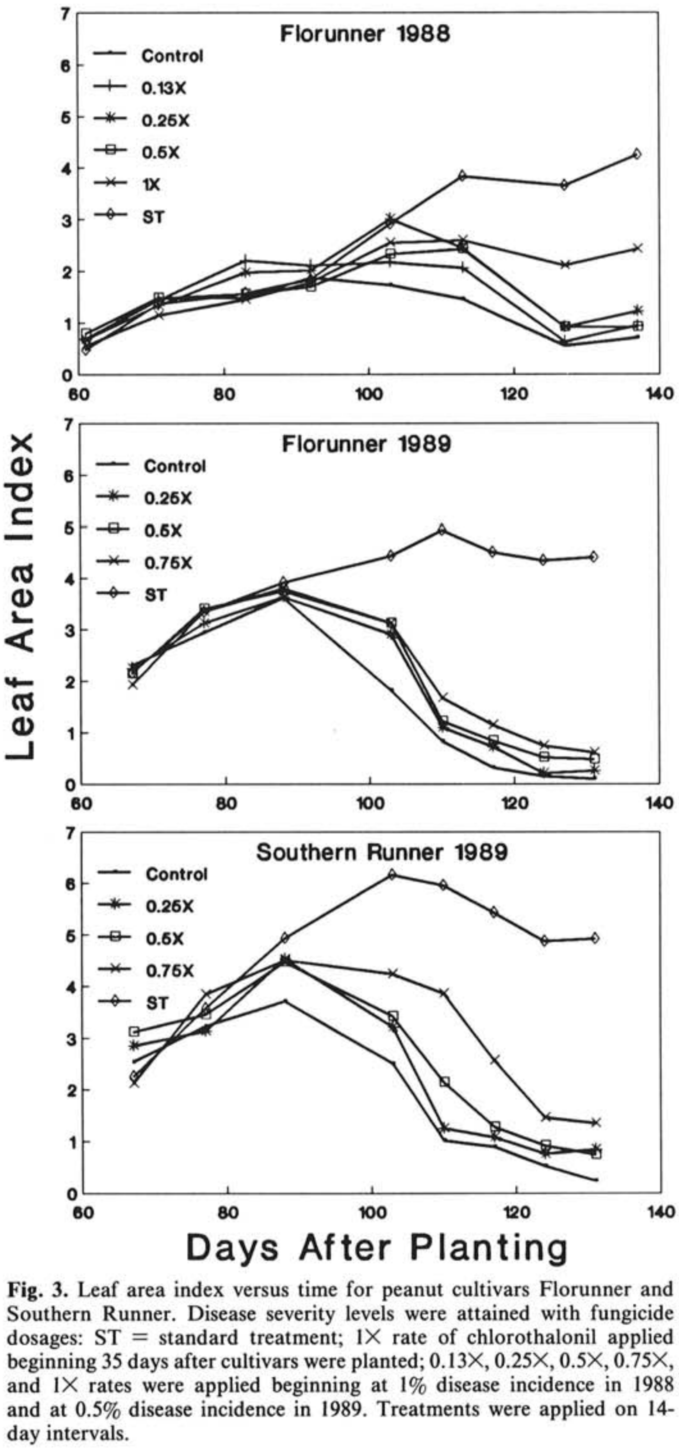

Fig. 3. Leaf area index versus time for peanut cultivars Florunner and Southern Runner. Disease severity levels were attained with fungicide dosages: ST = standard treatment; 1× rate of chlorothalonil applied beginning 35 days after cultivars were planted; 0.13×, 0.25×, 0.5×, 0.75×, and 1× rates were applied beginning at 1% disease incidence in 1988 and at 0.5% disease incidence in 1989. Treatments were applied on 14-day intervals.

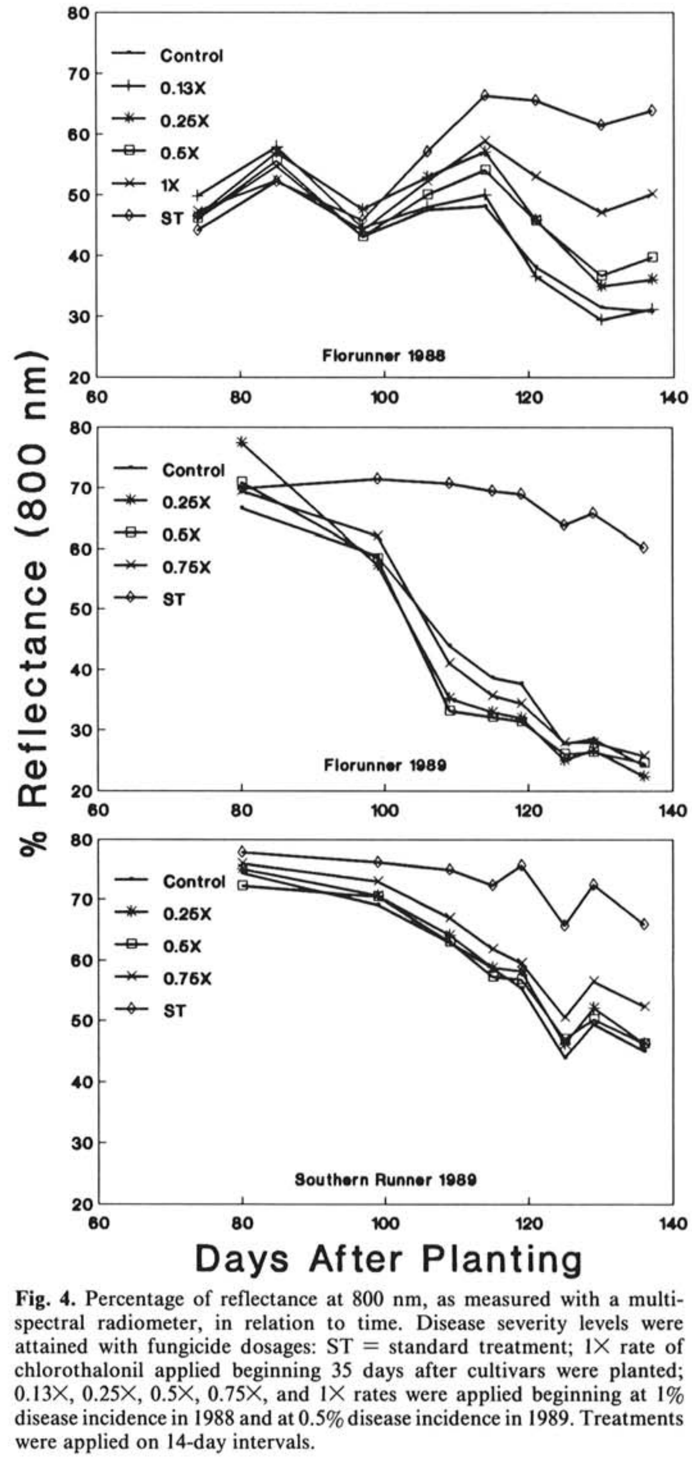

Fig. 4. Percentage of reflectance at 800 nm, as measured with a multispectral radiometer, in relation to time. Disease severity levels were attained with fungicide dosages: ST = standard treatment; 1× rate of chlorothalonil applied beginning 35 days after cultivars were planted; 0.13×, 0.25×, 0.5×, 0.75×, and 1× rates were applied beginning at 1% disease incidence in 1988 and at 0.5% disease incidence in 1989. Treatments were applied on 14-day intervals.

the yield of Florunner when harvests were near optimum, as the harvests were in these experiments. The modified model was:

$$\text{Yield (g m}^{-2}) = 735.5*\exp\{-3.6*\exp[-0.00794*(\text{HAD} - 55.47)]\} \quad (5)$$

With this model, the actual yields of Florunner from our experiments had a random distribution around the predicted response with an average deviation of about 11%. The 11 pairs of values for HAD and yield of Florunner (Table 1) and the eight pairs of values from Bourgeois (Table 2-2 in [6]) were added to the 78 pairs of values used in the original model. These added values resulted in only a very minor change in parameter values of the model equation and a barely perceptible change in the response curve for HAD vs. yield. Thus the original model is

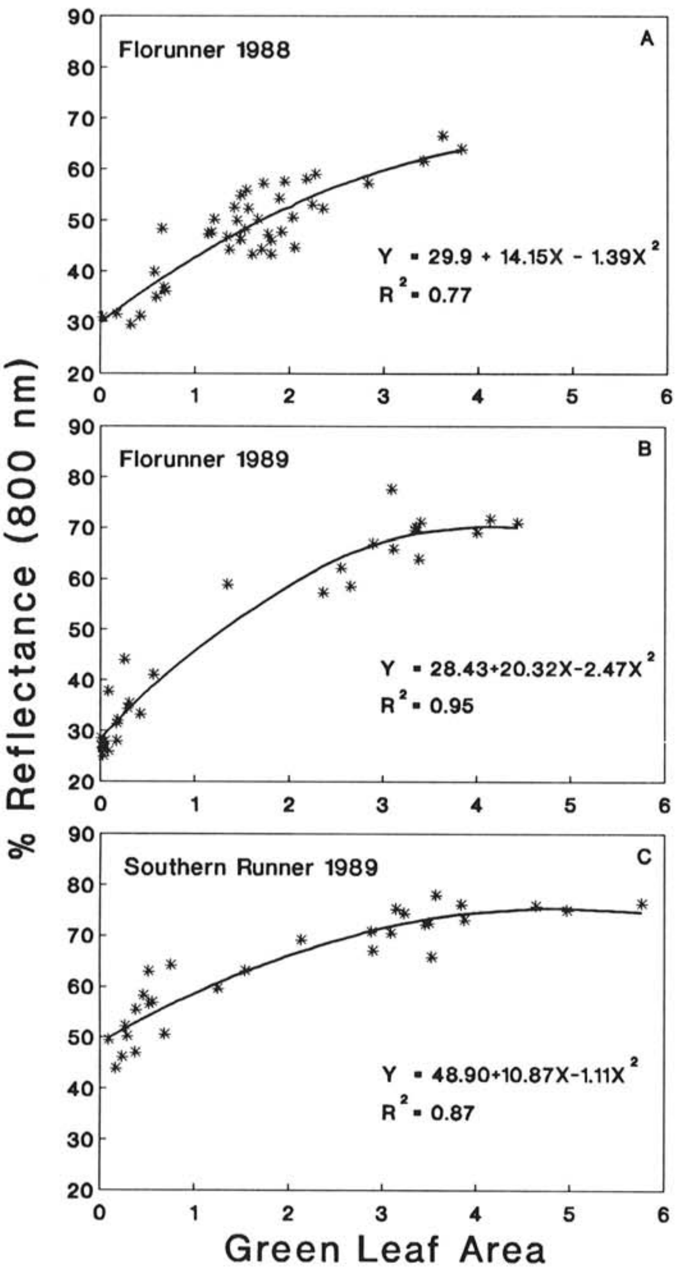

Fig. 5. Regression of reflectance at 800 nm, as measured with a multispectral radiometer, versus green leaf area. Disease severity levels were attained with fungicide dosages: ST = standard treatment; 1× rate of chlorothalonil applied beginning 35 days after cultivars were planted; 0.13×, 0.25×, 0.5×, 0.75×, and 1× rates were applied beginning at 1% disease incidence in 1988 and at 0.5% disease incidence in 1989. Treatments were applied on 14-day intervals.

considered appropriate to predict an average yield response when crop maturity is unknown.

Because Southern Runner has a lower partitioning of photosynthate to pods than Florunner, predicted pod yields for Southern Runner were overestimated with the Florunner model by an average of 18%. The HAD-yield model was then parameterized for the lower photosynthate partitioning of Southern Runner by curve fitting to the limited narrow range set of values (Table 1). The yield prediction equation for Southern Runner was:

$$\text{Yield (g m}^{-2}) = 800*\exp\{-3.6*\exp[-0.0057*(\text{HAD} - 56.57)]\} \quad (6)$$

With this model, the actual yields were randomly distributed around the predicted response with an average deviation of only 6% (Table 1). Predicted vs. actual yields (g/m^2) were not significantly different ($P > 0.05$) for either the original model or the new models.

DISCUSSION

In the 1988 field test for Florunner, six treatments were designed to establish different levels of disease epidemics, and distinct levels of disease were discernible (Fig. 2). In 1989, the 0.13× and 1.0× treatments (applied after 1% disease incidence) were not used. Instead of the 1.0× treatment, a 0.75× treatment was used in an attempt to get better separation from the standard treatment. The number of treatments was decreased by one because of the labor intensity required for the leaf area index measurements. This decrease was necessary with the addition of the second cultivar, Southern Runner, in 1989. Also in 1989, all treatments except the standard treatment were started at 0.5% disease incidence instead of 1% incidence. Starting treatments at a lower level of disease incidence might make possible better separation of disease levels. This did not happen. In 1989, we had an extremely high rainfall (60.2 cm of rain in the first 10 wk of the test; Fig. 1). This excess moisture resulted in rapid growth and greater increase of disease earlier in the season than in 1988. Therefore, the 0.25×, 0.5×, and 0.75× spray treatments did not give significantly different levels of disease from the untreated control in 1989. Although we would have preferred to have five distinct disease levels, the two disease levels obtained were sufficient for this study.

The peanut crop in 1989 attained a higher leaf area index than the crop in 1988. There are two possible reasons for this. In 1988, watering was more difficult because a low pressure, overhead sprinkler system was used. Peanuts received less total water from irrigation and rainfall (Fig. 1). A second factor was a buildup of root-knot and lesion nematodes at the site used in 1988. No nematicide was used in 1988 to control the nematode population, because the test site was near a well. Although growth was less in 1988, disease progress was slower, and better separation of disease intensity between treatments was obtained than in 1989 (Fig. 2). The increased leaf area index (maximum of 5.0 for Florunner at 110 days after planting) was evidence of the better growing conditions at the 1989 site and in that season. In 1988, the maximum leaf area index of Florunner (4.5) was not attained until 135 days after the cultivar was planted (Fig. 3). In 1988, the epidemic rate for the increase of late leafspot on Florunner was $0.04 < r < 0.11$, and in 1989 was $0.05 < r < 0.15$. Alderman et al (1) reported rates for late leafspot epidemics on Florunner, which ranged from 0.02 to 0.25 logits day^{-1}. During the 1989 season, the rate of leafspot progression for untreated Florunner was higher than that of the previous year. The rate of disease progress in untreated Southern Runner was significantly less than that of untreated Florunner. Southern Runner is known to possess rate-reducing resistance and the ability to produce more leaves (16,17). Continual leaf production throughout the season results in the maintenance of greater leaf area during most leafspot epidemics. Southern Runner has no known resistance to infection. In some years, if there is not a major influx of inoculum from outside sources, Southern Runner may maintain a leaf area index >2.0 until harvest without fungicide protection (16). A high leaf area index was not maintained in 1989 even with the low-level fungicide treatments (Fig. 3); we attribute this to the extreme disease severity and massive inoculum production of nearby plots of Florunner, which were untreated or treated with low dosages of fungicide.

Percentage of reflectance (800 nm) ranged from 25% in a defoliated crop to 75% in a full canopy crop. Reflectance for untreated Florunner at the end of the season averaged 25%, whereas values for untreated Southern Runner averaged 45%. Percentage of reflectance at 800 nm was highly correlated with GLA. The high positive coefficients of determination obtained for Florunner in 1988 ($R^2 = 0.77$) and 1989 ($R^2 = 0.95$), and for Southern Runner in 1989 ($R^2 = 0.87$) indicate that the canopy reflectance should give a reliable representation of the GLA. These results support the hypothesis of Nutter (15) that the radiometer, at the 800-nm wavelength, is actually measuring healthy GLA. Canopy reflectance should then be useful to screen peanut genotypes for resistance to late leafspot and to evaluate treatments for the control of disease. Values of reflectance for Southern Runner may have been higher because of a slightly lighter green, leaf coloration, but most of the difference was probably attributable to the greater GLA.

The HAD values obtained from estimates of leaf area index and disease proportion were used to predict pod yield. Predictions were reasonable for the 1988 and 1989 Florunner crop, but the yields were generally underestimated. It is known that the pegs of peanut plants with severe leafspot and defoliation soon deteriorate, and a high percentage of the pods become detached and remain in the ground at harvest. Therefore, a delay in harvest of a peanut crop with severe leafspot can result in a substantial loss of yield. Because the model equation was derived from a wide range of crop maturities at harvest, an underestimation of yield for the plots of Florunner in 1988 and 1989 by the model implies that these crops were harvested at near optimum maturity. Consequently, the original HAD-yield model was modified by changing the scale parameter to adjust for the maturity of the crop at harvest. The modified model provided appreciably improved predictions of yield from HAD for the crops in 1988 and 1989. Some of the greatest deviations with the model were underestimations of pod yield in the unsprayed and most severely diseased plots. These underestimations can be explained: diseased plants were not as severely stressed as the HAD-yield response indicated; the HAD was underestimated because of inaccuracies in assessment of diseased or healthy areas; or the severely diseased plants in these experiments had not yet dropped the proportionate number of pods usually associated with the level of disease. Bourgeois (6) suggested that total pod yield (harvested pods plus dropped pods) should be used to examine the relationship of yield to HAD. However, the recovery of dropped pods from the soil volume in which pods develop is a tedious task, even for small plots. The relationship of yield to HAD is a characteristic of a cultivar in that it is a measure of its leaf production, leaf orientation, radiation-use efficiency, and photosynthate partitioning.

Southern Runner is known to have some resistance to late leafspot and to have more leaf production and lower partitioning of photosynthate to pods compared to Florunner. To obtain a reasonable prediction of pod yield of Southern Runner from HAD, a separate equation with a unique rate value was required. For our limited set of values, the rate for Southern Runner (0.0057) was about 30% less than that for Florunner (0.00794). Additional experiments in which the yield of Southern Runner is measured over a broad range of HAD are needed to characterize the response for this cultivar. The relationship of pod yield to HAD may be a method to examine the partitioning of photosynthate and the radiation-use efficiency of any cultivar.

Researchers (e.g., plant pathologists, agronomists, physiologists, etc.) in their studies of responses of peanut plants to various treatments have always noted a substantial within-experiment random variation in yield (see e.g., 2, 9, 17, 23, 25). It is not unusual in experiments with peanut that the mean yields of treatments need to differ by as much as 15% before a significant difference ($P \leq 0.05$) can be assumed. Because peanut is especially responsive to edaphic conditions, the season-to-season variation

TABLE 1. Prediction of the pod yield with healthy leaf area duration (HAD) in 1988 for cv. Florunner and in 1989 for cvs. Florunner and Southern Runner

Treatment[a]	HAD[b]	Actual pod yield ($g\ m^{-2}$)	Predicted pod yield[c] ($g\ m^{-2}$)	Percentage of deviation from actual	Predicted pod yield[d] ($g\ m^{-2}$)	Percentage of deviation from actual
Florunner 1988						
Control	154.2	183.0	108.1	−40.9	142.1	−22.3
0.13×	186.1	193.0	168.1	−12.9	205.3	+ 6.4
0.25×	211.4	264.3	221.7	−16.1	259.0	− 2.0
0.50×	220.6	229.1	241.9	+ 5.5	278.7	+21.6
1.00×	238.6	307.8	281.8	− 8.4	317.2	+ 3.0
ST	261.3	353.4	331.7	− 6.1	364.4	+ 3.1
Florunner 1989						
Control	199.7	292.3	196.4	−32.8	234.0	−19.9
0.25×	230.4	256.1	263.6	− 2.9	299.7	+17.0
0.50×	265.1	333.5	339.9	− 1.9	372.1	+11.6
0.75×	235.3	357.3	274.5	−23.2	310.2	−13.2
ST	373.9	585.4	536.0	− 8.4	551.9	− 5.7
Southern Runner 1989						
Control	379.5	479.5	543.7	+13.4	451.8	− 5.8
0.25×	386.1	424.3	552.4	+30.2	461.4	− 8.7
0.50×	421.2	479.6	593.3	+23.7	509.9	+ 6.3
0.75×	424.8	510.5	597.1	+17.0	514.5	+ 0.8
ST	435.4	577.0	607.4	+ 5.3	528.0	− 8.5

[a]Treatments for Florunner in 1988 included an unsprayed control and four spray rates initiated at 1% incidence, in which × = 1.75 L/ha, and ST or standard treatment was initiated at 35 days after planting. Treatments for Florunner and Southern Runner in 1989 included an unsprayed control and three spray rates initiated at 0.5% incidence, in which × = 1.75 L/ha, and ST (1× rate of chlorothalonil initiated at 35 days after planting). All treatments were applied on 14-day intervals.

[b]HAD is healthy leaf area duration and was determined by using the origial model of Waggoner and Berger (26), in which HAD = $\Sigma\{[(1-y_i)L_i + (1-y_i)L_{i-1}](t_i - t_{i-1})/2\}$; y_i, L_i, and T_i, respectively, are the proportion of diseased area, the leaf area index, and the time of sampling in days.

[c]Predicted pod yield for the original model = 735 exp{−315*exp[−0.00821*(HAD − 0.93.71)]} (Waggoner and Berger 1987).

[d]Predicted pod yield for the new Florunner model = 735.5*exp{−3.6*exp[−0.00794*(HAD − 55.47)]}. Predicted pod yield for the new Southern Runner model = 800*exp{−3.6*exp[−0.0057*(HAD − 56.57)]}.

in yield may be considerable (15–20%). Because of this variation in yield, the use of a single-point or a multiple-point model to make reasonably accurate predictions of yield or yield loss of peanut from disease severity would be worthless. As Waggoner and Berger (26) have shown mathematically, both single-point and multiple-point models can succeed only when the leaf area is the same in the treatments that are being compared (e.g., healthy crop vs. diseased crop, $season_1$ vs. $season_2$, etc.). The same proportion of disease severity (y) on different leaf areas would not have the same impact on yield. In addition, the use of models to determine yield (or yield loss) from disease severity is more troublesome for those pathosystems in which defoliation is a major part of the disease syndrome because of the difficulties in assessing this fraction (26). The use of the HAD model avoids these problems, because yield is estimated from the true determinant of yield, the duration of the healthy leaf tissue.

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