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EVALUATION OF REMOTE SENSING TO IDENTIFY VARIABILITY IN COTTON PLANT GROWTH AND CORRELATION WITH LARVAL DENSITIES OF BEET ARMYWORM AND CABBAGE LOOPER (LEPIDOPTERA:NOCTUIDAE)

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ABSTRACT

Field experiments were conducted from 2000 to 2002 in the Mississippi Delta to evaluate remote sensing technologies for identifying factors in cotton growth and development related to infestations of beet armyworm and cabbage looper. Larval defoliation of plants was monitored using remote sensing techniques including aerial and hand-held sensors as well as visual measurements of damage. Percent reflectance differed for beet armyworm infested leaves compared to uninfested leaves. In two whole field studies, more beet armyworm hits were found in zones of less vigorous and open canopy, which corresponded to lower normalized difference vegetation index (NDVI) values calculated from remotely sensed imagery. Percent light penetration of canopy was greater for plots damaged by looper larvae than for less damaged plots where looper larvae were controlled with insecticide, but NDVI values were not different.

Key Words: Insect management, beet armyworm, cabbage looper, cotton defoliators, remote sensing

RESUMEN

Se llevaron a cabo experimentos de campo desde el año 2000 al 2002 en el Delta del Mississippi para evaluar las técnicas de observación remota (remote sensing) para identificar los factores en el crecimiento y desarrollo del algodón relacionadas con las infestaciones del gusano trozador de la remolacha y el gusano medidor del repollo. La defoliación de plantas por las larvas fué monitoreada usando técnicas de observación remota incluyendo sensores áereos y de mano y medidas visuales del daño. El porcentaje de la reflección varió en las hojas infestadas con el gusano trozador comparado con hojas no infestadas. En dos estudios que abarcaron todo el campo, se encontraron más concentración (encuentros positivos) del gusano trozador de la remolacha en sonas donde el dosél de las plantas es abierto y vigoroso, lo cual corresponde a valores del indice de la diferencia vegetal normalizada (NDVI en inglés), más bajos calculados de las imágenes de observación remota. El porcentaje de la penetración de luz al dosél fué más alto en las parcelas dañadas por larvas del medidor que en las parcelas menos dañadas donde las larvas de medidor fueron controladas con insecticida, pero los valores de NDVI no fueron diferentes.

Beet armyworm, *Spodoptera exigua* (Hubner), is an occasional pest of cotton in the Midsouth that can become a severe pest under some environmental conditions (Leigh et al. 1996). Beet armyworm outbreaks are typically associated with high temperatures, drought conditions, and intensive insecticide regimes that eliminate natural enemies (Stewart et al. 1996). Infestations of beet armyworm in cotton also are associated with canopy development and varying levels of plant nutrients such as low levels of potassium and high levels of zinc (Parajulee et al. 1999; Graham & Gaylor 1997; Akey et al. 1990).

Cabbage looper, *Trichoplusia ni* (Hubner), is an occasional pest of cotton that only reaches damaging levels in late-season in Mississippi (Jost & Pitre 2002). High plant densities and vigorously growing plants are typically attractive for cabbage looper oviposition and larval densities are usually greater under these conditions (Wilson et al. 1982; Greene 1984).

Remote sensing is a promising technology that may provide early detection of localized infestations of these pests based on associated crop conditions (Allen et al. 1999). Remotely sensed data may permit reduced applications of insecticides using variable rate technology (Dupont et al. 2000). Insect pests like tarnished plant bug, have been found in abundance in vigorously growing portions of cotton fields that generally have faster fruiting rates, taller plants and/or greater canopy closure (Willers et al. 1999). These vigorous growth zones can be identified in remotely sensed imagery to target site-specific insecticide applications with variable rate technology (Dupont et al. 2000, Willers et al. 2000). Multi-spectral remotely sensed imagery of cotton fields is acquired aerially and the normalized difference vegetation index (NDVI) is calculated. The NDVI is associated with crop vigor and is a calculation of the near infrared (NIR) and red (R) wavelengths such that NDVI = (NIR-R)/(NIR+R) (Willers et al. 1999). In remotely sensed imagery, NDVI values can be used to identify spatial variability in the cotton canopy. Insecticide savings of 20-50% in control of tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), can be achieved through the use of prescription application maps that are generated from classed NDVI values (DuPont et al. 2000; Sudbrink et al. 2001).

Studies to determine the utility of this technology for managing other pests are needed. For example, other researchers report that beet armyworm infests stressed or open cotton canopy zones (Stewart et al. 1996). These zones may be treatable on a site-specific basis. More information is needed to determine if those zones can be identified with remotely sensed imagery. The objective of these studies was to evaluate remote sensing technologies for identifying factors in cotton growth and development related to insect pest infestation populations including infestations of beet armyworm and cabbage looper.

MATERIALS AND METHODS

Field experiments were conducted from 2000 to 2002 on the Delta Branch Experiment Station, Stoneville, Mississippi, or the nearby (ca. 10 miles distance) satellite station at Tribbett, MS, to evaluate potential for remotely sensed data to detect cotton plant characteristics associated with infestations of leaf feeding insects such as beet armyworm and cabbage looper. These tests included grid-sampled fields as well as plot studies where varietal, insecticidal, and plant growth regulator effects on these pests in cotton were investigated. Statistical analyses were performed with ARM software (Gylling Data Management, Inc., Brookings, SD) and correlation analyses were performed using SAS for Windows 8e (SAS Institute 1990).

Test 1 Tribbett—2000

A test was conducted at Tribbett, MS in 2000 on a 2.4 acre field (320-ft × 320-ft square) subdivided into a geometrically square 8 × 8 grid. Each grid unit was 40-ft × 40-ft square. The 64 basic units of the grid were further subdivided diagonally to create 128 sub-sample units, each a 40-ft × 40-ft × 56.6-ft right triangle.

Plots were geo-spatially mapped with a Trimble® (Trimble navigation, Sunnyvale, CA) Ag124 GPS unit. Plant development was monitored weekly using the COTMAN expert system, which includes measurements of plant height, square shed, and nodes above white flower (NAWF) (Cochran et al. 1998). Beet armyworm damage was monitored by observations of hits per 80-row ft. Data were converted to hits per 100-row ft. for treatment decision purposes and for data analysis and presentation. A beet armyworm hit is defined as an area on a cotton leaf where a group of beet armyworm larvae feed and skeletonize the lower leaf surface, often spinning silk over the site. Treatment decision (spray or not spray) was based on the Mississippi State University Extension Service *Cotton Insect Control Guide* (Layton, 2000).

Aerial remote sensing fly-overs were made approximately every 7-14 d. Spectral reflectance data were acquired in the aerial fly-overs with a Duncan MS2100, 3-Chip Progressive Scan, Digital Smart Camera. Spectro-radiometry data were also recorded from field plots on fly-over dates and other intervening dates with a GER® 1500 spectro-radiometer (Geophysical Environmental Research Corp., Millbrook, NY).

Test 2 Stoneville—2002

Whole field observations of beet armyworm infestations were made in an 8-acre cotton field at Stoneville in late August, 2002. Imagery data (aerially acquired with equipment as described for Test 1 Tribbett 2000) were used to select paired observation sites—one in closed canopy (higher NDVI) cotton and one in open canopy (lower NDVI) cotton. Paired observations were made at fifteen locations over the field. Each observation consisted of beet armyworm hits/100 row ft. (n = 30). Means and standard errors of beet armyworm hits were calculated from data that were classed into four equal-interval categories of the NDVI values.

Test 3 Stoneville—2001

A plant growth regulator by cotton variety trial was arranged as a factorial experiment in a randomized-complete-block design replicated four times. Cotton was planted on 05/21/01. Each plot was 26.7 ft (8 rows) wide by 50 ft long. Mepiquat chloride treatments were applied on 07/20/01, 07/21/01 and 08/3/01. The two factors were (1) plant-growth-regulator treatments (PGR) (two levels, non-treated, and treated with mepiquat chloride {Pix®, 8 oz/acre, applied 2 times}), and (2) cotton varieties (four levels—Stoneville 474 [non-transgenic], Deltapine 5415 [non-transgenic], Deltapine NuCotn 33B [transgenic], and Stoneville 4691B [transgenic]). Spectroradiometry readings (GER 1500 spectro-radiometer as described for Test 1 Tribbett 2000) were taken weekly from each plot and NDVI values were calculated with these data.

The test was modified in late season after beet armyworm and cabbage looper infestations became established. Plots in each replicate were divided (without randomization and perpendicular to row direction) into two equal size plots. The south end plots were untreated and north end plots were treated with spinosad. This non-random assignment of Factor C treatments was necessary to limit potential influence of drift. The spinosad treatment was applied on 09/19/01.

The final experimental arrangement was a factorial RCB design replicated four times with three factors, (A) PGR treatment—2 levels, (B) cotton variety—4 levels, and (C) caterpillar insecticide treatment—(2 levels, untreated and treated with spinosad {Tracer®, 0.07 lb ai/acre}).

The purpose of this experimental design was to create plant growth differences with different varieties and different PGR treatments and to create different beet armyworm and/or cabbage looper infestations with different insecticide treatments, and to determine if the differences could be detected with remotely sensed data.

Results

Test 1 Tribbett—2000

A beet armyworm infestation reached treatment threshold levels during August in the grid-sampled test at Tribbett in 2000. Results from spectroradiometry readings of individual leaves revealed that percent reflectance patterns were distinctive for BAW damaged leaves compared to healthy leaves (Fig. 1). Damaged leaves had lower near infrared values than the healthy leaves. Beet armyworm hits were found above treatment threshold levels in zones that had lower NDVI values calculated from aerial remote imagery (Fig. 2). The NDVI values in the gray zones in Fig. 2 were lower than NDVI values in the white zones. The image was classed into four equal interval NDVI classes. Average plant height was significantly taller with each progressively higher quartile of NDVI values. Progressively higher average numbers of BAW hits were associated with progressively lower NDVI classes (Table 1). The lower NDVI classes were associated with less vigorous plants that were shorter than those in the higher NDVI classes.

Correlation analyses revealed that there was a significant negative correlation between beet armyworm hits and NDVI value on two dates (7 & 14 August) (Table 1).

Test 2 Stoneville—2002

In late August of 2002 a beet armyworm infestation reached treatment threshold levels in the parts of the field study site at Stoneville. On 30 August 2002, aerial image-based observations revealed that beet armyworm hits occurred over treatment threshold levels in the two lower NDVI class zones sampled (which were associated with open or nearly open canopy) (Table 2). Sub-threshold levels of beet armyworm hits were found in samples taken in the two higher NDVI class zones. Similar observations have been made in very large commercial cotton fields at Gunnison, MS, about 60 miles north of Stoneville. Image based scouting there revealed that beet armyworm was found only in areas of lower NDVI, albeit in extremely low populations (<1%) (J.L.W., unpublished).

Correlation analysis revealed a highly significant negative relationship between beet armyworm hits and NDVI values (Table 2).

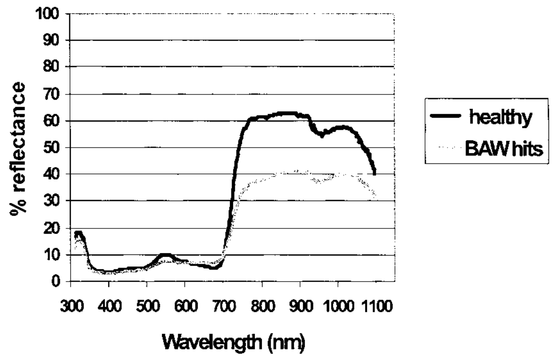

Fig. 1 Reflectance curves for leaf canopy with beet armyworm damage versus healthy canopy, Tribbett, MS, 8 August 2000.

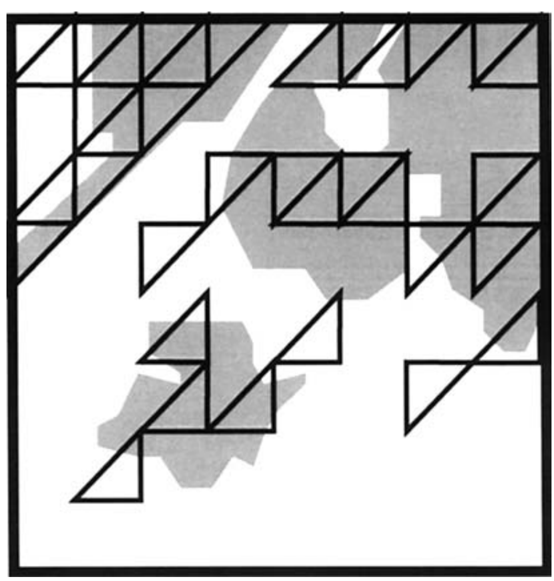

Fig. 2. Test 1 field with low (gray) and high (white) NDVI zones. Overlaid triangular sample units had beet armyworm hits above treatment threshold.

TABLE 1. NDVI CLASS VALUES FROM AERIAL REMOTE SENSING, PLANT HEIGHTS, AND MEAN NUMBER OF BEET ARMYWORM (BAW) HITS/100 FT ROW AND CORRELATIONS BETWEEN BEET ARMYWORM HITS AND NDVI, TRIBBETT, MS, AUGUST 2000.

NDVI class and range 8/7/00	n	Plant height (inches) Mean ± SEM 7/26/00	BAW hits/ 100ft. row 8/7/00 Mean ± SEM	BAW hits/ 100ft. row 8/14/00 Mean ± SEM
Class I 0.367-0.423	15	36.60 ± 1.04	4.67 ± 0.55	5.42 ± 0.51
Class II 0.423-0.479	20	40.35 ± 1.01	3.44 ± 0.49	4.63 ± 0.51
Class III 0.479-0.535	40	42.58 ± 0.65	2.78 ± 0.38	4.03 ± 0.35
Class IV 0.535-0.591	53	43.38 ± 0.71	2.19 ± 0.21	2.97 ± 0.23

Correlation BAW hits vs. NDVI	Correlation analyses				
	n	Slope	Intercept	r	P
8/7/00	128	-12.52	9.248	-0.343	<0.0001
8/14/00	128	-14.19	11.09	-0.386	<0.0001

Test 3 Stoneville—2001

Populations of beet armyworm larvae remained below treatment threshold levels at the Stoneville test in 2001. Late in the season, an infestation of cabbage looper approached economic threshold levels. There were no significant differences in numbers of cabbage looper larvae among variety or mepiquat chloride treatments and no significant interactions.

Spinosad treatments had significantly fewer cabbage looper larvae than untreated plots (Table 3). Larval feeding was measured by determining percentage light penetration through the canopy as measured by a Li-Cor® (Li-Cor, Inc., Lincoln, NE) light bar. Percent light penetration was significantly lower in spinosad treated plots than in untreated plots. This result indicates that less feeding occurred in the spinosad treated plots. However, there was no significant difference in mean NDVI between spinosad treated and untreated plots (Table 3). Thus, despite measurable differences in looper feeding damage in this test, a difference in spectral reflectance was not detected.

DISCUSSION

Results from these experiments indicate that beet armyworm infestations were associated with lower NDVI values in remotely sensed data that represented zones of open and/or stressed canopy. This association may be useful in the development of future sampling plans or site-specific management techniques that direct insecticide applications for beet armyworm at lower NDVI zones in a field.

The remotely sensed spectral reflectance data did not detect crop damage by cabbage looper larvae despite measurable differences in light penetration between infested (damaged) and sprayed (less damaged) canopy. This illustrates the difficulty of detection via remote sensing of insect damage, even visually observable leaf feeding, before it is too late for corrective action. Additional

TABLE 2. NDVI CLASS VALUES FROM AERIAL REMOTE SENSING AND MEAN NUMBER OF BEET ARMYWORM (BAW) HITS/100' ROW AND CORRELATION BETWEEN BEET ARMYWORM HITS AND NDVI, STONEVILLE, MS, 30 AUGUST, 2002.

NDVI class and range	n	BAW hits/ 100 ft. row Mean ± SEM
Class I <-0.097>-0.024	3	5.67 ± 0.67
Class II 0.024-0.145	7	4.71 ± 0.42
Class III 0.145-0.266	10	2.90 ± 0.94
Class IV 0.266-0.387	10	0.50 ± 0.22

Correlation	Correlation analyses				
	n	Slope	Intercept	r	P
BAW hits vs. NDVI	30	-16.794	6.074	-0.774	<0.0001

TABLE 3. EFFECT OF SPINOSAD ON A CABBAGE LOOPER INFESTATION, PERCENT LIGHT PENETRATION IN PLANT CANOPY, AND NDVI VALUES FROM HAND-HELD SPECTRO-RADIOMETRY, FIELD 11, STONEVILLE, MS, 2001.

Treatment	Mean looper larvae/6 ft row 24-Sep-01	% Light penetration 01-Oct-01	NDVI value 01-Oct-01
Control	11.7	7.85	0.7623
Spinosad	2.7	5.34	0.7788
LSD	1.9	1.42	0.0330
Prob (F)	0.0001*	0.0001*	0.488 ns

*Indicates significant difference (P = 0.05) in Factorial test.

study will be needed to determine if cabbage looper infestation can be associated with plant characteristics that are detectable via remote sensing techniques.

Image-based scouting through characterization of canopy development for beet armyworm may be useful in site-specific management of this cotton pest. Further research is required to elucidate the relationship of lower NDVI levels to beet armyworm hits and develop it into a useful sampling and site-specific management plan.

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