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## Early Warning and Crop Condition Assessment

August 1981

### AIRBORNE OBSERVED SOLAR ELEVATION AND ROW DIRECTION EFFECTS ON THE NEAR-IR/RED RATIO OF COTTON

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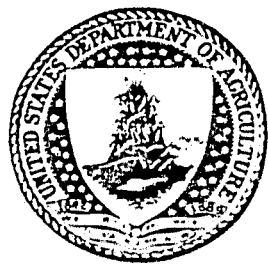
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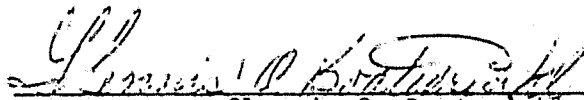
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ABSTRACT

An airborne multispectral scanner was used to evaluate sun elevation and row direction effects on the near-IR/red ratio of cotton. Data were obtained with a Daedalus DEI 1260 multispectral scanner over two adjacent cotton fields, one with east-west oriented rows and the second with north-south oriented rows. The near-IR/red ratios were displayed in image form, so that within-field variations and differences between fields could be easily assessed. The near-IR/red ratio varied with changing sun elevation (time of day) for north-south oriented rows, but no variation was detected for east-west oriented rows.

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## INTRODUCTION

Multispectral data acquired in the red and near-IR portions of the electromagnetic spectrum have potential for use in agricultural crop assessment. Combinations of these two bands have been related to leaf area index and green biomass (Wiegand et al., 1979; Tucker, 1979; Colwell et al., 1977; Pearson et al., 1976; and Haas et al., 1975). They have also been used for yield estimation (Aase and Siddoway, 1981; and Idso et al., 1980).

The amount of reflected solar radiation received by a sensor above a row crop is affected by sun elevation and row direction (Jackson et al., 1979b). This effect occurs as a result of changing amounts of solar irradiance, changing fractions of sunlit and shaded soil, and changing fractions of sunlit and shaded vegetation. Duggin (1977) and Jackson et al. (1979a) demonstrated the effect of sun elevation on spectral data utilizing nadir oriented, ground-based radiometers over wheat. Jackson et al. (1979a) demonstrated that the near-IR/red ratio changed considerably with sun elevation for north-south oriented rows. To the author's knowledge these effects have not been documented for aircraft data.

This report presents results of an experiment in which an airborne scanner was used to obtain multispectral data over two fields having rows perpendicular to one another, at three times of day (different solar elevations), and on two dates (different plant sizes). The data were processed into images of the near-IR/red ratio.

## EXPERIMENTAL

Flights were made over two adjacent cotton fields located about 40 kilometers south of Phoenix, Arizona on 12 June and 12 July 1979. The east field had one-meter spaced rows of cotton running north and south, and the west field had similarly spaced rows running east and west. At the time of the 12 June flights the cotton was about 27 cm high and 25 cm wide. Ground cover was estimated at 25%. By 12 July the plants were about 73 cm high and 64 cm wide, covering about 62% of the soil.

Measurements were made with a Daedalus DEI 1260 multispectral scanner from a nominal altitude of 914 meters. The scanner had 11 channels, ten in the visible/near-IR region and one in the thermal-IR. The wavelengths used in this paper are: (a) 0.600 - 0.650  $\mu\text{m}$  (red); and (b) 0.800 - 0.850  $\mu\text{m}$  (near-IR). Two scan configurations were available. On 12 June, the scanner had an instantaneous field-of-view of 2.50 mrad and a total scan angle of 84°. On 12 July, the scanner had an instantaneous field-of-view of 1.25 mrad and a total scan angle of 42°. Images were produced as described by Millard et al (1978).

## RESULTS AND CONCLUSIONS

Field averages of the near-IR/red ratios for the two dates are plotted in Figure 1 versus solar elevation. Also included is a scale to relate time of day to solar elevation. Field averages were computed from data acquired on the east-west flight track. On 12 June, when the plants were small the near-IR/red ratio was independent of solar elevation and row direction. On 12 July, when the plants were more mature, solar elevation

had a marked effect on north-south planted rows but little effect on east-west rows. Figure 2 shows near-IR/red images of the two fields for two times of day on 12 July 1979. The effect of time of day is quite dramatic for the north-south planted rows (east field). For the 8:57 a.m. flight the east field near-IR/red average is about 4.5 whereas the 12:33 p.m. image yields a value of about 2.8. The near-IR/red image of the east-west planted rows (west field) is nearly independent of time of day.

An explanation of why the near-IR/red ratio changed with time of day, or solar elevation, over the north-south planted rows (east field), can be obtained with the aid of figure 3. This is a plot of radiance in the red and near-IR channels for the 8:57 a.m. and 10:47 a.m. flights on 12 July. The red radiance increased about 60% from 8:57 a.m. to 10:47 a.m., whereas the near-IR radiance increased only about 30%. An increase of about 30% could be expected in both channels due to increasing solar irradiance. The red channel, however, increased significantly more because early-morning-shadowed soil became sunlit. The near-IR radiance did not exhibit the same "shadow" effects because green plants are partially transparent in the near-IR (Tucker, 1977; and Gausman et al., 1973). The combined effect was to lower the near-IR/red ratio with increasing sun elevation. For the east-west planted rows the soil was mostly sunlit throughout the entire day at the location and time of year of this experiment. Thus there was less of a "shadow" effect and both the red and near-IR radiances increased in about the same proportion as solar irradiance.



The results presented here demonstrate the degree to which row orientation and solar elevation can influence aircraft measurements of near-IR/red ratios. They also suggest that multispectral data acquired at several times of day may be useful for evaluating crop parameters such as plant cover and row orientation (Jackson et al., 1979b).

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## LIST OF FIGURES

- Fig. 1. Field averaged near-IR/red ratio versus solar elevation and time of day: N-S and E-W row orientations on two dates corresponding to different percent canopy covers.
- Fig. 2. Near-IR/red images acquired 12 July 1979: flight direction is from east to west (north is the top of page).
- a. 8:57 a.m.
  - b. 12:33 p.m.
- Fig. 3: Radiance in the red and near-IR channels versus angle of view for two times of day.

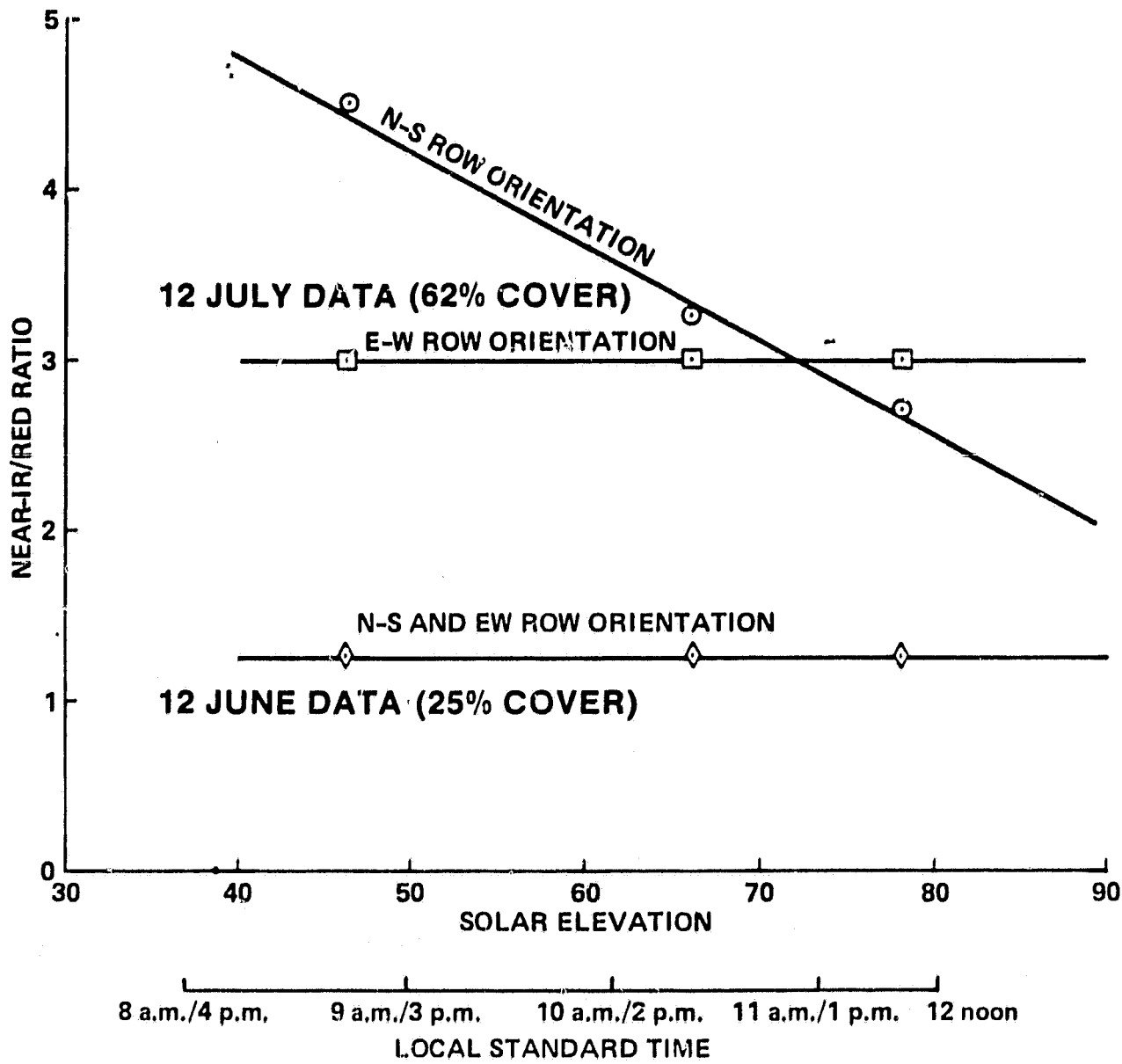


Figure 1

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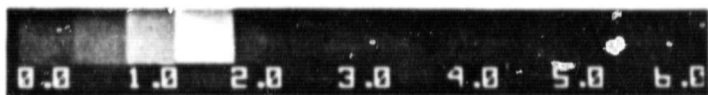
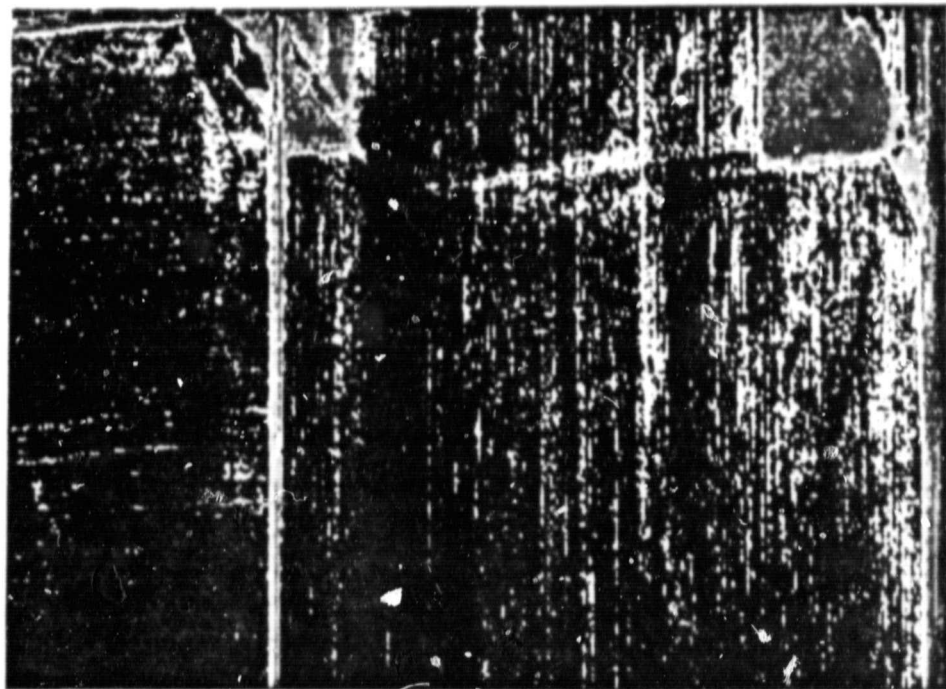
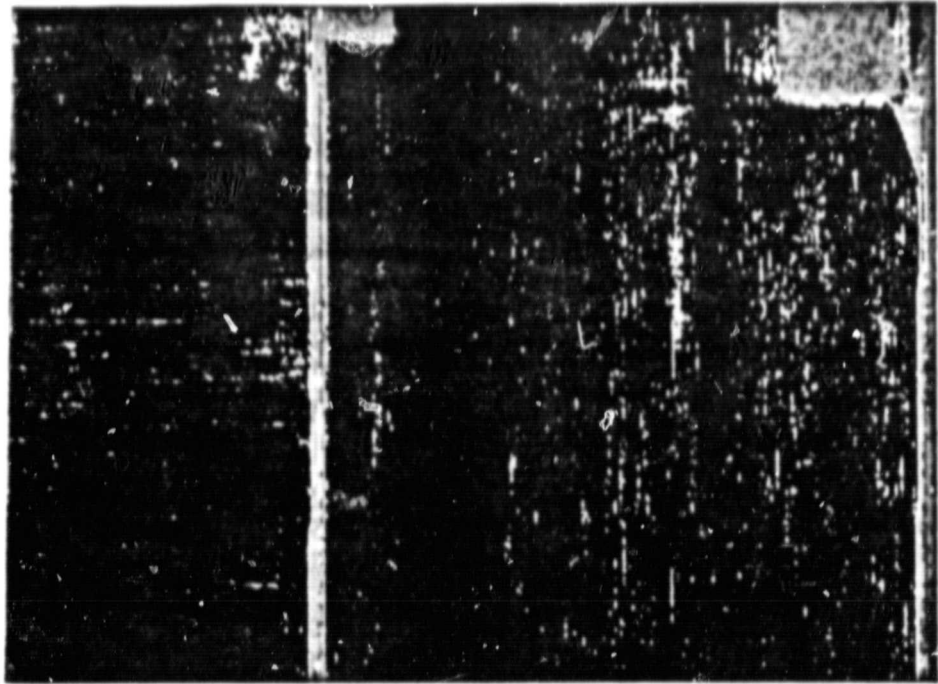
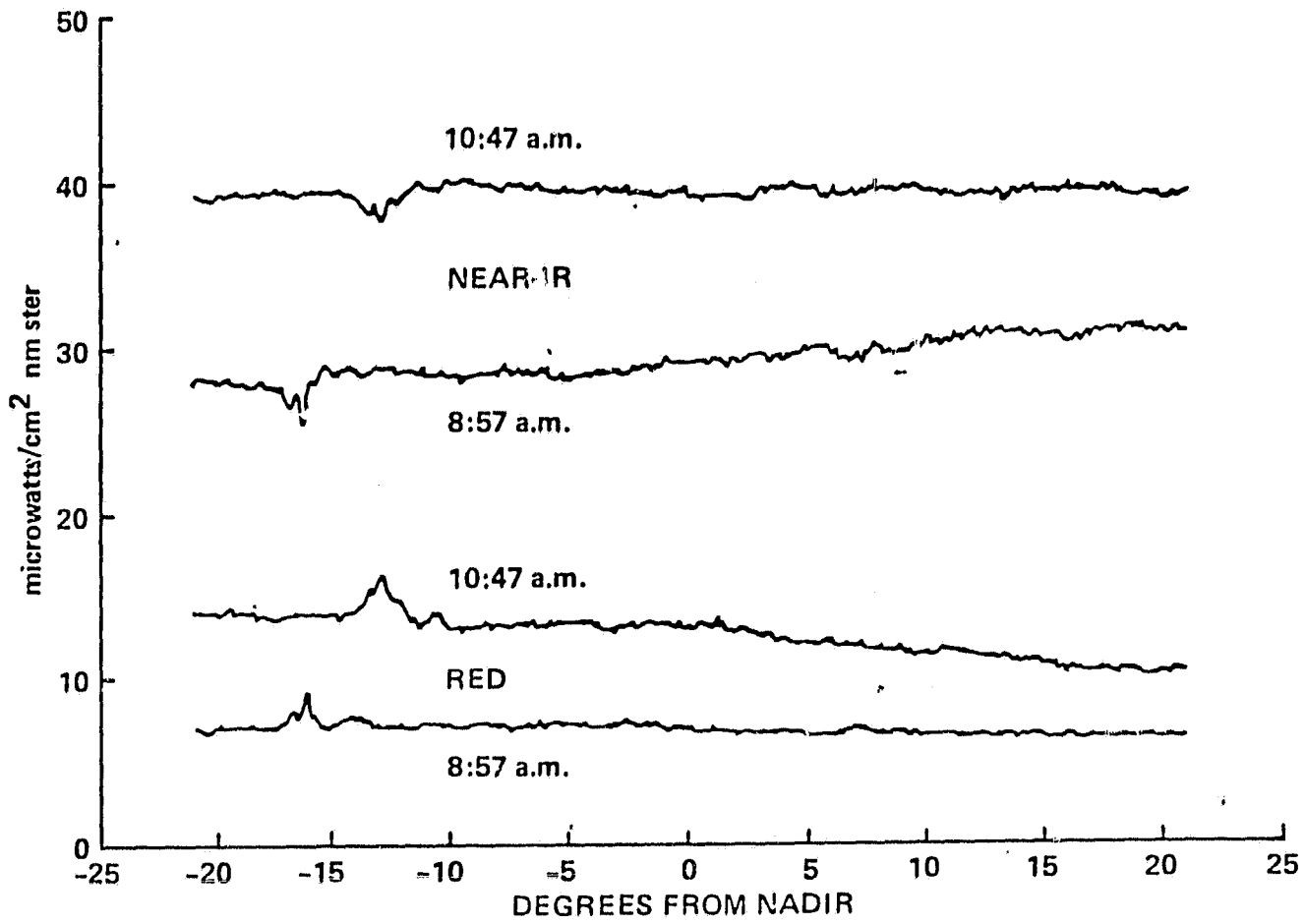


Figure 2



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Figure 3