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REMOTE SENSING FOR DISCRIMINATION OF POTATO DISEASES

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ABSTRACT

To determine if stress caused by two distinct potato diseases could be detected and identified in aerial color infrared photography, measurements of spectral reflectance from healthy and diseased potatoes were made with a ladder mounted spectral radiometer. Healthy plant canopies and canopies infected with early blight and early dying each had unique spectral reflectance curves in experimental plots. Digital analysis of large-scale color infrared photography indicated that the relative alteration of reflectance in diseased canopies is similiar in direction and magnitude to that measured electronically. Combining spectral information in film with spatial and/or temporal information from photo-interpretation could allow identification of these diseases and other stresses in commercial fields.

I. INTRODUCTION

The use of remote sensing in disease detection in agriculture has generally been limited to delineation or quantification of stress where the type of problem was known beforehand. An exception was the work done by Payne et al[3]. They were able to discriminate several peach and pecan pests and diseases on the basis of foliage color and crown shape. Where only one disease was economically important, the ability to detect it with aerial photography has been useful for several crops (1,2,4,5).

In the Wisconsin Central Sands potato growing region, three diseases (early blight - _Alternaria_ _solani_, late blight - _Phytophthora_ _infestans_, and early dying - _Verticillium_ _sp._ and associated causal organisms) as well as a number of insect, weed, and environmental stresses have the potential to significantly affect potato production. Since prevention or treatment strategies vary with different stresses, it would be useful to monitor the spread of these problems over time and space.

To identify these diseases in aerial photographs, it was necessary to determine if each disease had a unique effect on canopy spectral reflectance. This was done by measuring reflectance from healthy and infected plots at the University of Wisconsin Experimental Farm at Hancock, Wisconsin. Color and color infrared aerial photographs of these experimental plots and nearby commercial fields planted with the same variety of potato were taken to determine if reflectance differences were observable on film.

II. RADIOMETRY

A. MATERIALS AND METHODS

A Gamma Scientific DR-2 spectral radiometer was used to measure spectral reflectance from potato canopies. A model 2020-31 Photometric Telescope and a model 2020-18 Monochromator Assembly with a model 2020-5 Photomultiplier Tube were mounted on a ladder ten meters above the canopy. These were connected by cable to a DR-2 Digital Radiometer. Measurements were made at ten nanometer intervals from wavelengths of 400 nm. to 800 nm. A total of twenty sets of measurements were taken between 1000 and 1330 hours on August 12, 13, 18, 19, and 21, 1981.

A problem with instrument calibration prevented analysis of raw data in terms of percent reflectance, and so direct comparison of data from one date to another was not possible. It was propitious that healthy and diseased plots were located next to each other. This allowed data from any one period of instrument operation to be analysed in terms of alteration of reflection by disease compared to a healthy canopy. To do this, the voltage response at each wavelength in a diseased canopy was divided by the corresponding voltage response in a healthy canopy measured under the same instrument and illumination conditions. By assuming the reflectance of a healthy canopy to be unity, plotting this ratio of reflectance showed the direction and relative magnitude of alteration in a diseased canopy.

B. RESULTS AND DISCUSSION

Figure one shows the average of six reflectance ratio calculations for early blight and four for early dying. Symptoms from late blight were not developed sufficiently to warrant measurement. In mid-August, canopies of experimental plots infected with early blight and early dying could be distinguished from each other and healthy canopies on the basis of spectral reflectance.

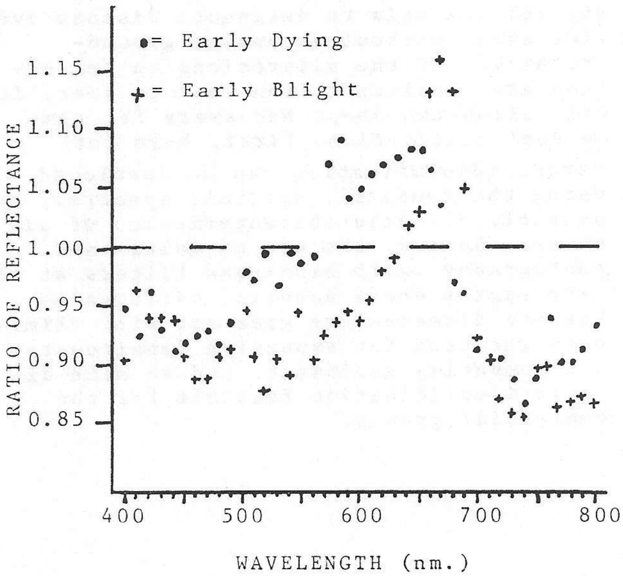

Figure 1. Relative Reflectance From Diseased Canopies

These alterations of reflectance can be explained in terms of disease effect on foliage, and so it is likely that discrimination of disease will be possible only as long as foliage rather than the underlying soil remains the major component of reflectance. Early dying is characterized by a chlorosis (yellowing) of leaves. As expected, this results in a decrease in blue reflection (400-500 nm.) and an increase in green and red reflection (570-670 nm.). Both diseases show a marked decrease in infrared reflectance (700-800 nm.). Foliage infected with early blight was characterized by brown, purple, or black lesions. This shows up as an overall decrease in reflection with one peak in a portion of the red wavelengths (650-690 nm.). It will be useful to determine during what stages of disease development these relative alterations are observable.

III. PHOTOGRAPHY

A. MATERIALS AND METHODS

Color and color infra-red positive transparencies were obtained with Kodak 2448 Aerochrome MS and Kodak Aero Infrared 2443 film on July 17 and 28, 1980, and August 8 and September 5, 1981. Photos were taken with 70 mm. Hasselblad cameras with 80 mm. lenses and appropriate filters mounted in the belly-hole of a Cessna 180. Photographs of the experimental plots and seven commercial fields were taken from 1160 m. (3800 feet) above terrain so that a 160 acre field would just fill the film format (1:14,500). Experimental plots were also photographed from 180 m. (600 feet) so a 200 um. densitometer spot size would correspond to half the distance, 1.5 feet, between potato rows (1:2300).

Color infrared photos and a step-wedge placed on the film at the time of development were scanned with a scanning densitometer at wavelengths of 450, 550, and 650 nanometers. Data was digitized and recorded on tape with a PDP11 computer. Digital images were analyzed with algorithms developed by the Environmental Remote Sensing Center, Institute for Environmental Studies, University of Wisconsin.

B. RESULTS AND DISCUSSION

Manual/visual interpretation of the photographs revealed temporal and spatial patterns that provided clues to disease

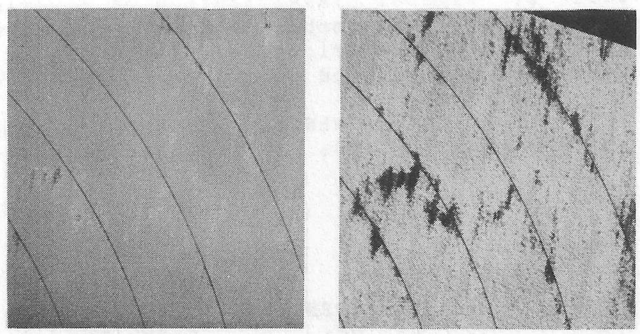

Figure 2. Disease Pattern From Early Blight Portion of a commercial potato field on August 8and September 5, 1981.

identification. Random foci of stressed plants or gradients of foci from a point source suggest an aerially disseminated disease. Figure two shows the enlargement of an initial early blight and the appearance of "daughter" foci with time. Fields infected with early dying, a soil-borne disease, do not show these foci of infection or enlargement with time. There is some evidence that early dying may be correlated with areas of sandier, lower organic content soils. The spectral differences between the two diseases are not visible to the naked eye.

Densitometric analysis of color infrared film showed that the relative alterations of reflection from disease can be observed in film. Experimental plots infected with early dying had a lower transmission density at 450 nm. and 550 nm. scan wavelengths than healthy plots, corresponding to an increase in green and red reflectance on the false color film. Plots infected with early blight had a lower density at 550 nm. but an increased density at 450 nm. Both types of disease decreased infrared reflectance (measured at 650 nm.). The pattern of relative alterations of reflectance from disease shown in Table 1. form the basis for distinguishing the two diseases in air photos. Training sets taken on healthy potatoes can be altered in the directions suggested to classify for diseases.

Table 1. Transmission Densities in Diseased Canopies Relative to Healthy Canopies

STRESS	TRANSMISSION WAVELENGTH		
	450 nm.	550 nm.	650 nm.
Early Blight	lower	lower	higher
Early Dying	higher	lower	higher

A minimum distance to mean algorithm was used to classify a field experimentally infected with varying severities of early dying as a function of inoculum loading and fumigation. Pixels in each plot were classified as healthy or diseased. Table 2. suggests that it is not only possible to classify early dying infected potatoes, but it may also be possible to quantify disease severity.

IV. CONCLUSION

Before the information from these experiments can be of any commercial use, it will be necessary to determine how the noted alterations in reflection are altered by other stresses. Because there are so many possible stresses, it will be necessary to integrate the spatial and temporal information from photo-interpretation with spectral information from digital analysis to delineate disease over wide areas without extensive ground-truthing. If the alterations in reflection are consistent from year to year, it will allow two steps necessary for commercial utilization. First, keys for stress identification can be developed using the temporal, spatial, spectral, and probably climatic characteristics of disease. Second, the use of multi-band photography with band-pass filters at the wavelengths where spectral differences between diseases are greatest will eliminate the need for expensive densitometry and computing equipment, and so make disease identification feasible for the commercial grower.

Table 2. Digital Classification of Experimental Plots.
For each plot the number of pixels classified as diseased was put over the number classified as healthy. Plots were rated ten or fourteen days after the photographs were taken and were ranked from least to most diseased.

TREATMENT:	Terrocide	Soil Boron	Telone	Untreated Control
RATING:	Least Disease	----------------	----------------	--> Most Disease
plot 1-1 to 4-1	21/106	16/103	119/2	100/19
plot 1-2 to 4-2	24/89	44/75	80/43	101/15
plot 1-3 to 4-3	11/115	19/109	58/56	66/49
plot 1-4 to 4-4	10/99	19/93	52/59	66/49
TREATMENT:	Methyl Br	Terrocide		Untreated Control
RATING:	Least Disease	----------------	----------------	--> Most Disease
plot 12-3 to 9-3	27/98	25/100		57/66
plot 12-4 to 9-4	8/120	12/114		80/43
plot 12-5 to 9-5	14/96	18/90		62/50

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