1. Roy Eason sH3

CR-175384

CR. none

2. AgRISTARS

7. EW-U2-04244
JSC-17818

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

Early Warning and Crop Condition Assessment

6. FEBRUARY 1982

REFLECTANCE MEASUREMENTS OF COTTON LEAF SENESCENCE ALTERED BY MEPIQUAT CHLORIDE

(E84-10089) REFLECTANCE MEASUREMENTS OF COTTON LEAF SENESCENCE ALTERED BY MEPIQUAT CHLORIDE (Agricultural Research Service) 15 p HC A02/MF A01 CSCL 02C

N84-19960

Unclas
G3/43 00089

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle REFLECTANCE MEASUREMENTS OF COTTON LEAF SENESCENCE ALTERED BY MEPIQUAT CHLORIDE		5. Report Date 6. Performing Organization Code
7. Author(s) H. W. Gausman, D. E. Escobar, and R. R. Rodrigue.		8. Performing Organization Report No.
9. Performing Organization Name and Address USDA/ARS Remote Sensing Research Unit Weslaco, Texas 78596		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address EW/CCA 1050 Bay Area Blvd. Houston, Texas 77058		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		

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17. Key Words (Suggested by Author(s))	18. Distribution Statement
Spectral reflectance cotton leaf Mepiquat chloride leaf senescence	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

*For sale by the National Technical Information Service, Springfield, Virginia 22161

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February 1982

Reflectance Measurements of Cotton Leaf Senescence Altered by Mepiquat Chloride

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Abstract

Spectrophotometric reflectance measurements were made on plant-attached leaves to evaluate growth chamber-grown cotton leaf (Gossypium hirsutum L.) senescence (chlorophyll degradation as criterion) that was delayed by mepiquat chloride (1,1-dimethylpiperidinium chloride) rates of 0, 10, 40, 70, and 100 g a.i./ha. Mepiquat chloride (MC) increased both chlorophyll and leaf water contents as compared with that of untreated leaves. Reflectance was inversely and linearly correlated (r = -0.873**) with water content at the 1.65 µm wavelength and was inversely correlated (r = -0.812**) with chlorophyll concentration at the 0.55 µm wavelength but best fit a quadratic equation. Either wavelength measurement might be useful to remotely detect cotton leaf senescence or fields of MC-treated cotton plants.

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Introduction

Plant leaf senescence has been modified by unrelated chemicals (1, 14, 18), stress (3, 6), plant hormones (14, 16, 17), and has been involved in leaves' ultrastructure and metabolism (13, 15, 20). A recent review (23) indicates that senescence is controlled by a nuclear genome that represses the plastids' genetic system and is manifested primarily by chlorophyll degradation and organelle disintegration.

We found (6) that the growth regulator mepiquat chloride (1,1-dimethylpiperidinium chloride) delayed cotton (Gossypium hirsutum L.) leaf senescence in both pot and field studies and that senescence could be detected spectrally. Spectral measurements of senescing leaves are related to crop phenology (12, 25) and to yield estimations (11). Chlorophyll degradation increases visible light reflectance by decreasing light absorptance, particularly at a waveband around the 0.55 μm wavelength (4). As a leaf dehydrates, its reflectance increases over the entire 0.45 to 2.5 μm waveband (4). However, best evaluations of water loss can be made at wavebands that encompass either the 1.65 or 2.20 μm wavelengths (5, 7, 10, 24), because effects of leaf chlorophyll content and internal structure are minimal (4). Changes in leaf water content can be noted quicker spectrally than changes in chlorophyll concentration (10, 24). A good correlation has been reported between spectral results for individual leaves and plant canopies (5).

Our objective is to show how reflectance measurements can be used to evaluate cotton leaf senescence that was altered by MC applications.

MATERIALS AND METHODS

Cotton plant seeds (cv 'GH-8-10-75') were planted in Jiffy-7™ peat pellets and placed in a growth chamber environment. After germination, healthy and uniform seedlings were transplanted into 2.5 liter capacity plastic pots containing a 1:200 (V:V) mixture of Perlite™ and Hidalgo sandy clay loam (Typic Calciustolls). A 10-20-5 fertilizer was added to the mixture at the equivalent rate of 67.2 kg/ha of N. All pots were surface irrigated equally every 2 days with rain water. Mean daily temperature ranged from 20.5 to 30.5 C, and relative humidity ranged from 61.0 to 91.0%. A 12 hour light-dark cycle was used. Light intensity was about 8600 lux at the plants' apexes.

A randomized complete block experimental design was used with six replications of five treatments: an untreated plant (control) and four plants treated with MC concentrations of 10, 40, 70, and 100 g a.i./ha, respectively. The MC was applied to the cotton plants with a hand sprayer when they were at the 7th true leaf stage of growth. The total spray volume per plant was equivalent to 252 liter/ha. Control plants were sprayed with distilled water.

Seventy-five days after MC treatments were applied, about the time when leaf chlorophyll degradation became evident on the untreated plants' lower leaves, light reflectance measurements were conducted on all plants' 9th true leaf. A Beckman DK-2A™ spectrophotometer, equipped with a reflectance attachment was used to measure total diffuse reflectance on the upper (adaxial) surfaces of the plant-attached leaves over the 0.5 to 2.5 μm waveband. Data were corrected for decay of the barium sulfate standard to give absolute radiometric data (2).

To interpret the reflectance data, two wavelengths were used: the 0.55 μm wavelength (the green reflectance peak) to evaluate the effect of chlorophyll (21), and the 1.65 μm wavelength to measure the effect of leaf water content (22).

Samples were obtained from leaves that were used for reflectance measurements for total chlorophyll assays (9) and water content determinations: dried in an oven at 68°C for 72 h then cooled in a desiccator before weighing. Correlation ($p = 0.01$) (19) was used to study relations of leaf chlorophyll concentration with reflectance at the 0.55 μm wavelengths and of leaf water content with reflectance at the 1.65 μm wavelength.

RESULTS AND DISCUSSION

Mepiquat chloride-treated cotton leaves had higher chlorophyll (delayed senescence) (Fig. 1) and water contents (Fig. 2) than untreated leaves. Leaf reflectance measurements, discussed below, were used to characterize both leaf chlorophyll and water content.

Chlorophyll

Mean leaf reflectance measurements, made at the 0.55 μm wavelength, were correlated with leaf chlorophyll concentrations (Fig. 1) and were plotted with a quadratic equation. The quadratic polynomial accounted for about 66% ($r = -0.812$**) of the total variance. The correlation is higher than previously reported for cotton leaves (21). Nevertheless, considerable variability occurred among leaves, which was undoubtedly caused by differences in their maturation (4) and possibly unobservable leaf senescence. Even so, it is feasible that delayed senescence in MC-treated fields in large cotton growing areas could be detected with remote sensing techniques, including hand-held radiometers, aerial photography, and possibly satellite imagery, depending on field size and sensor resolution. For example, we have shown, in an unpublished work at Weslaco, that both conventional and infrared color photography easily distinguishes MC-treated from untreated cotton experimental plots. Also, interesting and purposeful studies could be conducted on correlations of cotton biomass with lint yield comparing MC-treated and untreated cotton fields, since MC is a growth retardant and reduces canopy size without decreasing lint yield (8).

Water Content

Mepiquat chloride-treated cotton leaves had higher water content (more succulence) than untreated leaves (Fig. 2). Leaf succulence markedly affects reflectance (4, 5, 7). Reflectance measurements at the 1.65 µm wavelength were linearly correlated ($r = -0.873^{**}$) with percent water content when two unusual data points, indicated by arrows, were eliminated. Including these data points gave a coefficient of 0.749**. We think that the two extreme data points were caused by the occurrence of leaf maturation or senescence in our sampling procedure or possibly by errors in our reflectance measuring technique.

Single leaf reflectance measurements in the laboratory correlated well with field radiometric measurements for succulent vs. nonsucculent plant species at the 1.65 and 2.20 µm wavelengths (5). Therefore, research is in progress with a hand-held radiometer to determine whether or not MC-induced increased leaf water content can be measured at the 1.5 µm wavelength on cotton canopies in the field.

CONCLUSION

Reflectance measurements made on plant-attached leaves can be used to detect MC-delayed leaf senescence of growth chamber-grown cotton plants at either the 0.55 μm wavelength, affected by chlorophyll concentration, or at the 1.65 μm wavelength, affected by leaf water content: MC increased both leaf chlorophyll and water content which decreased reflectance. Either wavelength measurement might be useful to evaluate the rate of cotton leaf senescence or to remotely detect fields of MC-treated cotton.

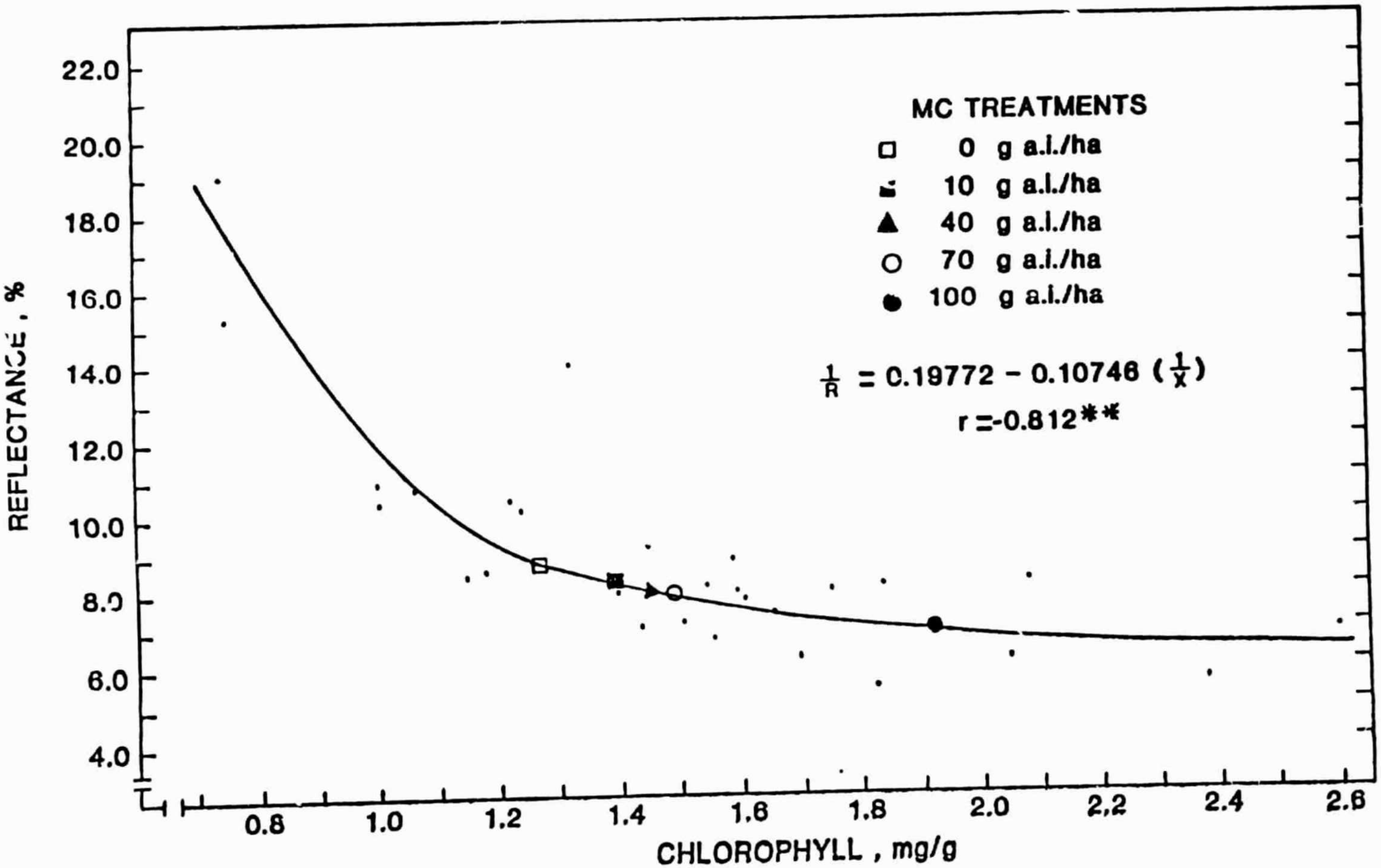

Fig. 1. Quadratic relation of cotton leaf reflectance at the 0.55 μm wavelength with leaf chlorophyll concentration that was altered by mepiquat chloride (MC) foliar treatments.

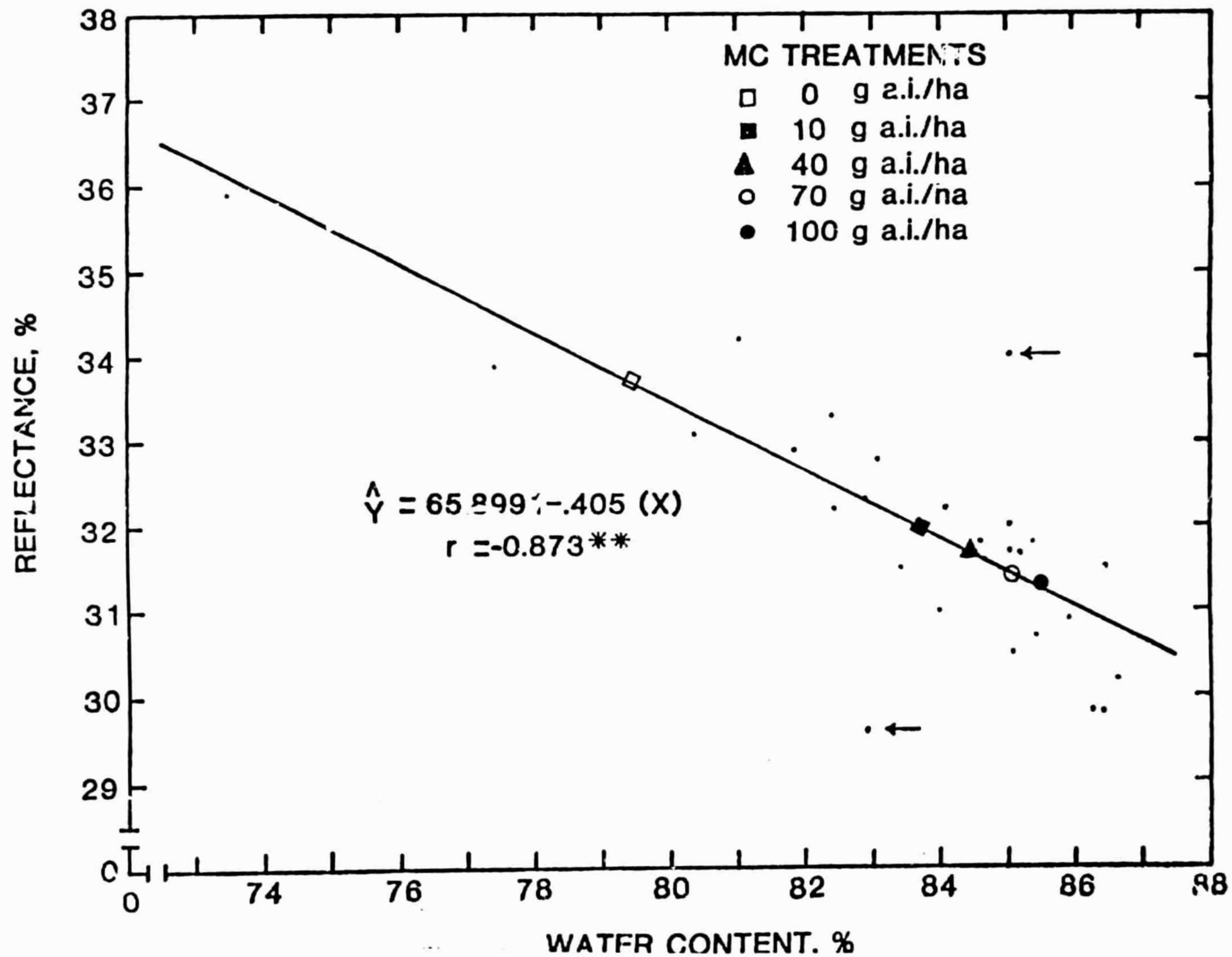

Fig. 2. Linear relation of cotton leaf reflectance at the 1.65 μm wavelength with leaf water content that was altered by mepiquat chloride (MC) foliar treatments.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1982—589-011/544