2003 BELTWIDE COTTON CONFERENCES, NASHVILLE, TN – JANUARY 6-10

# PROSPECTS OF INSECT MANAGEMENT USING REMOTE SENSING AND VARIABLE RATE TECHNOLOGY

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## Abstract

Remote sensing technologies are tools that can provide cotton producers with information to improve their decisions for cotton production strategies. Images of cotton fields developed from remotely sensed data are useful in detecting variation in crop growth patterns that can be associated with seedcotton yields and the presence of selected cotton arthropod pests. These images allow cotton producers to identify well-defined field zones that exhibit yield-limiting problems. The development of site-specific procedures, including prescription applications of pesticides at variable rates, can target specific management zones within a field. Remote sensing and variable rate pesticide application technologies can result in more efficient crop scouting procedures, reduced pesticide inputs, and fewer undesirable effects in the environment. The cotton industry's access to remote sensing technologies will continue to improve as site specific tools and services become more common.

## Introduction

Cotton production systems are rapidly evolving due to advances in genetics, integrated pest management (IPM), and engineering technologies. Geospatial and precision (site-specific) technologies are currently available and being used in several areas of agriculture that have application to the cotton industry Pierce (Pierce and Nowak 1999). Precision technologies can provide the framework for managing production problems that vary spatially and temporally within fields. The immediate application to cotton producer is the ability to create a map based on any number of variables (soil characteristics, elevation and drainage, plant development, yield, etc.) that can accurately delineate different zones within a field. These maps can then be used to identify site-specific crop yield or income limiting problems within a field and assist producers in making informed decisions about management solutions. Until recently, nearly all cotton production practices were managed at the whole-field level on farms. The few instances that actually attempted to manage production problems on a smaller scale within fields were usually based on visual estimates obtained from field scouts or crop managers. Usually, even if the location of the area was properly identified, there was no accurate system to transfer the local coordinates of the within-field area to the person capable of managing the problems.

After identifying and precisely locating a field zone associated with a management problem, site-specific application technologies are required to take corrective action. In the mid-western and central U.S., commercial applicators have contracted site specific fertilizer applications and a limited number of herbicide use strategies in grain crop production for several years. Site specific fertilizer and pesticide application technologies are not common in southern row crop production systems, but their value has been recognized. Southern row crop producers have only recently begun to develop the information base necessary to use site specific application technologies. In addition, these producers typically do not rely on commercial applicators with ground-based equipment to apply fertilizers and pesticides. Therefore, the purchase, installation, and maintenance expenses of site-specific equipment have been cost-prohibitive when limited to an individual farm. Compared to other crops, limited research and equipment development has been done to support adapt site specific technologies for cotton production. Furthermore, much of the hardware and software components comprising such a system are complicated and technical support services have not been easily obtained. However, given the accelerated rate of technology development at this current time, site specific technologies can be adapted to address the specific plant protection needs of cotton producers.

The full potential of geospatial and precision agricultural technologies in cotton production will not be realized until all segments of the cotton industry become confident in this technology and recognize the value of site specific management strategies.

Therefore, state and federal scientists must continue to develop non-biased information to validate geospatial and precision agricultural technologies for cotton production. The purpose of this report is to provide a brief justification and review of the recent progress on the use of remote sensing and variable rate pesticide application technologies in cotton production strategies.

## Remote Sensing and Insect Pest Management (IPM)

Remote sensing in the context of precision agriculture for southern row crops has generally been associated with those procedures that allow the historical or "real time" observation of a target from some distance. Data generated from remote sensing techniques have been applied to entomological issues by surveying actual insect populations or studying insect and environmental interactions. The foundation of an IPM strategy in many crops is based on information from sampling and the utility of remote sensing should improve the accuracy of information used to develop management tactics for insect pest problems.

Remote sensing techniques have been used for a number of years by the military and other government agencies for various purposes including those relating to agriculture such as evaluating crop development and plant health. Remote sensing methods can include primitive drawings, photography, radar, acoustic sounding, videography, and multispectral, hyperspectral or thermal scanning from aircraft or satellite-based platforms. Some of these methods were used as early as the 1930's to detect tree defoliation in forests by insects (Chiang and Meyer 1974). However, the application of remote sensing in crop IPM is still considered an emerging science and has been examined only by a limited group of researchers. Public access to remotely sensed data from satellites and aircraft coupled with the commercial availability of inexpensive global positioning system (GPS) devices have created opportunities for more intensive research with direct application to crop production systems.

Initially, research efforts focused on remote sensing techniques to survey the distribution of specific arthropod species. Riley (1989) and Liebhold et al. (1993) reviewed applications of remote sensing in entomology and found that most studies were associated with arthropod population surveys. Radar methods can be used to directly observe arthropods and their behavior, particularly as it relates to migration.

Presently, remote sensing procedures produce vegetation maps that scan large areas of land appear to have the most potential in cotton IPM. Combined with GIS, these data can identify and evaluate the potential habitat of arthropods, thereby indirectly indicating their presence. This information is extremely valuable in the development of and maintenance of area-wide pest management programs such as boll weevil, *Anthonomus grandis grandis* Boheman, eradication (Summy et al. 1989, Smith and Wiygul 1997). Recent research has focused on the use of multispectral remote sensing systems to detect either cotton plant injury from arthropods or areas of extreme vegetative growth that have a high probability of association with pest infestations. Fitzgerald et al. (1999) was able to identify early season spider mite, *Tetranychus* spp., injury to cotton in California using images developed with this type of system. Infestations of cotton aphids, *Aphis gossypi*i (Glover), and silver leaf whiteflies, *Bemisia argentifolii* (Bellows & Perring), on leaves covered with a black sooty-mold fungus were also detected using similar remotely sensed data (Summy et al. 1997).

Willers et al. (1999) found that remotely sensed images could identify variations in cotton plant development and be used to separate areas within fields during the production season. Using geo-referencing techniques, field maps that defined similar zones of plant development were created. These maps were used to evaluate the distribution of tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois), within cotton fields. These insects were found in specific highly vegetative areas of the fields and not randomly distributed across the entire field. Sudbrink et al. (2002) also used multispectral images to study within field variation of tarnished plant bugs and established a strong correlation between the occurrence of this insect and areas of plants associated with extreme vegetative growth. Similar GIS technologies were used in California as a tool to improve the understanding of western tarnished plant bug, *Lygus hesperus* (Knight), population dynamics across multiple crops on a regional scale (Goodell et al. 2002). Plant et al. (2000) evaluated correlations between remotely sensed reflectance data, main stem nodes above white flower (NAWF), and main stem nodes above cracked boll (NACB). There was a relatively weak positive correlation between the normalized difference vegetation index (NDVI) and NAWF, but the correlation between NDVI and NACB was significant. Other researchers have successfully used remotely sensed data and NDVI calculations to develop field maps that are strongly related to estimates of cotton plant growth and development (Read and Jenkins 2002, Stewart et al. 2002).

The results of this and other previous research support the use of remotely sensed data to improve sampling plans for arthropods pests in cotton fields. Research in these areas has been limited by the inability of researchers to examine entire fields, identify well-defined areas of variability, and associate that information with arthropod pest densities. Remote sensing techniques are extremely powerful and provide an opportunity to evaluate the influence of macro-scale or regional cropping systems on pest population dynamics, as well as the detection of localized site-specific problems within individual fields. The agricultural chemical industry has already began to recognize the value of GIS in cotton IPM with the development of software (SCOUTLINK, Bayer Corporation; Kansas City, MO) compatible with palm sized computers for site-specific sampling (Holman 2002). Other research efforts evaluating remote sensing and its application in cotton arthropod management include work in Georgia, Mississippi, and selected USDA-ARS locations across the United States.

## Development of Spatially Variable Insecticide Application (SVI) Systems

### Equipment

Spatially variable insecticide (SVI) application research is in various stages of development. Engineering systems and software have been adapted for tractor mounted spray equipment used to apply insecticides against cotton insect pests. Commercial GPS units and spray controllers similar to those used for site-specific fertilizer applications in other crops have been modified and are being used to deliver prescription pesticide applications in cotton (Dupont et al. 2000, Bethel et al. 2002, Frigden et al. 2002, Sudbrink et al. 2002). The results of these studies indicate that SVI can reduce total insecticide use by as much 40% compared to broadcast whole-field applications.

Across much of the cotton belt, insecticide treatments applied with ground-based equipment are restricted due to rainfall events and irrigation. In Louisiana, a prototype application system for delivering SVI treatments with aircraft has been in the developmental phases for two years (Leonard et al. 2003). The approach of the Louisiana team of researchers was to adapt an example of current technology being used by commercial agricultural pilots for pesticide application. During 2002, 3 site-specific insecticide applications were successfully applied with the prototype system. Similar application systems are being developed in California for cotton IPM and in Canada for forest insect control.

### Generating Prescriptions

To effectively use SVI or any site-specific application equipment, a prescription describing the target area(s) for treatment must be developed. The actual purpose of the prescription is to indicate to the mechanical controller an automatic 'spray on: spray off' sequence as the applicator travels across the field. The complex component of the prescription is to develop base criteria for describing the exact location of the areas to be treated. Agronomic problems related to soil properties, such as low Ph or nutrient deficiencies, can be characterized with physical measurements used create a map of management zones that detail variation across a field. The map is used to generate a prescription based upon the management zones that are considered yield- limiting. Although considerable research has been done in establishing the basis for site specific nutrient management plans, only limited successes have been reported. Interactions among numerous biotic and abiotic factors are capable of influencing the outcome of site-specific prescriptions.

Many of the prescriptions for SVI applications against cotton pests have been based on multispectral images obtained with remote sensing technologies. Much of the research in Mississippi and Louisiana during the past five years has used NDVI data from multispectral images to create a field map of management zones for control of tarnished plant bug (Dupont et al. 2000, Bethel et al. 2002, Frigden et al. 2002, Sudbrink et al. 2002). Remotely sensed images were used to identify those field zones likely to be infested and tractor mounted application equipment was modified to make prescription insecticide treatments that targeted those zones. Only limited success has been reported for NDVI based prescriptions and SVI treatments for other cotton pests.

Another procedure for creating prescriptions is based upon spatial variation of cotton yields across fields. Geo-referenced yield maps can accurately describe the contribution of various field areas to total yield for the entire field. The basis for a yield-based prescription is supported by the concept of IPM. An insecticide is not likely to correct a yield-limiting problem associated with soil properties or specific environmental restrictions. Zones within a field that do not have the capacity to produce revenue neutral yield levels should not receive the same input levels as zones that are characterized as highly profitable. Recently, researchers in Tennessee (personal communication T. Sharp, Jackson State University, TN) have begun to use yield maps coupled with remotely sensed images to develop variable rate crop production plans. The goal of a yield-based crop management strategy is to reduce inputs for lower yielding management zones without sacrificing the total production output for the entire field. As with NDVI based prescriptions, considerable research remains to validate these concepts across a wide range of environmental conditions.

## Benefits to the Cotton Industry

The benefits of remote sensing technologies and variable rate insecticide applications could be realized at several levels in cotton farming enterprises. The overall net return on crop value will be enhanced by improving the efficiency of crop production practices. Production costs can be moderated by using SVI technology in prescription applications with sufficient science-based data to support recommendations. If prescription SVI applications can be successfully implemented at the farm level, IPM tactics will become a more important part of a holistic production system. Crop managers can use remotely sensed images in combination with GPS/GIS tools and improve their precision and accuracy for sampling arthropod pest infestations. The opportunity to apply site-specific management strategies will decrease the amount of insecticide treated acreage and result in significant environmental benefits. The use of SVI technology in prescription applications can reduce the risk of off-target movement of pesticides and lower soil and water contamination. Scientific and economic bases for SVI action thresholds, application timing, and user simplicity are the keys to widespread implementation of these technologies.

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