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NORMALIZED DIFFERENCE VEGETATIVE INDEX, ARTHROPOD DENSITY AND WATER / NITROGEN INTERACTIONS IN ACALA 1517-99 COTTON, GOSSYPIUM HIRSUTUM (L)

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Abstract

A three year study was conducted to evaluate multispectral reflectance, nitrogen (N), water and insect interactions on Acala 1517-99 upland cotton [*Gossypium hirsutum* (L)]. Various levels of nitrogen fertilizer and irrigation water were applied to cotton plots. Multispectral reflectance was used to measure plant vigour by calculating the normalized difference vegetative index (NDVI). Arthropods were sampled with a high clearance vacuum sampler. Data show that there were significant NDVI differences among various N treatments. Treatments with higher NDVI readings corresponded to the higher levels of N fertilizer. There was a significant increase in lygus densities as N levels increased but in general no significant increase in predaceous insects. Profit/loss analysis showed that excessive N levels attributed to losses associated with amplified costs such as insecticides, growth regulators, water and defoliants. It may be possible to make precision N applications in cotton which would suppress lygus infestations and encourage increased population stability among predators. N reflectance technology can enhance precision farming and increase profits.

Introduction

N, as a plant nutrient, is required in quantities second only to carbon. N is a key element required by all living cells to build amino acids and proteins. All plant and animal life is ultimately limited by biologically available N (White 1993). Researchers have suggested that increasing insect pest and disease problems in agricultural ecosystems are often due to increased fertilizer and pesticide use and that excessive use of agrochemicals in combination with expanding monocultures has farther exacerbated pest problems (Conway and Pretty 1991). Phytophagous insect populations can be reduced with proper cultural practices, i.e. avoiding luxury consumption of N and water (Leigh 1996, and Altieri and Nicholls 2003).

Measuring N levels in agricultural cropping systems has always been a time consuming and variable process; however, diagnostic methods which assay leaf optical properties can provide rapid site-specific screening of crop nutrient status (Tarpley et. al. 2000). Visible light (from 0.4 to 0.7 µm) is absorbed by pigments (chlorophyll) in plant leaves for use in photosynthesis, but plant leaves strongly reflect near-infrared light (from 0.7 to 1.1 µm) (Smith 1995). Healthy vegetation absorbs most of the visible light that hits it, and reflects a large part of the near-infrared light. Unhealthy vegetation reflects more visible light and less near-infrared light.

The GreenSeeker® (GS) is a device that projects red and IR light to plant leaves from light emitting diodes and then calculates NDVI from the light reflected back from the leaves. NDVI is calculated from (NDVI=IR-R/IR+R), [where IR = infrared, R = red light]). NDVI responds well to environmental changes such as nutrient or water inclusions (Moges et al. 2004). Multispectral reflectance is a promising technology that may provide early detection of localized infestations of pests based on associated crop conditions (Allen et al. 1999).

Most studies have ignored nutritional quality when evaluating the cause of phytophagous insect buildups. Several studies indicate that plant feeding by insects corresponds to nutrient content (McClure 1991, Rossi and Strong 1991 and Letourneau 1995) and the general importance of N for the development of insect-plant interactions is well known (McNeill and Southwood 1978, Mattson 1980). Insect pests are often more attracted to areas that have lush vegetation than to areas that are stressed. Lygus have often been found in highest abundance in vigorously growing parts of cotton fields (Willers et al. 1999).

In order to improve sampling, diverse arthropod systems, a small four wheel drive (hydraulically driven) self propelled platform [Insectavac (IV)] with a 4,200-cfm high vacuum fan was designed and built to take representative cotton insect samples (Ellington et al. 1984). The IV collector was calibrated for 24 genera of insects in cotton and estimates the mean density of most insect species to within 80 ± 10% of their true value (Ellington and Southward 1996). Density estimates for genera collected by sweep-net were only within 7 ± 10% of their true value.

The objective of this research was to determine the optimal N and water use strategy needed to maintain yield and quality while discouraging phytophagous insect pest populations using IR leaf reflectance readings. The functional relationship between IR reflectance, N, moisture and insect densities may be used to optimize agronomic management practices**.**

Materials And Methods

Field Management. Treatments consisted of four, five and six irrigations, 45 and 135-lb of N/A in a split plot design with four replications in 2003. Irrigation measurements averaged approximately six acre inches per application. Each treatment replication consisted of eight, 40-in wide by 100-ft long rows. The outer two rows from each treatment replication were used as guard rows and were not sampled. Acala 1517-99 cotton [*Gossypium hirsutum* (L)] was planted at a rate of 16-lb/A. Sudan grass was the previous year's crop. Fertilizer was broadcast at 45-50-lb N/A prior to bed formation as a preplant. The soil type was a clay loam. Treatments that received 135-lb N/A included a side dress application of 90-lb N/A prior to first bloom. Most of the agronomic management practices were the same in 2004, with a few exceptions. One less irrigation was applied in each treatment due to excessive precipitation and treatments included an additional N rate of 270-lb N/A. There were two insecticide applications for pink bollworm (*Pectinophora gossypiella*) control. In 2005 one irrigation regime was used with rates of 50, 80, 115, 142 and 234-lb N/A.

All data was analyzed using appropriate Statistical Analysis Systems® models (SAS, Institute, Inc., Cary, NC). All statistical determinations were made using a split plot Proc mixed analysis.

Multispectral Reflectance. The GreenSeeker™ was used to collect NDVI data from one, 100 row-ft of cotton in each treatment replication weekly. Data from a Hewlett Packard® H2200 pocket pc device, attached to the GreenSeeker, was downloaded to a portable computer.

Insect Vacuum Sampling. A single 100-ft row IV sample was randomly taken from each treatment replication weekly during the growing season. Field collected IV arthropod samples were killed by placing the samples in a one gallon Ziploc® bag and freezing them. All leaf material and insects were manually separated by sieving. Sieved insects were then classified, counted and then data recorded. Sampled arthropods included; assassin bug adults and nymphs (*Reduviidae* spp.), big-eyed bug adults and nymphs (*Geocoris* spp.), collops beetle adults (*Collops* spp.), green lacewing adults and larvae (*Chrysoperla* spp.) lady beetle adults and larvae (*Hippodamia* spp.), nabid adults and nymphs (*Nabis* spp.), minute pirate bug adults and nymphs (*Orius* spp.), *Lygus* spp. adults and nymphs, and spiders. All predatory arthropods were also grouped into a total predator category.

Fiber Yield and Quality. In 2003 and 2005 a single 100-row ft from each treatment replication was harvested using a combine cotton picker. Cotton was bagged and weighed. Sub-samples were removed from each bag and sent to the New Mexico State University (NMSU) fiber quality laboratory for analysis. In 2004, 25 bolls were collected and weighed from each treatment replication and placed in bags. Cotton was handpicked in 2004 because of rain soaked fields. Samples were also sent to the NMSU fiber quality laboratory for analysis.

Results

In general, the predaceous arthropods did not responded to different N treatments. There were a few significant differences among specific predators in different years and treatments but the majority showed no significant density. Most of the significant density differences which did occur appeared in 2004 when five applications of chlorpyrifos were applied to the pink bollworm eradication program. Data for all three years suggest that predaceous arthropods are not as responsive to applications of N as primary consumers and that repeated insecticide applications disrupt the stability of the beneficial complex.

TABLE 1**.** Mean arthropod density from 100-row ft of Acala 1517-99 cotton for four, five and six irrigations and 45 and 135-lbs of nitrogen, Las Cruces, NM, 2003.

	Treatments[a/] [b/]					
	Four Irrigations		Five Irrigations		Six Irrigations	
	45lbsN	135lbsN	45lbsN	135lbsN	45lbsN	135lbsN
Reduviidae Adults	0.2ab	0.7a	0.2ab	0.7a	0.3ab	0.1b
Reduviidae Nymphs	0.0a	0.0a	0.0a	0.1a	0.0a	0.1a
Geocoris Adults	4.7ab	4.6ab	3.9b	6.3ab	6.8a	6.1ab
Geocoris Nymphs	0.3ab	0.9a	0.1b	0.2b	0.4ab	0.7ab
Collops Adults	6.2a	7.0a	7.1a	6.7a	5.6a	7.3a
Chrsoperla Adults	14.3b	30.0a	31.6a	34.5a	33.5a	28.3a
Chroperla Larvae	0.1a	0.3a	0.1a	1.2a	0.1a	0.2a
Hippodamia Adults	9.7b	11.7ab	8.4b	11.5ab	12.5ab	17.4a
Hippodamia Larvae	0.0a	0.0a	0.8a	0.0a	0.2a	0.0a
Nabid Adults	14.1a	13.8a	18.4a	15.9a	15.5a	16.3a
Nabid Nymphs	0.9b	1.8ab	2.6a	0.6b	0.9b	0.8b
Orius Adults	7.8a	7.3a	5.6a	9.2a	7.4a	6.5a
Orius Nymphs	0.1a	0.0a	0.1a	0.5a	0.1a	0.0a
Arachnidae	6.5a	5.8a	6.3a	5.6a	5.8a	6.7a
Total Predators	64.9b	83.9a	85.2a	93.0a	89.1a	90.5a

a/ Like letters are not statistically significant at P>0.05 among treatments.
b/ Study conducted 2003.

TABLE 2. Mean arthropod density from 100-row ft of Acala 1517-99 cotton for four, five and six irrigations and 45, 135 and 270-lbs of nitrogen, Las Cruces, NM, 2004.

	Treatments [a/ b/]						
	Four Irrigations		Five Irrigations		Six Irrigations		
	45lbsN	135lbsN	45lbsN	135lbsN	45lbsN	135lbsN	270lbsN
Reduviidae Adults	0.0b	0.5a	0.1ab	0.0b	0.2ab	0.0b	0.0b
Reduviidae Nymphs	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Geocoris Adults	2.4ab	2.7a	2.4ab	1.8ab	1.0ab	1.7ab	1.0b
Geocoris Nymphs	0.0a	0.1a	0.0a	0.0a	0.0a	0.0a	0.0a
Collops Adults	10.7ab	11.5a	6.0c	6.9bc	6.5c	7.0bc	9.8abc
Chrsoperla Adults	1.4ab	2.9a	2.3ab	2.2ab	1.4ab	2.8a	1.2b
Chroperla Larvae	1.6ab	2.6a	1.6ab	1.3ab	0.8b	1.2ab	0.7b
Hippodamia Adults	1.2a	2.1a	1.1a	0.7a	1.4a	1.5a	1.2a
Hippodamia Larvae	0.0a	0.0a	0.1a	0.0a	0.0a	0.0a	.0.a
Nabid Adults	6.9ab	8.6a	4.3bc	5.6bc	4.0c	5.2bc	6.1abc
Nabid Nymphs	0.1a	0.5a	0.2a	0.2a	0.1a	0.3a	0.2a
Orius Adults	2.0ab	3.1a	1.3b	2.2ab	1.5b	0.7b	1.3b
Orius Nymphs	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a
Arachnidae	1.7ab	3.0a	2.0ab	1.0b	1.8ab	3.1a	2.0ab
Total Predators	28.0b	37.6a	21.4c	21.9bc	18.7c	23.5bc	23.5bc

a/ Like letters are not statistically significant at P>0.05 among treatments.
b/ Study conducted 2004.

TABLE 3. Mean arthropod density from 100-row ft of Acala 1517-99 cotton for five irrigations and 50, 80, 115, 142 and 234-lbs of nitrogen, Las Cruces, NM, 2005.

	Five Irrigations [a/ b/]				
	50lbsN	80lbsN	115lbsN	142lbsN	234lbsN
Reduviidae Adults	1.2a	1.0ab	0.6b	0.5b	0.5b
Reduviidae Nymphs	0.1a	0.2a	0.1a	0.1a	0.1a
Geocoris Adults	7.1a	6.2a	7.8a	7.0a	6.6a
Geocoris Nymphs	2.1a	1.9ab	2.4a	1.5ab	1.0b
Collops Adults	5.6a	3.5b	4.1ab	5.4a	5.0ab
Chrsoperla Adults	0.9a	0.7a	0.8a	1.0a	0.8a
Chroperla Larvae	0.3a	0.2a	0.2a	0.5a	0.2a
Hippodamia Adults	21.3a	15.8b	14.9b	15.5b	15.6b
Hippodamia Larvae	0.0a	0.1a	0.7a	0.3a	0.0a
Nabid Adults	20.0a	20.0a	21.0a	24.2a	25.0a
Nabid Nymphs	0.8ab	0.5b	1.0ab	1.4a	1.3a
Orius Adults	1.1a	1.2a	1.7a	1.8a	1.7a
Orius Nymphs	0.0a	0.0a	0.0a	0.0a	0.0a
Arachnidae	10.5a	9.7a	9.2a	8.6a	8.6a
Total Predators	70.5a	61.0a	64.5a	67.6a	66.4a

a/ Like letters are not statistically significant at P>0.05 among treatments.
b/ Study conducted 2005.

Data from adult lygus samples from all three years showed significant differences in density among the various N applications (Figures 1, 2 and 3). As N rates increased so did, the density of lygus adults and NDVI readings. These results imply that NDVI readings may be used to estimate the vigor of cotton as well as determining whether phytophagous pest insects such as lygus may stay. Although reflectance varied year to year the response was consistent with the rate of N used and the density of lygus populations.

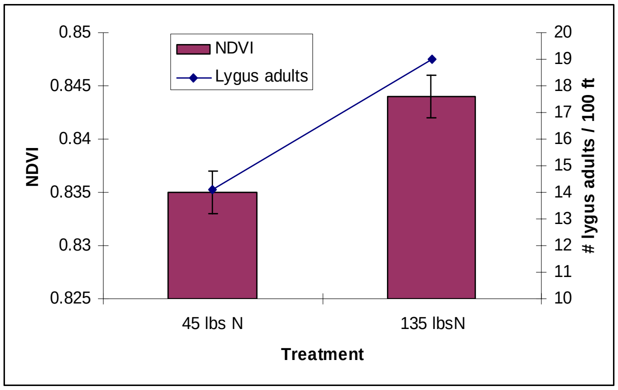

Figure 1. Lygus, NDVI and N interactions, 2003

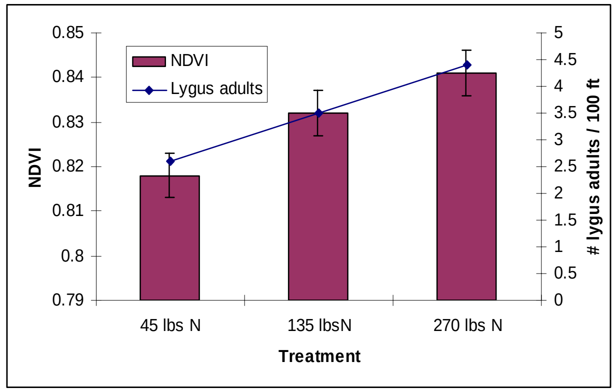

Figure 2. Lygus, NDVI and N interactions, 2004

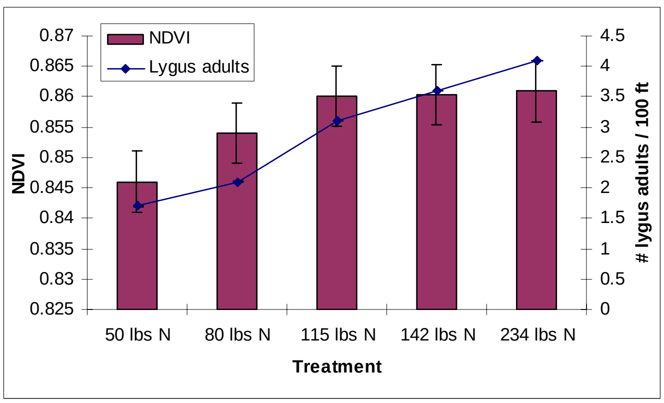

Figure 3. Lygus, NDVI and N interactions, 2005

An economic analysis (New Mexico State University, Nitrogen Use in Cotton Budget Calculator, Jay Lillywhite) was conducted to determine if excessive N applications effected profit / loss due to the value of increased inputs. Additional inputs associated with excessive N applications included: increased irrigation water, related labor, mechanical expenses, herbicides, insecticides, growth regulators and defoliants. When data from individual treatments were analyzed by fertilizer application, the most profitable irrigation and N application regime was five irrigations (approx. 27 acre inches) and a split application of 50-lbs of broadcasted N prior to bed formation and 30-lbs N at first bloom (Table 4). The model shows that reducing N can also reduce unwanted pest such as lygus, thus reducing the costs associated with insecticide applications. At higher N ratesEven though increased N rates translated into increased yields it did not translate to increased profit. Excessive N applications late in the season could lengthen the vegetative growth period requiring more growth regulator and defoliant applications, all added costs.

Precision insect sampling and N applications can increase profit and reduce environmental insults due to excessive use of agrochemicals.

Table 4. Profit-Loss model analysis conducted on three irrigation regimes (five) and various nitrogen rates (50, 80, 115, 142 and 234-lbs N/A), Las Cruces, NM, in 2005.

Irrigations and lbs N	Yield lbs/A	Profit-Loss $/A
Five / 50 lbs	1092	11.21
Five / 80 lbs	**1341**	**116.60**
Five / 115 lbs	1391	20.17
Five / 142 lbs	1492	3.02
Five / 234 lbs	1421	(51.69)

a/ Indicates most profitable irrigation and N application treatment 2003.

Summary

Presently, 500 million tons (453 billion kg) of artificial N fertilizer are produced requiring roughly 1% of the world's supply of energy. About 40% of our planetary population is sustained by artificial N fertilizer. Findings from this research indicate optimizing synthetic N fertilizer use may reduce associated direct and indirect costs i.e. additional expenses and environmental insults from excessive N use. More research needs to be conducted to evaluate the use of precision insect sampling and reflectance technology in cotton production and other cropping systems to determine the cost / benefit economics associated with applications of N. Economic thresholds for primary pest need to be reevaluated with considerations of the impact of N on arthropod density.

Acknowledgement

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