# ASSESSMENT OF SIMULATED BOLL WEEVIL DAMAGE USING AIRBORNE DIGITAL IMAGERY

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## Abstract

Airborne digital imagery in conjunction with ground reflectance and plant physical data was used to evaluate simulated boll weevil damage in a cotton field in 2000. Five different levels of artificial square damage (control, 10, 20, 40, and 60%) with three replications were assigned across 15 experimental plots in a randomized complete block design. The artificial square damage was performed on 25 May when punctured squares by boll weevils were found. Airborne color-infrared (CIR) digital images were obtained from the field on 20, 28 June and 11 July. Ground reflectance and plant physical data, including plant height, number of leaves, number of squares, and chlorophyll, were collected on 5 July. The 20 and 28 June images revealed that plants with high artificial square damage levels showed higher spectral response in the near-infrared (NIR) band and lower spectral response in the red and green bands than those with lower damage levels. Plant height and number of leaves were significantly higher for plants with high damage levels than for those with low damage levels. However, there were no significant differences in either spectral response or plant physical characteristics between some of the damage levels. These preliminary results indicate that airborne imagery has potential for assessing boll weevil infestations in cotton fields, but more experiments are needed.

## Introduction

The boll weevil remains one of the most damaging pests of U.S. cotton. It infested 57% of U.S. cotton acreage and caused 2.2% loss to U.S. cotton in 1999 (Williams, 2000). Texas suffered the highest loss to boll weevil at 5.1%, representing more than 480,000 bales of cotton. In the Lower Rio Grande Valley of south Texas, high levels of boll weevils were reported from many fields in 1999. Punctured square counts began at levels of only 1 or 2 squares per 100 plants in late May and early June, but rapidly built to levels exceeding 30-50 squares per 100 plants by mid to late June (Hardee and Burris, 2000). Square damage may cause the plant to increase foliage and stalk development because nutrients needed for boll development are redirected to vegetative growth. Therefore, plants with severe square damage tend to be more vegetative than those with minor square damage. Remote sensing observations in the visible and NIR regions of the electromagnetic spectrum and vegetation indices calculated from the spectral values are a measure of the amount of photosynthetically active tissue in plant canopies (Wiegand and Richardson, 1984). Therefore, remote sensing may have potential for assessment of boll weevil damage on cotton. The objectives of this pilot study were to: 1) use airborne digital imagery to monitor the growth of cotton plants with different levels of artificial square damage; and 2) compare the spectral responses and plant physical characteristics among different damage levels.

## Materials and Methods

The experiment was conducted on a cotton field within the compound of the USDA-ARS Kika de la Garza Subtropical Agricultural Research Center in Weslaco, Texas in 2000. Five levels of artificial square damage (control, 10, 20, 40, and 60%) with three replications were assigned across 15 experimental plots in a randomized complete block design (Figure 1). Plots measured approximately 3 m by 3 m and were separated from each other by about 4 m along the rows and 2 m across the rows. Cotton was planted on March 6. Number of squares per plant (10.4) and number of plants per square meter (11.0) were counted from the plots shortly before inflicting the artificial damage. The number of squares damaged for a plot was determined based on the average number of squares per plot (342) and the damage level assigned to the plot. Thus, the number of squares damaged was 0, 34, 68, 137, and 205, respectively, for the control, 10, 20, 40, and 60% damage levels. Artificial square damage was performed on 25 May by puncturing the predetermined number of squares within each plot with needles to simulate boll weevil damage.

Airborne CIR images were taken using a three-camera digital imaging system (Escobar et al., 1997) on 20, 28 June and 11 July. The three cameras were filtered for spectral observations in the green (555-565 nm), red (625-635 nm), and NIR (845-857 nm) wavelength intervals. Ground plant canopy reflectance was measured on five randomly selected canopies from each plot with a FieldSpec handheld spectroradiometer on 5 July. The spectroradiometer was sensitive in the visible to NIR portion of the spectrum (350-1050 nm). Plant physical data such as height, number leaves per plant, number of squares per plant, and chlorophyll concentration of leaves were also collected on 5 July. A Minolta SPAD-502 chlorophyll meter was used to measure the amount of chlorophyll in SPAD units from randomly selected leaves in each plot.

All images and ground reflectance data were subjected to postprocessing for analysis. The green and NIR band images were registered to the red band images for alignment. Digital count values within a 20×20 matrix of pixels within each plot were extracted and averaged from each of the three band images. The normalized difference vegetation index (NDVI) was calculated using the formula NDVI=(NIR-Red)/(NIR+Red). The five ground reflectance spectra from each plot were averaged and the reflectance values corresponding to the wavelengths of the three cameras were extracted from the averaged spectrum for each plot. The image data, ground reflectance data, and plant physical characteristics were analyzed using analysis of variance techniques and multiple comparisons were performed among the means using Duncan's multiple range test.

## Results and Discussion

Figure 2 shows the black-and-white NIR, red, and green band images acquired from the experimental plots on 28 June. The NIR band image had a light gray tone attributed to the plants' high light intensity in this spectral region, whereas the red and green band images had a dark gray tone as a result of the low light intensity in the visible spectral region. Differences in gray tones among the five damage levels are visible on the three band images. Plots with high damage levels tended to have a lighter gray color than those with low damage levels on the NIR band image, though the differences were subtle. Conversely, on the red and green band images, plots with high damage levels had a darker gray color than those with low damage levels. As hypothesized previously, plants with high square damage levels should have more vegetative canopy growth than plants with low square damage levels because more nutrients are available for foliage and biomass growth. Based on the spectral characteristics of vegetation canopies, plants with high square damage levels should have higher spectral response (lighter color) in the NIR band and lower spectral response (darker color) on the red and green bands than plants with low square damage levels. The observations from the band images tend to agree with the hypothesis. Similar observations were found from the 20 June band images, while the 11 July band images did not show as many differences as those from the other two dates because of the natural maturity of the plants and stresses by diseases, insects, and moisture shortage. Table 1 shows the mean digital values of the NIR, red and green bands and NDVI by treatment based on the images for 20 and 28 June. The results for 11 July were not shown because there were no or small differences among the treatments. There were significant differences among some of the treatments for the

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three bands and NDVI on 20 and 28 June. As expected, plots with high damage levels generally had larger values in the NIR band and NDVI and smaller values in the red and green bands than those with low damage levels. However, there were exceptions for the three bands and NDVI on the two dates.

Figure 3 presents the reflectance spectra of cotton plants for each of the treatments on 5 July. Reflectance was generally low in the visible region with a peak in the green, then rose sharply at the edge of the visible red, and eventually flattened out in the NIR region. This behavior of the spectra explains why the NIR band images produced a light gray tonal response and the red and green band images had darker tones. The low reflectance values in the visible region made it difficult to visually discriminate among the five damage levels as shown in figure 3. However, differences among the five treatments were more pronounced in the NIR region. The 60% damage level had the highest NIR response as expected, but results from the rest of the damage levels are difficult to interpret. Table 2 shows the mean reflectance values of the NIR, red and green bands corresponding to the wavelengths of the cameras, and NDVI by treatment extracted from the reflectance spectra for 5 July. There were no significant differences in the NIR, red, and green bands among the treatments. However, a few differences were found in NDVI. The lack of significant differences in ground reflectance among the damage levels was partially due to the variations in the amount of soil background and shadow in the small field of view (10-15 cm in diameter) of the spectroradiometer. In fact, the five spectra collected from each plot differed considerably. To improve ground reflectance accuracy, a large number of spectra should be collected or the spectroradiometer should be held higher above the canopy with the help of a ladder so that the field of view of the instrument has a diameter comparable to the size of the plot.

Table 3 shows the means of plant height, number of leaves per plant, number of squares per plant, and chlorophyll concentration of leaves by treatment on 5 July. Plant height for the 60% damage level was significantly higher than that for the three lower damage levels, though there were no significant differences among the three lower damage levels or between the two higher damage levels. Cotton plants receiving 40% and 60% square damage produced more leaves than those at the three lower damage levels, while no differences were found among the three lower damage levels or between the two higher damage levels. As expected, fewer squares were found in plots with high damage levels than in those with low damage levels. There were no differences in chlorophyll among the five damage levels.

## Summary

Results from this preliminary study showed that severe square damage caused increased foliage and stalk development, thus affecting the spectral response of the cotton plant canopy. Airborne digital imagery detected the differences in spectral response among various levels of square damage. These preliminary findings indicate that airborne remote sensing techniques have potential for assessing boll weevil infestations within fields. More experiments with more replications and intensive temporal observations are needed to further document and quantify the differences in plant characteristics and spectral response among various square damage levels.

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## References

Escobar, D. E., J. H. Everitt, J. R. Noriega, M. R. Davis, and I. Cavazos. 1997. A true digital imaging system for remote sensing applications. Proceedings 16th Biennial Workshop on Color Photography and Videography in Resource Assessment. pp. 470-484, American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.

Hardee, D. D., and E. Burris. 2000. 53rd annual conference report on cotton insect research and control. Proceedings Beltwide Cotton Production Conferences. 2:855-884.

Wiegand, C. L., and A. J. Richardson. 1984. Leaf area, light interception and yield estimates from spectral components analysis. Agronomy Journal 76:543-548.

Williams, M. R. 2000. Cotton insect loss estimates-1999. Proceedings Beltwide Cotton Production Conferences. 2:884-913.

Table 1. Mean digital values of spectral variables among five different artificial damage levels based on airborne image data on two dates in 2000.

| | | Spectral Variable | | | |
|---|---|---|---|---|---|
| **Date** | **Damage Level** | **NIR** | **Red** | **Green** | **NDVI** |
| 06-20-00 | Control | 162b | 31ab | 53ab | 0.675ab |
| | 10% | 158c | 32ab | 53ab | 0.660b |
| | 20% | 163b | 35a | 56a | 0.646b |
| | 40% | 165ab | 30ab | 51bc | 0.698ab |
| | 60% | 169a | 26b | 49c | 0.736a |
| 06-28-00 | Control | 86b | 29a | 45ab | 0.500b |
| | 10% | 87b | 25ab | 41bc | 0.552ab |
| | 20% | 89ab | 30a | 47a | 0.501b |
| | 40% | 92a | 22ab | 40bc | 0.612ab |
| | 60% | 92a | 19b | 38c | 0.661a |

[1] Means within a column followed by the same letter for each date are not significantly different at the 0.1 probability level according to Duncan's multiple range test.

Table 2. Mean reflectance values of spectral variables among five different artificial damage levels based on ground reflectance data on July 5, 2000.

| | Spectal Variable | | | |
|---|---|---|---|---|
| **Damage Level** | **NIR** | **Red** | **Green** | **NDVI** |
| Control | 0.461a | 0.049a | 0.076a | 0.807b |
| 10% | 0.481a | 0.047a | 0.077a | 0.821ab |
| 20% | 0.444a | 0.044a | 0.070a | 0.821ab |
| 40% | 0.450a | 0.041a | 0.070a | 0.833a |
| 60% | 0.503a | 0.045a | 0.075a | 0.836a |

[1] Means within a column followed by the same letter are not significantly different at the 0.1 probability level according to Duncan's multiple range test.

Table 3. Means of plant characteristics among five different artificial damage levels based on plant measurements on July 5, 2000.

| | Plant Characteristics | | | |
|---|---|---|---|---|
| Damage Level | Height (cm) | No. of Leaves | No. of Squares | Chlorophyll (SPAD) |
| Control | 53c | 49b | 10a | 44a |
| 10% | 59bc | 51b | 9ab | 45a |
| 20% | 60bc | 54b | 8ab | 46a |
| 40% | 64ab | 68a | 6bc | 46a |
| 60% | 72a | 67a | 4c | 46a |

[1] Means within a column followed by the same letter are not significantly different at the 0.05 probability level according to Duncan's multiple range test.

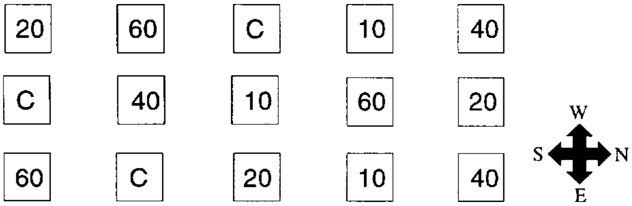

Figure 1. Layout of cotton experimental plots with five different artificial square damage levels (C-control, 10, 20, 40, and 60%) and three replications in a randomized complete block design.

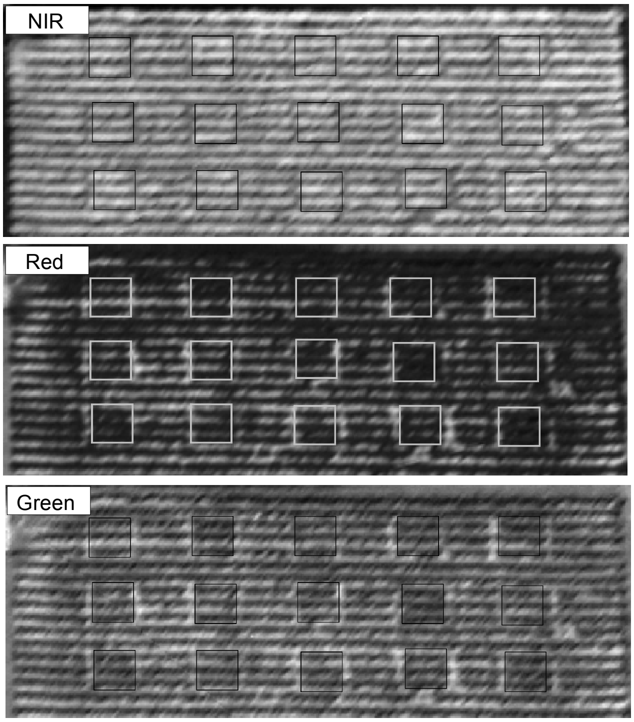

Figure 2. Near-infrared, red, and green band images acquired from cotton experimental plots with five artificial square damage levels and three replications on June 28, 2000.

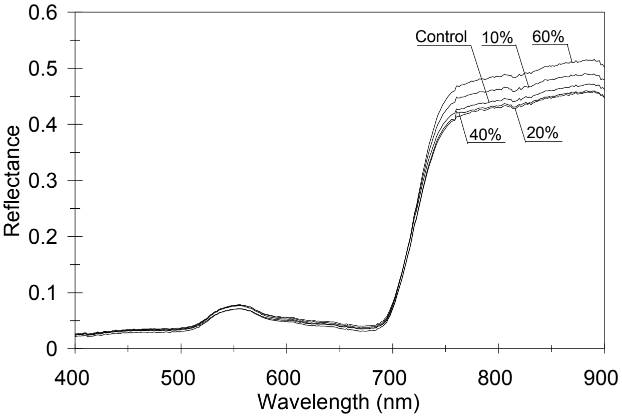

Figure 3. Reflectance spectra of cotton plants for five artificial square damage levels (Control, 10%, 20%, 40%, and 60%) obtained on July 5, 2000.