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Analysis of ACIR Transparencies of Citrus Trees with a Projecting Spectral Densitometer*

The ratios of film density at two peaks—490 to 500 nm and 600 to 610 nm—were lower for healthy trees than for stressed trees.

Abstract: *Ratios of selected spectral densitometric values of citrus tree images on aerial color infrared (ACIR) transparencies were determined using a set of three instruments: Dokumator DL-2 Microfilm Reader†, a Visible Monochromator, and an Auto-Photometer. Plots of film density for citrus tree images had two peaks, one at 490 to 500 nm and another at 600 to 610 nm. The ratios of the film density at these two peaks were lower for healthy trees than for stressed trees. A linear regression of the photointerpretation (PI) versus the ratio values for 60 tree images gave a correlation coefficient of 0.85.*

Introduction

This study was made to determine if a spectral densitometer could be used to assess the degree of citrus tree stress when using infrared photographs of citrus trees. Stress ratings determined in this way were compared with results from photointerpretation.

Aerial color infrared (ACIR) photographs can give a synoptic overview of citrus groves. Differences in color of citrus trees on ACIR transparencies are used for mapping, locating stressed trees, counting trees, estimating tree size, and counting trees that have been removed from an orchard (Edwards and Blazquez, 1979; Blazquez and Horn, 1980). Hochberg and Ravid (1977) used the change in ACIR hue from red to blue to detect the location of trees damaged by the tristeza disease, storms, scale insects, and drainage problems in Israel's groves. Hart *et al.* (1977) used ACIR photographs to delineate pest infestations and to survey groves for nutrient deficiencies and irrigation problems. These workers found that ACIR surveys cost less than conventional ground surveys, were more accurate, and gave a permanent record of the grove at the time photographs are acquired.

Various vegetation types may reflect visible light similarly. However, different vegetation types often do not reflect the same amount of near-infrared radiation. The near-infrared reflection from leaves has little relation to the visible color because it is controlled by the properties of the epidermal layers, stomata, nuclei cell walls, crystals, and cytoplasm (Gausman, 1977).

Lillesand *et al.* (1979) used a Macbeth TD-504

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† Use of trade names are for the reader's benefit and is not intended as an endorsement of a given product over another.

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densitometer attached to a Bausch and Lomb Zoom 240 stereomicroscope to make quantitative density readings with a 200 μm spot size and Wratten 94, 93, and 92 filters. Results showed that no single spectral density measurement or combination of measurements correlated with overall tree vigor. Disbrow (1979) projected 35-mm color infrared transparencies onto a color analyzer to observe changes in irrigation, fertilization, and disease within large acreages. Pearson and Miller (1972) developed a hand-held biometer to determine the ratio of reflectance values measured at two selected wavelength intervals, 600 to 700 nm and 770 to 825 nm. Their biometer measurements correlated well with the dry biomass of Colorado grasslands. Tucker *et al.* (1980) used a normalized difference ratio to show the variations within a field of winter wheat.

ACIR photographs are useful for grove management and give a permanent record of the grove. However, results using visual interpretation of the film may be affected by eye fatigue which occurs after a period of time and can lead to errors in rating tree stress.

Materials and Methods

Kodak's 2443 aerial color infrared film, exposed with appropriate minus-blue or yellow filter, was used to photograph a citrus grove near the Citrus Research and Education Center of Lake Alfred, Florida. The flight was made in March 1978 from an altitude of 1220 m (4000 ft) with a 30.5-cm (12-in) lens. This produced photographs at a scale of 1:4000 (40 m/cm, or 333 ft/in). Area coverage per photograph was 260 acres (105 ha) on the 22.9- by 22.9-cm (9- by 9-in) format (Blazquez and Horn, 1980). The camera, airplane, and film were furnished by the Florida Department of Transportation under an agreement with NASA Kennedy Space Center.

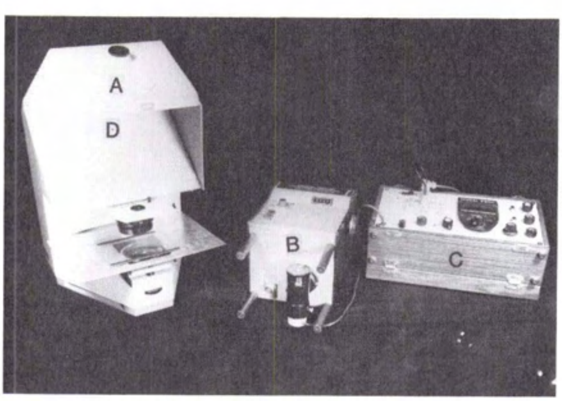

FIG. 1. Equipment used to determine spectral ratio of ACIR images of citrus trees. (A) DL-2 Microfilm Reader. (B) Monochromator. (C) Photometer. (D) Face of fiberoptic probe.

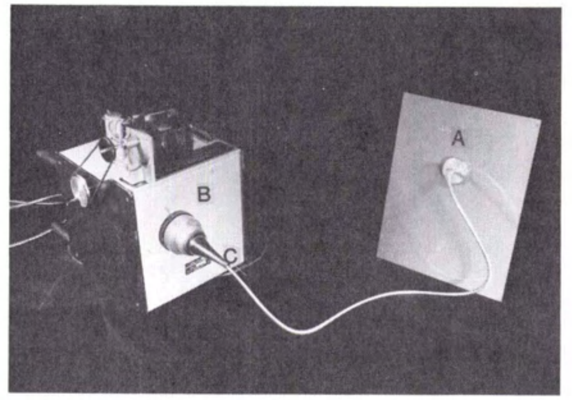

FIG. 2. Fiberoptic probe connected to projection screen and monochromator. (A) Rear of projection screen. (B) Coupling and monochromator. (C) Fiberoptic probe.

A Jenoptik Jena GmbH Dokumator DL-2 microfilm reader was the light source and image magnifying system of the spectral densitometer (Figure 1). The projection screen of the DL-2 was replaced with a 14-gauge aluminum plate covered with white posterboard. A hole was drilled near the center of the plate to hold a Gamma Scientific 914-mm by 3.18-mm (36- by 0.125-in) flexible fiberoptic probe. A brass plate was mounted to the underside of the aluminum plate to hold the face of the probe flush with the face of the screen, and the other end was connected to a Gamma Scientific monochromator case, Model 700-3, with a brass coupling (Figure 2). A Bausch and Lomb visible grating, catalog No. 33-86-76, was mounted in the monochromator case. Light from the monochromator was measured with an R-777 Hamamatsu photomultiplier (Pm). A Gamma Scientific exit slit C 0.75 was mounted in front of the Pm tube. Output of the Pm tube was read on a Gamma Scientific Auto-Photometer, Model 2900.

The film holder of the DL-2 was modified to hold the 9- by 9-in ACIR transparencies. Images of mature citrus trees were approximately 1 mm in diameter and read at a magnification of 9×; for smaller trees the magnification was increased to 17.5× so that the tree filled the face of the probe. Tree crown images were centered over the probe so as to avoid imaging tree shadows.

Sixty tree images were read on the spectral densitometer. Film density readings, in digital display units, for each 10-nm wavelength interval from 400 to 650 nm were read from the Auto-Photometer and the two maximum values were recorded for each tree. The intensity value near 500-nm maximum was divided by the intensity value near 600-nm maximum to obtain the ratio value of the tree.

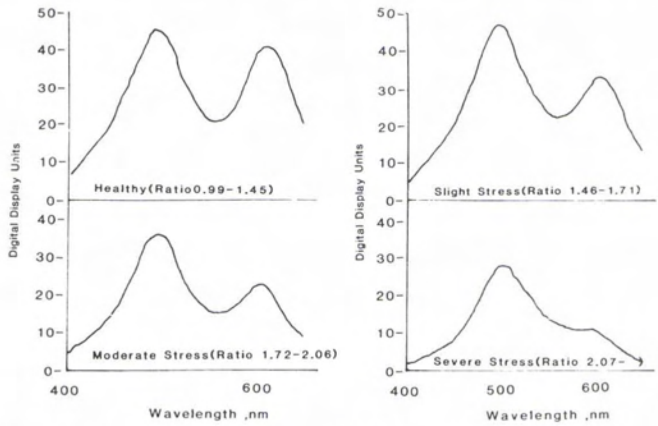

FIG. 3. Typical density curve in digital display units for each type of tree stress.

Ratio values and photointerpretation (PI) of each tree were used as the X,Y values in a linear regression analysis. The analysis computed the correlation coefficient and the predicted Y value. The predicted Y value was related to the PI by plotting the ratio on the X axis and the predicted Y on the Y axis.

Photointerpretation was done by an interpreter with three years of experience in ACIR interpretation of citrus groves. Trees were rated on a 0 to 4 scale; 0 = healthy; 1 = slight stress; 2 = moderate stress; 3 = severe stress; and 4 = a dead tree. The color of healthy trees (0) was light pink and the color of dead trees (4) was blue. Rating the slight stress (1) category is the most difficult to judge by eye; it is characterized by a pink color and/or a subjective feeling by the interpreter that "all is not well with the tree."

RESULTS

Figure 3 shows the generalized curve for each type of tree. The peak value near 600 nm falls as tree stress increases. As a result, tree ratio values for healthy trees were consistently smaller than for stressed trees. Linear regression of the photointerpretation and ratio gave a correlation coefficient of 0.85. This was significant at the 1 percent level. The calculated stress ratings from the linear regression analysis of the ratios fell into four distinct areas related to the PI values (Table 1). The calculated ratio value for the young (Y) tree at 17.5× magnification was 1 rather than 0. The comparisons should be made using the same magnification as there is no factor in the ratio equation to account for a change in magnification.

TABLE 1. SUMMARY OF RESULTS AND NUMBER OF TREES FROM PI AND RATIO OF SPECTRAL MEASUREMENTS

Rating	Ratio Range	Predicted Y Range	No. trees	
			PI	Cal. Y
0	0.99 to 1.45	−0.56 to 0.75	47	49
1	1.46 to 1.71	0.76 to 1.50	7	4
2	1.72 to 2.06	1.55 to 2.50	2	5
3	2.07 to —	2.55 to —	3	1
Y	1.37	1.01 to —	1	1

0 = healthy; 1 = slight stress; 2 = moderate stress; 3 = severe stress; Y = young tree.

CONCLUSIONS

The spectral densitometer is an instrument that shows the film density at specific wavelength intervals. When maximum intensity values are ratioed, healthy trees can be differentiated from stressed trees. The degree of stress in non-healthy citrus trees (slight, moderate, severe) can also be estimated.

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