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COMPARISON OF AERIAL COLOR INFRARED VIDEO AND 70 mm COLOR INFRARED PHOTOGRAPHY OF CITRUS TREES

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Abstract. **This paper describes the spectral analysis of images on aerial color infrared video and 70 mm color infrared film. Color infrared video image was recorded on a standard VHS video cassette recorder. The tape was played back and stop framed to photograph the image. Ektachrome-64, 35 mm color film, was used to photograph the TV monitor. Images on the 35 mm and 70 mm film were analyzed with a spectral densitometer. Spectral densitometer results showed maximum intensity peaks at 2 wavelengths, one near 500 nm and the other near 600 nm. Spectral ratios were formed from the ratio of the 2 intensities. Two citrus groves were photographed, one with stressed citrus trees and the other, the Florida citrus arboretum containing 255 cultivars. Spectral ratios and spectral ratio times wavelength differences were lower for healthy trees and higher for trees under stress. Each tree in the arboretum had a separate spectral ratio or ratio product number. When the average was determined for each cultivar group, they had a specific value. There was a great overlap of all the numerical values of the trees. Due to the overlap, no values could be assigned to represent the different cultivar groups.**

The use of color infrared film to photograph citrus trees was demonstrated by Norman and Fritz (8). Here we introduce a new imaging system, color infrared video to photograph citrus. This gave instant pictures of the grove; you do not have to wait for an image to be developed.

Nixon et al. (7) compared video color infrared imagery with photographic color infrared photography. A black and white video camera was used to photograph successive images of the same scene. The image was obtained with specific filters. Spectral Data's infrared blocking filter was used in combination with Wratten No. 92 (red) and No. 93 (green). A Spectrcoat monopass filter was used for the near infrared. The images were played back through a I^2 S image processor. The digitized image scenes were stored on a disk. The image processor was used to register the narrow band filtered digitized scenes. The results indicate the video color infrared is a promising real time, versatile and cost-effective remote sensing management tool.

In the spring of 1983, the University of Minnesota developed a color infrared video camera. The camera is a modified 3 tube, RGB, color camera where the color scheme is the same as used for color infrared film and Landsat false color composites: the blue image tube receives the green in the scene; green image tube receives the red in the scene; red image tube receives the near infrared in the scene. The camera generates a National Television System Committee Standard (NTSC) color signal so the camera can be used with standard video cassette recorders and color monitors or TV's (6).

Clegg and Scherz (1) compared the 22.5 cm, 70 mm and 35 mm format cameras. Besides the lower cost of cameras and film, they found that the small format cameras were preferred for vegetation mapping.

Spectral densitometer analysis of citrus tree images with color IR film shows 2 maximum intensities. One is a product of the amount of yellow and magenta dyes in the film which yields red. The other is a product of the magenta and cyan dyes in the film which yields blue (2, 5).

When the ratio of these 2 intensities are calculated, the healthy trees have a value less than one, while the citrus trees under stress have increasing ratio values corresponding to the increased amount of stress (3, 4).

There is a shift in the 2 wavelengths as the colors of the image change. Shih et al. (9) found the absolute deviation to be less than one for the healthy citrus trees and greater for trees under stress. The absolute wavelength differences, intensity differences, and intensity ratios could be used in assessing citrus trees.

This paper describes the use of spectral ratio and the product of the spectral ratio and wavelength differences to compare aerial color infrared video copied on to 35 mm Ektachrome-64 film and aerial 70 mm color infrared photography.

Materials and Methods

A 70 mm Hasselblad camera loaded with Kodak color infrared film was mounted in the camera port of a high wing aircraft. The film was developed in Eastman's E-4 chemistry. Test strips were used to insure proper development.

A modified 3-tube color video camera fitted with a Cannon f 2.8-108 zoom lens was used to record the scenes on a video tape recorder. This system is now commercially available under the name of Biovision Systems. An AC-DC color monitor was connected to the recorder to monitor the scene while in the air. The same recorder was used to still frame or freeze frame the image for coping the scene on 35 mm Ektachrome-64 film. A Konica Auto T-3 with a Promaster 28-80 f 3.5 zoom lens was used for copying the monitor.

[1]Florida Agricultural Experiment Stations Journal Series No. 6060.

A spectral densitometer, composed of a microfiche reader, fiberoptic probe, monochromator, and a photometer were used to analyze the images on the film. Magnification of the microfiche reader was set to fill the face of the probe with the diameter of the citrus tree. Smaller trees were not read as the magnification affects the results. See Fig. 1 for spectral densitometer set up.

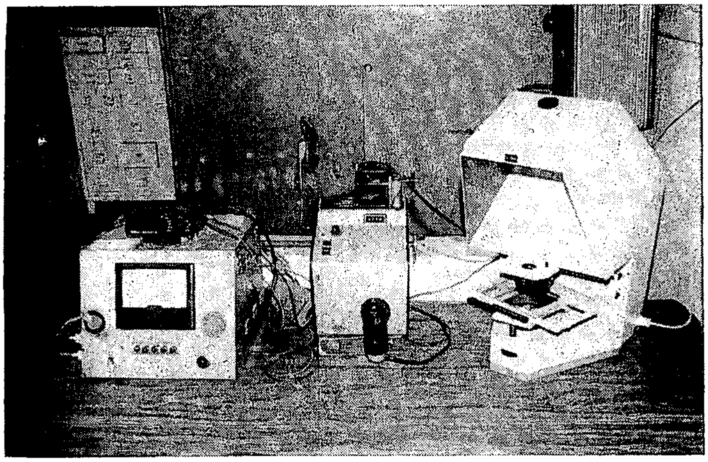

Fig. 1. Spectral densitometer set up.

A commercial grove, of 'Valencia' oranges [*Citrus sinensis* (L.) Osb.] on sour orange (*C. aurantium* L.) root stock about 18 yr old, east of the Citrus Research and Education Center was video taped at 800 ft with the video camera at a ground speed of 90 mph on May, 1984. This grove had been used, in the past, for aerial color infrared photography. The same altitude was used to record, on 70 mm color infrared film, the trees in Florida citrus arboretum which is maintained by the Division of Plant Industry, Florida Department of Agriculture and Consumer Services, on highway 17-92 just north of Winter Haven, Florida. Only the arboretum was photographed on 70 mm color infrared film.

Results and Discussion

A scene was taken from the video recording that contained 3 trees located in the southwest corner of the grove. The trees appeared to range from healthy to severe stress. This scene was copied from a color video monitor on Ektachrome-64 color film. The 3 tree images were scanned from 400 to 650 nm with the spectral densitometer. The intensity values vs. the wavelength were plotted to give a spectral curve for each tree (Fig. 2).

Healthy and stressed tree spectral curves have 2 maximum peaks, one at 520, another at 590 nm. The severely stressed tree, by visual observation, had its second maximum shifted to 580 nm. The ratio of intensities for the first to second peaks had a spectral ratio (SR) value of 1.55 for the healthy tree while the more stressed trees had a value of 1.63 and 2.03. From previous work, trees with a SR value of one or less were a healthy tree. When the healthy tree was field checked on July 30, one sector had a blight-like look, i.e., the leaves were wilted. Citrus trees under the stress of blight have wilted leaves, many small leaves standing up in rosette patterns. According to the length of time the tree has been under stress the fruit will be smaller, less abundant, and the amount of dead wood increases.

Multiplying the wavelength difference, where the intensity maximum occur, by the SR value did not change the trend of the numbers. The assumed healthy tree had a value of 108.50 and the stressed trees had values of 118.99 and 121.63.

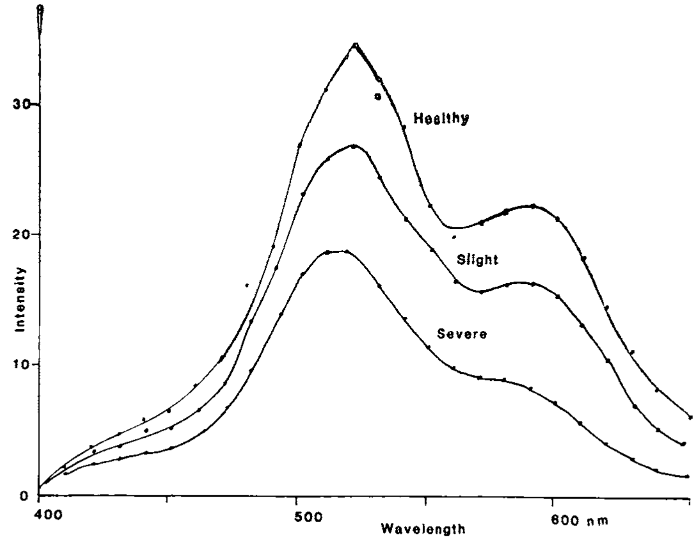

Fig. 2. Plot of intensity vs. wavelength of healthy, slight, and severe stress in citrus trees.

From the arboretum, 134 tree images were analyzed from the 70 mm IR film. They consisted of 11 groups of cultivars (Table 1). From the Ektachrome copies of the video monitor, there were 86 tree images analyzed consisting of 7 groups of cultivars (Table 2). The data show considerable interaction between cultivars for both the 70 mm and video tape copies of the trees. This makes the assignment of a specific value in each cultivar meaningless. The correlation coefficient for the 70 mm film was 0.94 with a standard error of 1.22. The correlation coefficient for the video tape copy was 0.99 with a standard error of 1.27.

The 2 trees that had extreme SR values copied from the TV monitor were plotted as well as the same 2 trees on the 70 mm film (Fig. 3). Spectral curves of the 70 mm images were similar for each tree, pummelo [*C. grandis* (L.) Osb.] (arboretum 6-6) and Smooth Flat Seville sour orange (*C. aurantium* hyb.?), (arboretum 12-12). A better test for the video would have been to determine the spectral curve

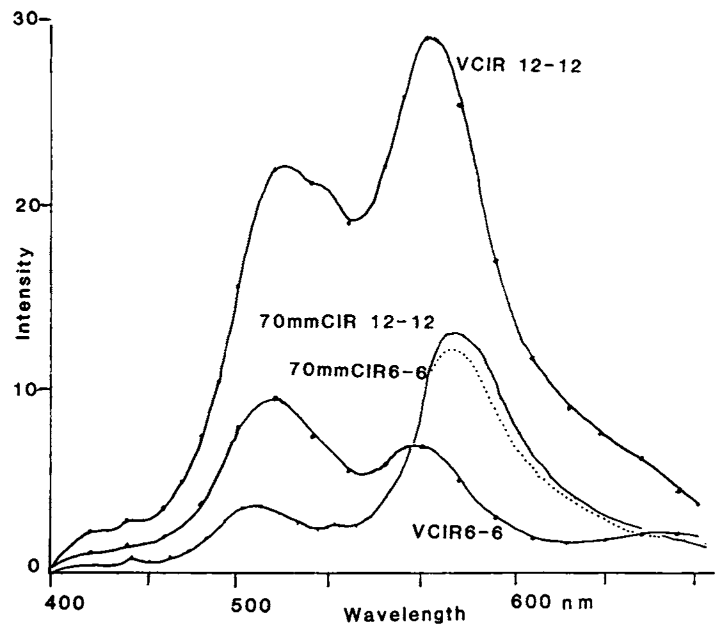

Fig. 3. Extreme case of variability of the video (VCIR) as compared to same trees on the 70 mm CIR infrared film. Tree 6-6 is a pummelo and tree 12-12 is a Smooth Flat Seville sour orange.

Table 1. Spectral ratio total product SR and T values[z] of 70 mm color IR.

Group	No. of Samples	SR values Max	SR values Mean	SR values Min	T values Max	T values Mean	T values Min
Mandarin (*C. reticulata* Blanco)	38	0.56	0.37	0.26	56.15	39.31	27.58
Grapefruit (*C. paradisi* Macf.)	16	0.51	0.36	0.28	49.03	37.58	30.35
Pummelo	12	0.54	0.35	0.26	53.20	36.92	27.40
Shaddock (*C. grandis*)	1	—	0.35	—	—	36.29	—
Papeda (*C. ichangensis* Swingle)	2	0.35	0.33	0.32	36.59	35.92	35.26
Sour orange	11	0.35	0.33	0.29	41.25	35.37	29.96
Sweet orange	29	0.44	0.32	0.26	45.67	35.04	27.64
Lemon [*C. limon* (L.) Burm. f.]	14	0.40	0.30	0.21	42.49	32.94	23.20
Limon (*C. sulcata* Hort. ex Takahaski, *C. tamurana* Hort. ex Tan.)	2	0.34	0.30	0.27	35.78	32.82	29.87
Citrus fruit trees (miscellaneous)	8	0.38	0.30	0.19	40.98	31.75	21.29
Lime [*C. aurantifolia* (Christm.) Swingle]	1	—	0.25	—	—	27.05	—

[z]SR = I-1/I-2; T = SR x (W-2 — W-1); Sr = Spectral Ratio; T= Specctral Ratio X Wavelength Difference; I-1 = Intensity 1; I-2 = Intensity 2; W-1 = Wavelength 1; W-2 = Wavelength 2.

Table 2. Spectral ratio total product SR and T values[z] of video IR EK-35.

Group	No. of Samples	SR values Max	SR values Mean	SR values Min	T values Max	T values Mean	T values Min
Grapefruit	1	—	1.43	—	—	104.03	—
Pummelo	19	1.57	1.34	1.09	131.75	106.26	90.08
Sweet orange	26	1.66	1.26	1.01	136.28	99.54	75.77
Lemon	11	1.60	1.29	0.95	124.88	95.44	73.71
Mandarin	19	1.55	1.24	0.98	118.04	93.85	78.43
Lime	1	—	1.16	—	—	88.04	—
Sour orange	9	1.35	1.10	0.85	103.70	87.79	70.63

[z]SR = I-1/I-2; T = SR x (W-2 — W-1); Sr = Spectral Ratio; T= Spectral Ratio X Wavelength Difference; I-1 = Intensity 1; I-2 = Intensity 2; W-1 = Wavelength 1; W-2 = Wavelength 2.

for each tree off the color monitor rather than copying on to Ektachrome-64 color film.

The spectral curves of 70 mm color infrared film and copies of the video tape from the monitor are similar in that they have 2 peaks.

Copying the video tape displayed on the monitor onto the film and analyzing the film rather than being able to analyze the face of the monitor directly may be the cause for the larger SR values. Although the values are large, the trend is the same—larger values for the trees under stress.

The use of color IR film or color IR video gives a specific value for each group of citrus cultivars but the overlap of SR values or product values does not allow the assignment of specific values for each cultivar group.

This study indicates that citrus trees imaging made with color infrared video camera yield the same general results as trees photographed using 70 mm color infrared film.

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