Spectral response of spider mite infested cotton: Mite density and miticide rate study

Yubin Lan[1*], Huihui Zhang[2], W C Hoffmann[1], Jr. Juan D Lopez[1]

(1. *United States Department of Agriculture, Agricultural Research Service, Areawide Pest Management Research Unit, College Station, Texas, USA*;
2. *United States Department of Agriculture, Agricultural Research Service, Water Management Research Unit, Parlier, California, USA*)

Abstract: Two-spotted spider mites are important pests in many agricultural systems. Spider mites (Acari: Tetranychidae) have been found to cause economic damage in corn, cotton, and sorghum. Adult glass vial bioassays indicate that Temprano™ (abamectin) is the most toxic technical miticide for adult two-spotted spider mite. From an aerial application standpoint, additional research is needed to identify aerial application parameters for this miticide. The objective of this study was to investigate spectral response of spider mite-infested cotton plants with different density levels of mites and treated with different rates of miticide. Results showed significantly different spectral signatures of cotton plants infested with different density levels of mites. By treating mite-infested cotton plants with five different Temprano rate treatments (control, one-eighth, one-fourth, one-half, and full rates), spectral reflectance curves were found to be significantly different. Four wavelengths of 550 nm, 560 nm, 680 nm and 740 nm were important for detecting the spectral differences among mite infested cotton plants treated with various rate of Temprano. Normalized Difference Vegetative Index imagery was able to detect different levels of cotton plant damage. Half-rate application of Temprano controlled mite-infested plants as effectively as the full-rate application. These findings may lead to reduced cost and quantity of miticides used to maintain effective crop production and protection.

Keywords: spectral reflectance, infested cotton plants, crop protection, Normalized Difference Vegetative Index (NDVI), Temprano rate treatments

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1 Introduction

Spider mites (Acari: Tetranychidae) have been found to cause economic damage in corn[1], sorghum[2], and cotton[3]. Chandler et al.[4] found that the mite population in corn remained low before the corn tasseled and rapidly increased prior to soft dough. They also reported that populations could be reduced by rain or irrigation events. To limit economic damage caused by spider mites, a wide range of insecticides, such as monoterpenoids, carvomenthenol, terpinen-4-ol[5], imidacloprid[6], and pyrethroids[7]. Gerson and Cohen[7] reported that the application of synthetic pyrethroids can lead to a resurgence of spider mite populations in a week after application. Before deciding whether a spider mite population has reached an economically damaging level, an assessment of the population must be made by hand examination and counting throughout the field[8], limited counts with statistical inference[9], or sweep nets[10]. These methods are laborious and time-consuming;

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Biographies: Huihui Zhang, PhD, Research Agricultural Engineer, USDA-ARS Water Management Research Unit, Parlier, California, USA. Tel: 1-559-596-2832. Email: huihui.zhang@ars.usda.gov. **W C Hoffmann,** PhD, Agricultural Engineer, USDA-ARS, College Station, Texas, USA. Tel: 1-979-260-9521. Email: clint.hoffmann@ars.usda.gov. **Jr. Juan D Lopez,** Research Entomologist (retired), USDA-ARS, College Station, Texas, USA. Tel: 1-979-260-9530. Email: juan.lopez@ars.usda.gov.

*__Corresponding author: Yubin Lan__, PhD, Agricultural Engineer, USDA-ARS, College Station, Texas, USA. Tel: 1-979-260-3759. Fax: 1-979-260-9386. Email: yubin.lan@ars.usda.gov.

therefore, there is a need for a quicker and easier method to assess spider mite populations, such as remote sensing.

Two-spotted spider mite (TSSM) adults, as the name suggests, have two large dark spots on the sides of their yellowish green bodies. Two-spotted spider mites are important pests in many agricultural systems and are the most important arthropod pest of fresh cut roses. Both immatures and adults are fed by extracting fluids from plant cells. Spider mites can directly kill plant cells and entire leaves, or plants. Damages can be detected by a decrease in near infrared (NIR) energy, so remote sensors can be combined with variable rate pesticide applications to treat only infested areas of fields[11].

Adult glass vial bioassays indicate that Temprano™ (abamectin) is the most toxic technical miticide for TSSM adults. From an aerial application standpoint, additional research is needed to identify aerial application parameters for this miticide. Several aspects need to be evaluated before aerial application parameter research is completed based on field applications and verification. One of these aspects is to evaluate the effect of different concentrations relative to the lowest labeled rate of the formulated miticide on mortality of TSSM on cotton when applied via a spray table.

The goal of the research was to integrate remote sensing and variable rate systems that enhance and optimize applications of crop production and protection products. The objective of this study was to use remote sensing data to investigate spectral response of spider mite-infested cotton plants infested with different density levels of mites and treated with different rates of miticide.

2 Materials and Methods

2.1 Experimental plants

Five flats of the same age and a uniform cotton plant stand were infested as uniformly as possible by putting pieces of mite-infested bean or cotton plants depending on availability of massed TSSM. An effort was made to obtain a uniform infestation of the mites over the plants in the flats. The plant parts used to infest the cotton plants had a mixture of adults and immatures based on how long they had been massing on the plants and by checking the massed mites on leaf tips on terminals. Flats were randomly numbered (1-5) and the treatments were assigned to the flats randomly by a random number generator process. Once the treatments were assigned, the flats were properly labeled by the flat number as well as the assigned treatment. A period of two days between infestation and treatment were allowed to have active reproduction on the plants in the flat.

There were a total of five different Temprano rate treatments, control, one-eighth, one-fourth, one-half, and full rates. Each treatment had three replicates. Application of the treatments was at a rate of 2 GPA and a volume median diameter ($D_{v0.5}$) of 275-300 μm. A flat fan nozzle was used to deliver the spray. The flats were positioned on the spray table with the long axis aligned with the table. The quality of the spray over the flat was checked with water sensitive paper to make sure that the distance between the table and the top of the canopy of the cotton plants allowed for uniform application across the plants.

Three spider mite density levels were tested: three masses per flat for light density treatment, 20 masses per flat for medium density treatment, 40 masses per flat for heavy density treatment, and 30 masses per flat were tested for Temprano rate study.

2.2 Data acquisition and analysis

Spider mite damage on each flat was assessed with FieldSpec® (Analytical Spectral Devices, Inc., Boulder, CO, USA) handheld spectroradiometer. All of the spectral measurements were collected between 12:00 and 14:00 pm to avoid the influence of illumination changes on the spectral responses. Each flat was placed on a plant cart with the long axis aligned with the long axis of the cart. Each flat was sampled by ten spectra readings. This spectroradiometer measures radiation ranging from a wavelength of 325 nm to 1 075 nm with a sampling interval of 1.6 nm and an angular field-of-view of 25°. Since the reflectance property of the crop canopy is affected by the spatial distribution of vegetated and non-vegetated areas, the spectroradiometer was placed at a height of approximately 30 cm above the canopy surface to reduce the non-vegetated area that the sensor might view. The instrument optimization and white reference measurements were performed prior to each treated flat measurements according to Castro-Esau et al. (2006). The white reference was collected with a Spectralon white panel until a straight 100% reflectance line appears. Spectral reflectance data were exported into a spreadsheet for further analyses.

Averaged reflectance values at a bandwidth of 10 nm between 400-1 000 nm were analyzed with principal component analysis (PCA) for band selection. The information content contained in the original variables is projected onto a smaller number of principal components (PCs), which are linear combinations of those variables. The process of PCA returns PCA scores, which are the estimated values for each PCs, and PCA loadings. The PCA score plot can present the clustering of the data, and the PCA loading plot can be used to investigate the contribution of each variable. In this case, first three PCs were used to identify important wavelengths. The PCA was performed using the PRINCOMP procedure in SAS (SAS Institute, Inc., Cary, N.C.).

For analyzing the feasibility of detecting mite damage using multispectral imagery, we used an agriculture digital camera (ADC) (Teracam, Chatsworth, CA) to take images of the plants under different treatments. The camera is a single-sensor digital camera with 1.3-megapixel resolution and optimized for capture of green (550 nm), red (650 nm) and near infrared (800 nm) wavelengths of reflected light. After processing the reflectance images, reflectance spectra of damaged cotton leaves treated with different Temprano rates were extracted from an area of interest (AOI) of the multispectral image using Erdas Imagine 2011 software (Intergraph Corporation, Madison, AL, USA). Mean 100 pixels were selected to compute the representative reflectance spectra for each treatment flat. All statistical analyses were carried out using the GLM procedure in SAS (SAS Institute Inc., Cary, NC).

3 Results and discussion

3.1 Spectral response of different spider mite density treatments

Figure 1 shows mean reflectance spectra of cotton plants infested with light, medium and high mite density levels over three spectral wavebands. Reflectance values of infested cotton plants with light mite density were consistently higher than the other two treatments. A statistical test showed the significant differences in reflectance values among different treatments at the significant level of 0.05 (Table 1).

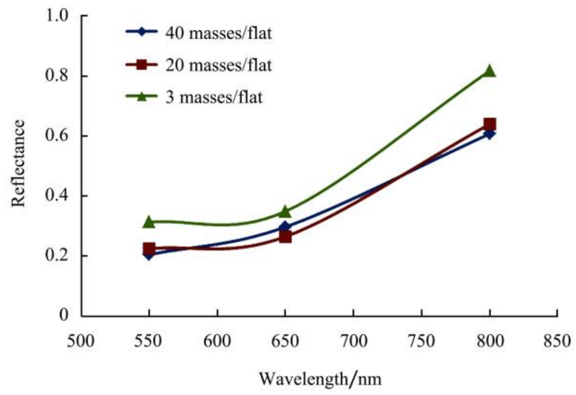

Figure 1 Reflectance spectra of cotton plants infested with light, medium and high mite density levels

Table 1 Spectral reflectance in Green, Red and NIR wavebands responding to different mite density levels

Treatment	Green	Red	NIR
Light	0.6067[a]†	0.6389[a]	0.816[a]
Medium	0.2648[ab]	0.2973[a]	0.3133[b]
High	0.2051[b]	0.225[a]	0.3492[b]

Note: † Means data followed by different superscript letters within a column are significantly different at $p = 0.05$ according to the Tukey's studentized range (HSD) test.

Colored Normalized Difference Vegetative Index (NDVI) images of cotton plants infested with light, medium and high mite density levels are shown in Figure 2. The infested cotton plants with a high mite density level had less vegetation than light and medium mite density level. Most leaves of infested cotton plant in high mite density level were dead as indicated by pink color.

3.2 Spectral response of different Temprano rate treatments

3.2.1 Multispectral image

The cotton plants were infested on March 9, 2010. Images were taken on seven days after Temprano treatment. Figure 3 shows the mean reflectance spectra of infested cotton plants treated with different Temprano rate over three spectral wavebands. A statistical test showed no significant differences in reflectance from infested cotton plants among different Temprano rate treatments.

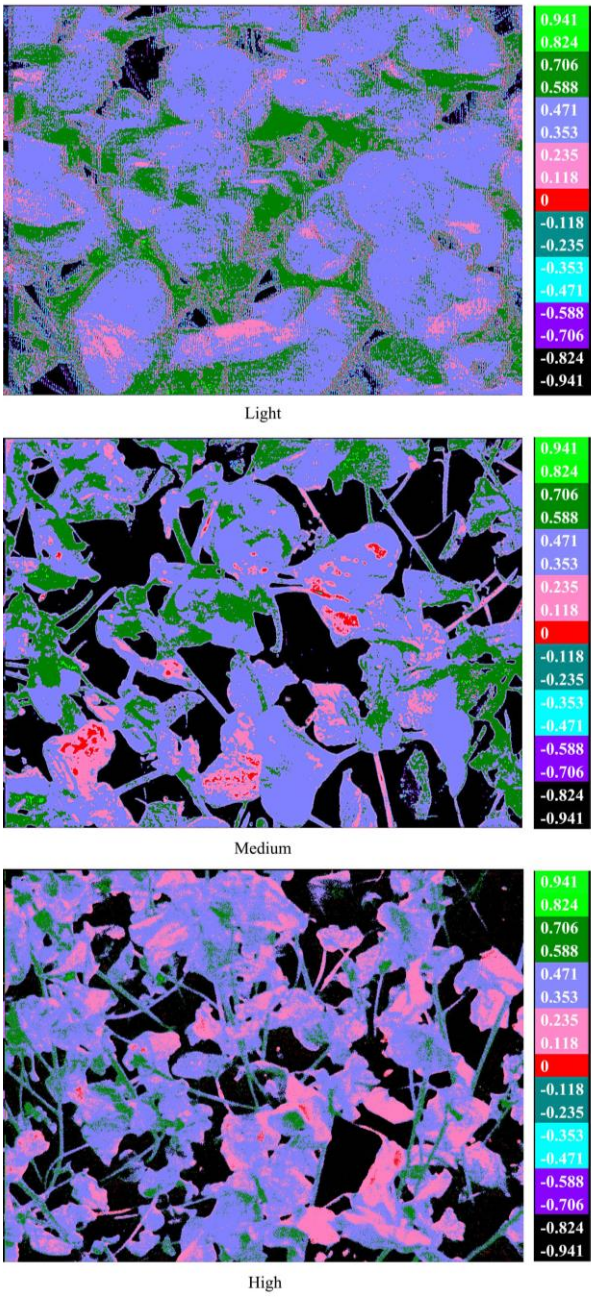

Figure 2 NDVI images of infested cotton plants with light, medium and high mite density levels

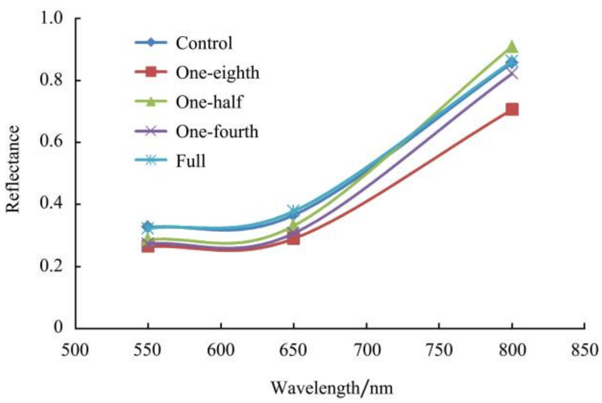

Figure 3 Reflectance spectra of infested cotton plants treated with control, one-eighth, one-half, one-fourth, and full Temprano rate extracted from multispectral images taken on seven days after Temprano treatment

3.2.2 FieldSpec Spectroradiometer

The spectral data were taken on one and seven days after treatment using FieldSpec spectroradiometer. Figure 4 shows the mean reflectance spectra of infested cotton plants treated with different Temprano rates over spectral region between 400 nm and 1 000 nm. Each curve represented an averaged spectral reflectance from the treated cotton flat. The spectral reflectance differences from the cotton plants under different Temprano treatments were not significant on the first day after treatment. However, on the seventh day after treatment, spectral variation among treatments became apparently at both green and NIR spectrum regions. Reflectance spectra of cotton plants from the one-half treatment flat had consistently higher reflectance values than the other treatments which indicated less damaged green vegetation. It could be concluded that half-rate application of miticide was as effective as the full-rate

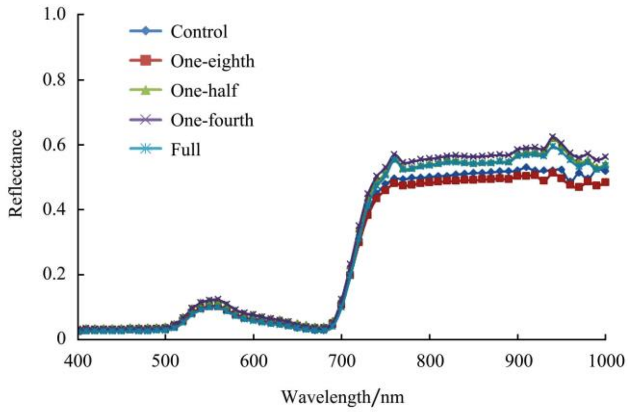

Figure 4 Mean reflectance spectra of infested cotton plants treated with different Temprano rates over spectral region

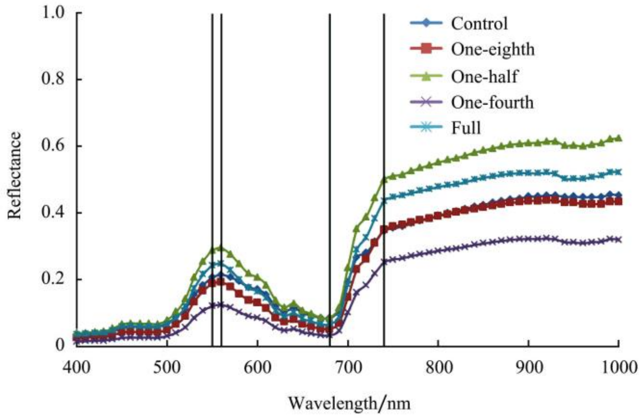

Figure 5 Spectral response of infested cotton plants treated with control, one-eighth, one-half, one-fourth, and full Temprano rate using FieldSpec on DAT1 and DAT7

application. The important wavelengths selected by PCA were indicated as vertical solid lines in Figure 5. The four wavelengths (550 nm, 560 nm, 680 nm, and 740 nm), determined by PCA, revealed that the wavelengths in green, red and NIR could be important for detecting the spectral differences among mite infested cotton plants treated with various rate of Temprano.

4 Conclusions

The objective of this study was to investigate spectral response of cotton plants infested with different density levels of spider mites treated with different rates of miticide. Spider mite damage on cotton plants clearly elicits a response in the spectral reflectance patterns of plant canopies. By treating infested cotton plants with five different Temprano rate treatments, control, one-eighth, one-fourth, one-half, and full rates, the spectral reflectance curves were found to be significantly different. The NDVI imagery was able to detect the different degrees of mite-damaged cotton plants. Four wavelengths, 550 nm, 560 nm, 680 nm and 740 nm, were important for detecting the spectral differences among mite infested cotton plants treated with various rate of Temprano. Half-rate application of Temprano controlled spider mite-infested plants as effectively as full-rate application. These findings may lead to reduced cost and quantity of miticides used to maintain effective crop production and protection.

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