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Estimating Defoliation of Peanuts From Spectral Data[1]

by

J.C. Harlan, W.D. Rosenthal, and D.H. Smith[2]

ABSTRACT

Analysis of spectral reflectance potentially can be used to determine the condition of a crop, e.g., drought stress and nutritional deficiencies. Since there is a paucity of information on the feasibility of quantifying disease severity in *Arachis hypogaea* (L.) with spectral reflectance measurements of the canopy, the objective of this study was to determine if spectral reflectance values of the peanut canopy could be used to estimate the amount of defoliation attributable to epidemics of Cercospora leafspot. Defoliation data and spectral reflectance values (Exotech 100-A radiometer) were periodically obtained in fungicide evaluation tests with varying amounts of defoliation, depending on the efficacy of the fungicide treatments. Combination parameters were developed from reflectance values and statistically compared with appropriate defoliation data. During this two-year study, defoliation percentages were accurately predicted (R^2=0.89) by subjecting the combination parameters to regression analyses. Therefore, these results indicate that there is a definite relationship between canopy reflectance and defoliation resulting from Cercospora leafspot epidemics. Since full sunlight near solar noon is the only requirement for reliable reflectance measurements, this radiometric technique can probably be used to monitor development of leafspot epidemics and quantify yield losses on a large scale with either aerial or satellite measurements.

Keywords: *Cercospora arachidicola*, *Cercosporidium personatum*, fungicides, spectral reflectance, remote sensing.

Epidemics of Cercospora leafspot cause premature defoliation of peanuts (*Arachis hypogaea* L.), and pod yields are substantially reduced, if appropriate control measures are not applied (2, 3). *Cercospora arachidicola* Hori, the early leafspot pathogen, and *Cercosporidium personatum* (Berk. & Curt.) Deighton, the late spot pathogen occur either separately or together in the same field. In some instances other foliar pathogens (*Phoma arachidicola* Marasas, Pauer & Boerema and *Puccinia arachidis* Spegazzini) are associated with the development of foliar disease epidemics. Therefore, since foliar diseases limit the productivity of peanuts, periodic measurements of defoliation during the growing season are useful in estimating the final yield.

Spectral reflectance is a satisfactory way of monitoring the condition of a crop. A healthy, green full canopy crop may have a reflectance as high as 70% in the near infrared region (0.8 to 1.1 μm), but a severely defoliated crop has lower reflectance, especially in the near infrared region (5). Powell *et al.* (6, 7) have used infrared and color aerial photography to detect Sclerotinia blight and Cylindrocladium black rot in commercial peanut fields, [6, 7].

At present, little is known about the quantitative relationships of disease severity and plant reflectance measurements. Therefore, the objective of this study was to determine if peanut canopy reflectance data could be used to quantify the defoliation which resulted from the development of Cercospora leafspot epidemics.

Material and Methods

Field experiments were conducted at Yoakum, Texas during 1975 and 1976, a location where Cercospora leafspot reached epidemic levels in both years. During both years, *Cercospora arachidicola* was the principal foliar pathogen. To obtain a wide range in the amount of defoliation, measurements were obtained in fungicide evaluation tests with a high probability of large differences in the effectiveness of fungicides, levels of defoliation, and yield. The treatments used in the experiments reported here were chosen with the anticipation of the following levels of defoliation: (1) one high defoliation treatment; (2) two medium defoliation treatments, and; (3) one low defoliation treatment. Based on these criteria, the following fungicide treatments were selected in 1975; (1) Orthocide 80W (N-trichloromethylthio-4-cyclohexene-1, 2-dicarboximide) at 4.5 kg/ha; (2) Bravo 6F (tetrachloroisophthalonitrile) lt 1.4 liters/ha; (3) Benlate 50W (methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate) at 0.6 kg/ha; and (4) an unsprayed control. The treatments in 1976 were: (1) Duter 47.5W (triphenyltin hydroxide) at 0.8 kg/ha; (2) Bravo 6F at 3.5 liters/ha; (3) Benlate 50W at 1.1 kg/ha; and (4) an unsprayed control. The fungicides were applied at higher rates in 1976 because the interval between fungicide application dates was seven days longer in 1976 than in 1975. The effect of moisture stress and insect damage on defoliation was minimized with timely application of water and insecticidal sprays.

Defoliation percentage is defined as:

$$\text{Defoliation (\%)} = (D/N) \times 100$$

where D and N represent the number of defoliated and total number of leaflets on five central stems in each replicate, respectively. Defoliation measurements were made either on the same date or within a few days of the reflectance measurements. Defoliation percentages were linearly interpolated to the spectral observation date by using successive defoliaton measurements and assuming that disease development was linear with respect to time. This technique should not be used when there is a large difference between the date of spectral data acquisition and the date of defoliation measurements.

Ground measurements of canopy reflectance, with an Exotech 100-A multispectral radiometer 1.5m above the canopy, were obtained at two sites in each replicate. The field of view for the radiometer was 15°, so 0.51m^2 was viewed for each measurement. The battery-operated radiometer measured reflected energy in four wavelength bands: (1) 0.5 to 0.6 μm (green); (2) 0.6 to 0.7 μm (red); (3) 0.7 to 0.8 μm (near infrared); and (4) 0.8 to 1.1 μm (near infrared). These wavelength bands are identical to those which are used in the current Landsat satellites. The radiometer output, which is a function of reflected energy, is measured by a voltmeter. Reference reflectance measurements were obtained from a white barium-sulfate panel, having a high known reflectance. Background noise within the instrument was determined by measuring the radiometric voltage when the lens was covered.

Raw data, which consisted of the reflected energy (volts) from the peanut canopy and reflectance panel in the selected wavelength band, were processed in several steps. First,

[1]Contribution of the Remote Sensing Center, Texas A&M University, College Station, Texas 77843.

[2]Associate Research Scientist, and Research Associate, Remote Sensing Center, Texas A&M University, College Station, Texas 77843; and Associate Professor, Plant Disease Research Station, Texas A&M Agric. Exp. Stn., Yoakum, Texas 77995.

reflectance of the peanut canopy was calculated from:

$$\% \text{ Reflectance} = \frac{CV - NV}{RV - NV} \times 100$$

where CV is the canopy voltage, RV is the reference panel voltage, and NV is the noise voltage from the radiometer. The mean values for each treatment are presented in Table 1. The reflectance values for each treatment were combined by ratioing or taking the difference of reflectance values in different wavelength bands. The combinations were developed to maximize canopy condition information in one parameter which would be more easily and efficiently used in correlation analyses than several individual band values. Such combining techniques have been used by the authors and other researchers for determining crop condition of rangeland (8), wheat (1, 4) and other vegetative targets. The combinations studied are shown in Table 2. Band 1 was not used in the combinations because reflectance changes in band 1 are smaller than changes in band 2, i.e., band 1 is less sensitive for vegetation. To determine the best estimating parameter, linear regression equations were developed between each parameter and defoliation percentage.

Table 1. Reflectance and Interpolated Defoliation Values Used in Regression Analyses. (Defoliation measurements were acquired on 9/3/75, and 10/9/75 and 9/17/76, 10/12/76, and 10/21/76)

Date	Treatment \ Band*	Reflectance (%) 1	2	3	4	Interpolated Defoliation (%)
9/23/75	Benlate A	05	.04	.43	.61	15.7
	Bravo 6F B	.05	.04	.44	.63	13.8
	Orthocide C	.06	.04	.38	.52	39.2
	Unsprayed D	.06	.05	.30	.39	70.1
10/4/75	Benlate A	.05	.05	.35	.52	29.0
	Bravo 6F B	.05	.04	.38	.55	15.2
	Orthocide C	.05	.06	.29	.42	51.1
	Unsprayed D	.06	.08	.19	.26	84.0
9/21/76	Benlate A	.04	.03	.40	.55	23.2
	Bravo 6F B	.04	.03	.37	.52	19.6
	Duter C	.04	.02	.39	.55	20.5
	Unsprayed D	.04	.02	.35	.49	26.2
10/2/76	Benlate A	.04	.03	.36	.53	23.0
	Bravo 6F B	.05	.03	.42	.59	19.9
	Duter C	.04	.03	.37	.51	19.6
	Unsprayed D	.04	.03	.28	.39	48.1

* Wavelength limits of the bands are: (1) 0.5-0.6μm; (2) 0.6-0.7 μm; (3) 0.7-0.8μm; and (4) 0.8-1.1μm.

Table 2. Combination parameters of ERTS 100-A radiation bands.*/

BRP1 * */ = (band 4 + band 3) / band 2

BRP2 = (band 4 - band 2) (band 3 - band 2)

BRP3 = (band 4 - band 2) / (band 4 + band 2)

BRP4 = (band 3 - band 2) / (band 3 + band 2)

BRP5 = (band 4 - band 2) / (band 3 - band 2)

BRP6 = (band 4 - band 3) / (band 4 + band 3)

BRP7 = band 4 / band 2

BRP8 = band 3 / band 2

BRP9 = band 4 / band 3

BRP10 = band 4 + band 3

*/ (Bands: 1-(0.5-0.6μm), 2-(0.6-0.7μm), 3-(0.7-0.8μm), 4-(0.8-1.1μm))

* */ BRP stands for Band Ratio Parameter

Results and Discussion

Significant differences in the amount of defoliation were observed (Table 3). For example, on 9 October, 1975, the defoliation percentage for the Orthocide 80W treatment was 55.2% as compared with 15.4% for the Bravo 6F treatment and 90.2% for the unsprayed treatment.

Table 3. Defoliation percentage on selected dates.

Fungicide	Date	
	9/23/75	10/9/75
Orthocide	39.2	55.2
Bravo 6F	13.8	15.4
Benlate	15.7	34.0
Unsprayed	70.1	90.2
	9/17/76	10/12/76
Benlate	23.2	22.8
Duter	21.0	18.6
Bravo 6F	19.8	18.7
Unsprayed control	31.2	59.3

Comparisons of defoliation percentages between years indicated that differences were at least partially attributable to climatic factors and differences in fungicide application procedures. For example, the defoliation percentage of the unsprayed treatment on 9 October 1975 and 12 October 1976 was 90% and 59%, respectively. This suggests that 1976 was a drier year than 1975, and this is substantiated by the fact that three irrigations were required prior to 12 October 1976 as compared with one irrigation prior to 9 October 1975. In addition, differences in defoliation were probably associated with the increased amount of fungicide per acre and the extended application interval in 1976. Defoliaton was 34% and 23% in Benlate plots during 1975 and 1976, respectively. Defoliation was 15% and 19% in Bravo 6F plots on 9 October 1975 and 12 October 1976, respectively.

Table 4. R^2 values for Band-Ratio-Parameters vs. defoliation percentage.

BRP	R^2	BRP	R^2
1	.71	6	.22
2	.89	7	.61
3	.75	8	.60
4	.74	9	.35
5	.06	10	.89

Based on a linear regression analysis of the ten radiation band parameters, it appears the BRP2 and BRP10 are the best parameters for estimating defoliation percentages (R^2=0.89) (Table 4). Results for the two parameters are given in Figures 1 and 2. Healthy green plants have a higher reflectance in bands 3 and 4 than in bands 1 and 2. As defoliation progresses, reflectance decreases most rapidly in band 4, but it remains approximately the same in bands 1 and 2. With this relationship, a higher parameter value is indicative of a higher defoliation percentage. We are unable to explain why BRP2 has the same accuracy as BRP10.

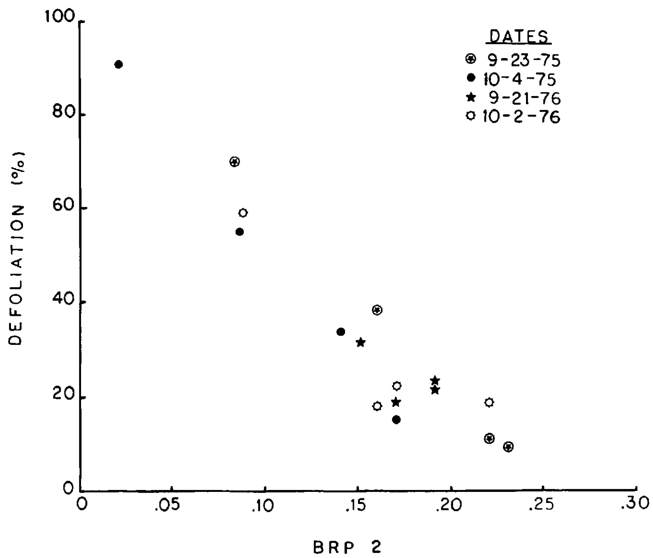

Fig. 1. Relationship between defoliation percentage and band-ratio-parameter-2 (BRP2) during 1975 and 1976.

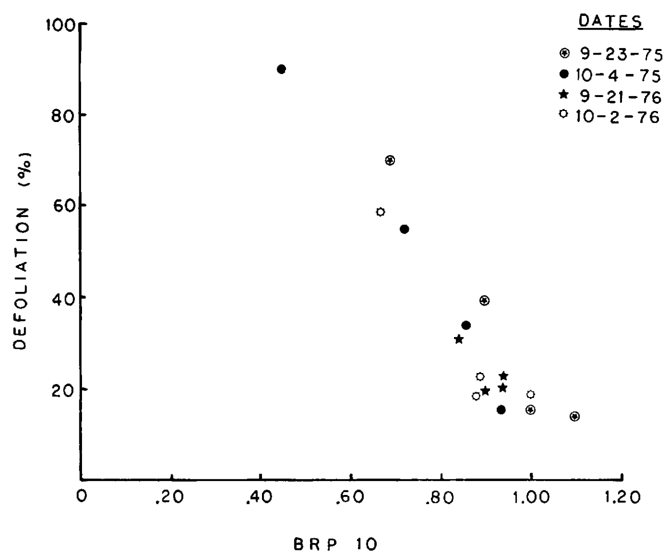

Fig. 2. Relationship between defoliation percentage and band-ratio-parameter-10 (BRP10) during 1975 and 1976.

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