H. W. GAUSMAN
A. H. GERBERMANN
C. L. WIEGAND
USDA Agricultural Research Service
Weslaco, Texas 78596

Use of ERTS-1 Data to Detect Chlorotic Grain Sorghum*

Chlorotic (iron deficient) sorghum areas 2.8 acres or larger were identified on a computer printout of Band 5 (chlorophyll absorption band) data gathered by ERTS-1. This resolution is sufficient for detecting chlorotic areas in grain sorghum.

ABSTRACT: *This study was conducted to determine if multispectral data from ERTS-1 could be used to detect differences in chlorophyll concentration between chlorotic (iron deficient) and green (normal) grain sorghum* (Sorghum bicolor *(L.) Moench) plants. Band 5 (0.6 to 0.7 μm) data were selected, representing the chlorophyll absorption band at the 0.65-μm wavelength. Chlorotic sorghum areas 2.8 acres (1.1 hectare) or larger were identified on a computer printout of band 5 data. This resolution is sufficient for practical applications in detecting chlorotic areas in otherwise homogeneous grain sorghum fields.*

INTRODUCTION

GRAIN SORGHUM (*Sorghum bicolor* (L.) Moench) is one of the annual crops most sensitive to iron deficiency (Krantz and Melsted, 1964). The deficiency symptom is easily identified; leaves are yellow with dark-green veins (Amador *et al.*, 1970). The interveinal chlorosis (striping) extends the full length of the blades. If iron deficiency (chlorosis) is very severe, plants turn white, become stunted, and die. Iron chlorosis is common wherever sorghum is grown on alkaline soils (Gauch, 1972). Because sorghum is drought-tolerant and soils of most semiarid and subhumid regions are alkaline, iron chlorosis of sorghum occurs throughout the world.

Chlorotic areas in sorghum fields are easily detected in aerial photographs (Gausman *et al.*, 1974). Such aerial photographs and other forms of remote-sensing imagery could be used for identifying sorghum areas that require foliar applications of iron (Krantz *et al.*, 1962) or possibly some other nutrient to attain maximum production and for surveying large areas to determine the acreage of chlorotic sorghum.

This study was conducted to determine if multispectral data from an orbiting satellite (ERTS-1) could be used to detect differences in chlorophyll concentration between chlorotic (iron deficient) and apparently green (normal) grain sorghum plants.

MATERIALS AND METHODS

A 340-acre (138-hectare) commercial grain sorghum (*Sorghum bicolor* (L.) Moench) field that contained areas of normal and chlorotic (iron deficient) plants was selected at Faysville, Texas. Chlorotic areas ranged in size from a very small fraction of an acre to 21 acres (8.5 hectares).

---

* Contribution from the Soil & Water Conservation Research, Southern Region, Agricultural Research Service, USDA, Weslaco, Texas. This study was supported in part by the National Aeronautics and Space Administration under Contract No. R-09-038-002.

Multispectral scanner data used were from an ERTS-1 overpass of the Faysville area on May 27, 1973, at 1130 central DST, during cloudless and haze-free conditions when the grain sorghum was in the early heading stage. Chlorosis was moderately severe — essentially all leaves of affected plants were yellow, but stunting was not evident.

On May 25, two days before the ERTS-1 overpass, plants in the largest chlorotic area and in the normal area (Plate 1) were sampled for total chlorophyll analysis (Horwitz, 1965). Within each area, a typical plant was selected every 60 feet (18.3 meters) until 10 plants had been sampled; a top leaf was excised from each plant. Leaf samples were placed on ice immediately and transported to the laboratory where they were stored in a freezer at −15°C overnight. All samples were analyzed for total chlorophyll on May 26.

On May 25, a ground-based, Exotech Model 20 Spectroradiometer* described by Leamer *et al.* (1973) was used to measure reflected radiation from chlorotic and normal plant canopies in the field over the 0.4- to 0.74-μm wavelength interval. Measurements were made 20 feet (6.1 meters) above the plants, with a 15° field of view. Spectroradiometric measurements were made to aid in interpreting ERTS-1 multispectral scanner imagery.

The sorghum field was aerially photographed by exposing Kodak Aerochrome infrared film 2443 at f/8 for 1/500 sec at an altitude of 6,000 feet (1,830 meters) during cloudless and medium-haze conditions on May 30, 1973, at 1142 central DST. A Hasselblad 500 EL camera was used equipped with a 120-mm lens and Hasselblad combination 2X CB6 and 4X O filters.

Computer printouts (gray maps) were obtained from ERTS-1 magnetic tape; symbols were used to represent increments of digital counts (see Plate 1 caption for explanation of symbols). Chlorotic areas on computer printouts for bands 4 (0.5 to 0.6 μm), 5 (0.6 to 0.7 μm), 6 (0.7 to 0.8 μm), and 7 (0.8 to 1.1 μm) were identified by comparing the printouts with aerial photographs. Chlorotic areas on photographs were planimetered to determine the smallest acreage that could be identified on the printouts.

To test the statistical significance of mean differences between ERTS-1 digital counts of the normal area and the largest chlorotic area (Plate 1), 15 resolution elements were randomly selected from printouts of each area for each of bands 4, 5, 6, and 7, and the unpaired *t* test was applied for each band (Snedecor, 1965).

RESULTS AND DISCUSSION

There was a statistically significant (p = 0.01) difference between mean total chlorophyll concentrations of chlorotic (iron-deficient) and apparently normal green sorghum plants. Chlorophyll concentrations in leaves were 9.4±1.05 (standard deviation) and 0.4±0.15 mg/g of plant tissue on a dry weight basis for normal and chlorotic plants, respectively.

Chlorophyll concentrations of chlorotic and normal plants significantly (p = 0.01) affected reflectance measurements made in the field with a spectroradiometer (Figure 1). Reflectance was 9.4, 27.7, and 26.3 percent higher for chlorotic than for normal plant canopies at the 0.45-μm (chlorophyll absorption band), 0.55-μm (green reflectance peak), and 0.65-μm (chlorophyll absorption band) wavelengths, respectively. These reflectance differences were caused by the unequal chlorophyll concentrations because

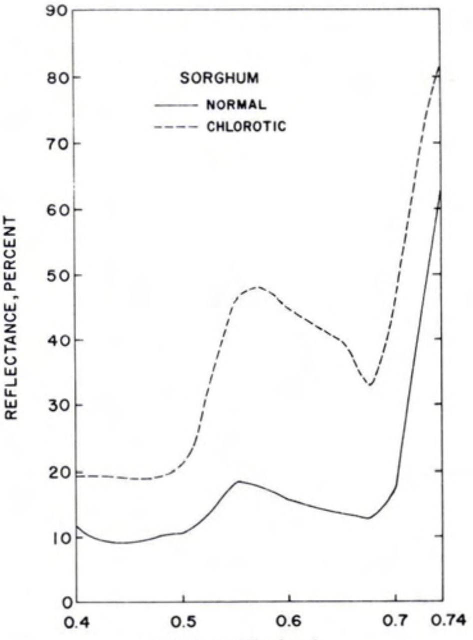

FIG. 1. Reflectance of normal and chlorotic grain sorghum canopies measured in the field with a spectroradiometer at the 0.4- to 0.74-μm wavelength interval.

---

* Mention of company or trademark is for the readers' benefit and does not constitute endorsement of a particular product by the U. S. Department of Agriculture over others that may be commercially available.

chlorotic and normal plants had the same soil background, and their size and geometry were essentially the same.

The upper oblique photo in Plate 1 is a positive print of an infrared transparency that readily shows the color difference between chlorotic and normal areas; chlorotic areas appear white, and normal areas appear magenta. Oblique photographs delineated chlorotic areas better than overhead photographs. The lower photo in Plate 1 depicts the computer printout for band 5 (0.6 to 0.7 μm). Although the difference in mean digital counts between the normal area and the largest chlorotic area was statistically significant ($p = 0.01$) for all bands (4, 5, 6, and 7), band 5 was selected because it contains the chlorophyll absorption band at the 0.65-μm wavelength; differences in mean digital counts were 5.3, 7.7, 7.2, and 2.4 for channels 4, 5, 6, and 7, respectively.

A comparison of encircled areas in the lower photo (Plate 1) with the chlorotic areas in the upper photo shows that most of the chlorotic areas can be identified on the computer printout of the ERTS-1 band 5 data. Chlorotic areas on the printout have higher digital counts (higher reflectance) than normal areas (see Plate 1 caption for explanation of symbols) because chlorotic plants have less chlorophyll than normal plants and, therefore, chlorotic plants absorb less and reflect more radiation than normal plants at the 0.65-μm chlorophyll absorption band.

Chlorotic areas were planimetered on photographs, and their size was calculated. From these results it was determined that chlorotic areas 2.8 acres (1.1 hectare) or larger could be identified on the band 5 printout in Plate 1. This resolution makes practical applications feasible. For example, ERTS-1 multispectral data could be used to detect chlorotic grain sorghum growing on alkaline soils throughout the world.

Results show that ERTS-1 multispectral data detected differences in chlorophyll concentration between chlorotic and apparently normal sorghum plants. Chlorotic areas 2.8 acres (1.1 hectare) or larger were identified. This resolution is sufficient for practical applications, e.g., in detecting chlorotic areas in otherwise homogeneous grain sorghum fields.

LITERATURE CITED

Amador, J., R. W. Berry, R. A. Frederiksen, C. W. Horne, W. H. Thames, and R. W. Toler, 1970, "Sorghum Diseases," *Texas A&M Univ. Bull.* 1085. 20 pp.

Gauch, H. G., 1972, *Inorganic Plant Nutrition,* Dowden, Hutchinson, & Ross, Inc., Stroudsburg, Pa. 488 pp.

Gausman, H. W., R. Cardenas, and A. H. Gerbermann, 1974, "Plant Size, etc., and Aerial Films," *Photogrammetric Engineering* 40(1):61-67.

Horwitz, W., 1965, *Official Methods of Analysis,* 10th ed., Assoc. of Official Agric. Chemists, Washington, D. C. p. 115.

Krantz, B. A., A. L. Brown, B. B. Fischer, W. E. Pendery, and V. W. Brown, 1962, "Foliage Sprays Correct Iron Chlorosis in Grain Sorghum," *Calif. Agr.* 16(5):5-6.

Krantz, B. A., and S. W. Melsted, 1964, "Nutrient Deficiencies in Corn, Sorghums, and Small Grains," p. 25-46. *In:* H. B. Sprague (ed.) *Hunger Signs in Crops,* David McKay Co., New York.

Leamer, R. W., V. I. Myers, and L. F. Silva, 1973, "A Spectroradiometer for Field Use," *Rev. Sci. Instrum.* 44:611-614.

Snedecor, G. W., 1965, *Statistical Analyses,* 5th ed. The Iowa State College Press, Ames. 534 pp.

PLATE 1. *See page 181.*

A.S.P. ANNOUNCES ORTHOPHOTO WORKSHOP III

ORTHOPHOTO WORKSHOP III, latest in the ASP series of symposia on the state-of-the-art in orthophotography, is scheduled for June 4-6, 1975.

Sponsored by the American Society of Photogrammetry, this year's event will be held at the El Tropicano Motor Hotel, San Antonio, Texas. The Society's Texas-Louisiana Region will host the workshop.

Several new orthophoto devices have come onto the market since the last workshop and many projects are underway or now complete, in which orthophotography plays a major role.

Richard T. Church, Workshop Chairman, indicates that workshop objectives are to 1) identify the state-of-the-art, 2) provide a forum for users of orthophoto equipment, and 3) to supply the buyer or potential buyer of orthophotos a clear understanding of the fundamentals and advantages of orthophotography and its many uses.

The Third workshop is to consist of six (6) technical sessions, (two each day) during which the invited technical papers will be discussed informally, along with a limited number of unsolicited papers. According to Dr. Robert T. Turpin and Dr. Robert Baker, Program Co-Chairmen, all accepted papers will be published in a bound volume.

No formal call for papers is planned. Anyone wishing to prepare an un-solicited paper should submit the following information:

1. The paper's title
2. Author's name, address and telephone number
3. An abstract of approximately 200 words

This information should be mailed to:

Dr. Robert T. Turpin
Civil Engineering Department
Texas A&M University
College Station, Texas 77843

The Co-Chairmen have indicated that invited papers will include the fundamentals, history, recent technical progress, user procedures and project descriptions of orthophotographic endeavours.

An exhibit area including both commercial and noncommercial exhibits will be open throughout the show. Manufacturers will be exhibiting new orthophoto equipment and recent projects will be featured in the noncommercial area.

Several other national organizations are cooperating in presenting the workshop. Members will receive more detailed information on this important technical meeting at a later date.

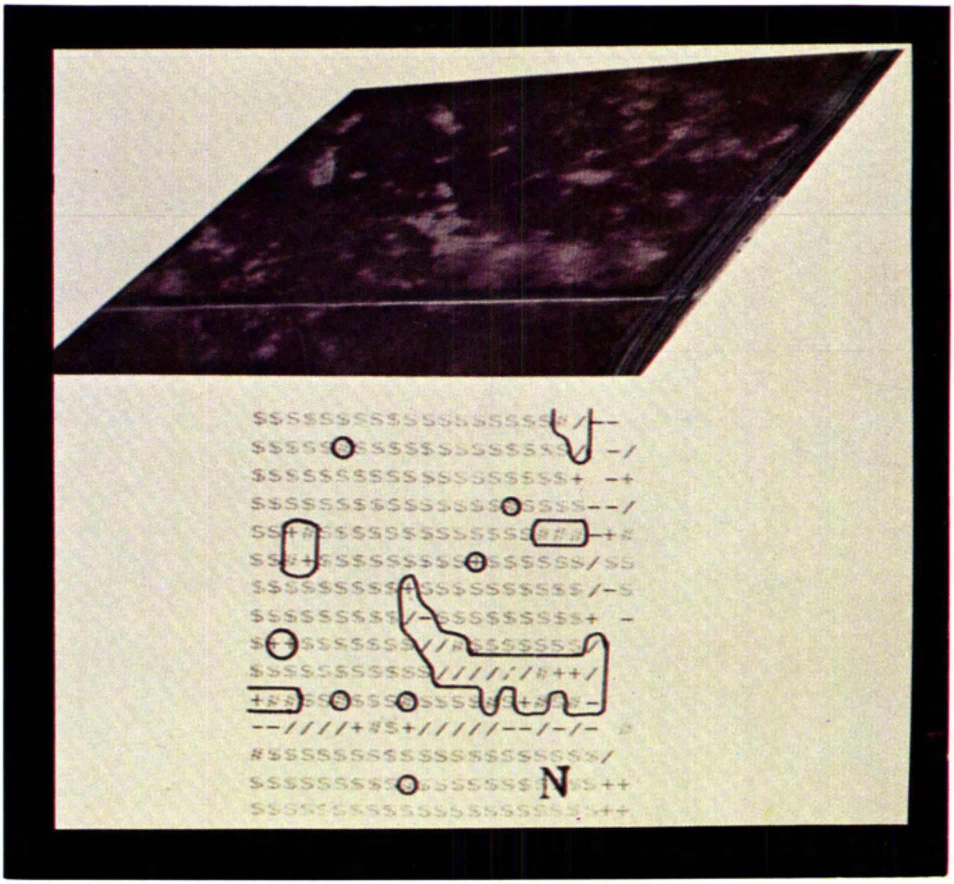

PLATE 1. Upper photo is a positive print of an infrared transparency showing areas of white-appearing chlorotic sorghum and magenta-appearing normal *(N)* sorghum. Lower photo is a printout of ERTS-1 band 5 data; chlorotic areas corresponding to those in the upper photo are encircled. Digital counts corresponding to the printout symbols are: $ = 30 to 33, # = 33 to 36, + = 36 to 39, / = 39 to 42, − = 42 to 45, and blank = ≥ 45.