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INSECTS IN LOW SPRAY ENVIRONMENTS AND MODIFIED COTTON ECOSYSTEMS

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Abstract

Recent changes in cotton, *Gossypium hirsutum* L., ecosystems have created new challenges in the development of cost-effective IPM strategies. New pest management strategies and patterns of cropland use in cotton ecosystems have reduced foliar insecticide inputs and created "low spray" environments. Pests that have typically been perceived as secondary problems were controlled with frequent applications of broad-spectrum insecticides used for major pests. In "low-spray" environments and diverse farm landscapes, secondary pests are driving the decision-making process in cotton IPM. Recognizing the influence of changes in cotton production systems allows agricultural consultants and producers to successfully refine IPM practices to address their immediate needs.

Introduction

Producers are incorporating significant changes in cotton, *Gossypium hirsutum* L., production systems in an effort to decrease production costs and improve profits. These changes significantly influence insect pest diversity and density as well as pest status. Most of the changes currently impacting insect pests in cotton ecosystems can be classified into two broad categories, pest management strategies and patterns of cropland use. The pest management strategies include adoption of Bollgard cultivars, boll weevil, *Anthonomus grandis grandis* Boheman, eradication, and target specific insecticides. Changes in cropland use patterns include conservation tillage practices, herbicide use strategies, crop rotations, and subsidized land management (conservation/wetlands reserve programs [CRP/WRP]).

These production technologies influence insect pest ecology on individual plants, across crop fields, and within native vegetation landscapes on crop field borders. The impact of changes in production systems on pest ecology may be indirect and difficult to quantify. Cotton producers and agricultural consultants have become more concerned about several insect pests including tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois); stink bug complex (Pentatomidae); fall armyworm, *Spodoptera frugiperda* (J.E. Smith); cotton aphid, *Aphis gossypii* (Glover); and beet armyworm, *Spodoptera exigua* (Hübner) (Leonard et al. 1999, Roberts 1999, Roof and Arnette 2000, Greene and Herzog 2000, Bachelor and Mott 2000). This summary will briefly discuss the implications of changes in production practices, IPM strategies, and agricultural landscapes on cotton insect pests. These comments apply primarily to the Southeastern and mid-southern region of the US, but some specific examples may also apply to other cotton production regions. A list of cotton pests influenced by production practice or agronomic system is presented in Table 1.

Pest Management Strategies

Several concurrent events in the recent implementation of novel pest management strategies can be associated with a change in the diversity and density of pests in cotton fields. Boll weevil eradication, transgenic technology (Bollgard), and novel target specific insecticides have been widely accepted by producers. These IPM tools have created "low spray environments" by selectively eliminating major pest problems and reducing the frequency of broad-spectrum insecticide treatments.

Boll Weevil Eradication

Boll weevil eradication programs are in various phases of completion across the cotton belt (El-Lissy and Greffenstette 2001). These area-wide efforts have had influenced the density, spectrum, and distribution of cotton arthropod pests. Prior to the eradication program, many of the broad-spectrum insecticides applied for boll weevil maintained secondary pest densities below injurious levels. Outbreaks of pests such as cotton aphid and beet armyworm have been associated with the frequent malathion sprays during the initial two seasons of that program in some production areas. Following eradication efforts, the reduction of insecticide sprays for boll weevil have allowed tarnished plant bug, and stink bug species to become more consistent pest problems.

Bollgard Cotton Cultivars

Bollgard cultivars currently are planted on a significant portion of the cotton acreage in the United States. Bollgard® cotton containing the Bt protein is active only against lepidopterous insects, including two of the most important caterpillar pests, tobacco budworm, *Heliothis virescens* (F.), and pink bollworm, *Pectinophora gossypiella* (Saunders) (Hardee et al. 2001). Additional insecticides are not needed to control these pests in Bollgard cotton fields. Supplemental control is still required for bollworm, *Helicoverpa zea* (Boddie); soybean looper, *Pseudoplusia includens* (Walker); armyworms; *Spodoptera spp*.; and non-caterpillar pests.

The widespread utilization of *Bt* cotton has created "low spray" environments (Greene et al. 1998, Roof and Arnette 2000). The use of Bollgard® cotton generally has reduced the frequency of foliar applications for cotton insect pest control over 50% across the cotton belt. In South Carolina, insecticide applications have been reduced to one-to-three applications/year compared to two-to-five applications/year prior to the availability of Bollgard (Turnipseed et al. 2001).

Populations of non-caterpillar pests including tarnished plant bug and stink bug species have become more serious pests in the absence of foliar treatments applied for tobacco budworm. In North Carolina, 0.75 treatments/acre were applied for late-season insect pests from 1996 to 1999 to Bollgard cotton, but a significant increase in the level of stink bug-damaged bolls was recorded compared with that on conventional cotton (Bachelor and Mott 2000).

The trend to reduce foliar insecticide treatments will continue with the commercialization of Bollgard II® cotton cultivars that express both the Cry 1A(c) and Cry 2A(b) proteins. These cultivars are more toxic to bollworm, soybean looper, and armyworms (Stewart et al. 2001). This technology will likely eliminate at least one more treatment for caterpillar pests in exchange for additional insecticide use for non-caterpillar pests.

Target-Specific Insecticides

Conventional cotton production systems historically have depended upon high inputs of broad-spectrum insecticides to control major pests. Considerable limitations imposed by federal and state regulatory agencies have forced agro-chemical industries to pursue the commercialization of extremely target-selective insecticides. Most of the insecticides registered during the last decade control a more restricted range of pests compared to the pyrethroids, organophosphates, and carbamates. Populations of some pests that would have been inadvertently controlled with broad-spectrum insecticides are affected very little or not at all with many of the new products. Within these conditions, minor pests have the opportunity to become significant problems.

These new insecticides are selective towards specific insects and exploit unique target sites. Some of the more common product classes include insect growth regulators, (ecdysone agonists [tebufenozide, methoxyfenozide]), avermectins (emamectin benzoate), spinosyns (spinosad), neonicotinoids (imidacloprid, thiomethoxam, acetamiprid), and oxadiazines (indoxacarb). Most of the new insecticide chemistries are remarkably toxic to caterpillar insects, with less toxicity toward sucking insects and beetles. Successful management of an insect complex with these new products usually relies on the co-application (tank mixes) of multiple insecticides.

Local and Area-Wide Land Use

Agronomic practices, multiple cropping systems and alternative (non-cropping) land use are influencing the diversity of landscapes in cotton ecosystems. Most cotton insect pests are polyphagous and have a broad host range including crops and native vegetation. Increasing plant diversity improves the opportunities for a sequence of preferred plant hosts to be available. Agronomic strategies such as conservation tillage and crop rotation improve the habitat for insect pests within crop fields and across farms. Transformation of cropland into fields of native plant species through Federal subsidized conservation programs increases the acreage of non-crop plant species that can serve as a refuge for insect populations that eventually immigrate to cotton fields.

Conservation Tillage and Herbicide Tolerant Cultivars

Many southern row crop producers have modified crop tillage practices compared to those used during the early 1990's. Species diversity and population densities of a wide range of pest and beneficial insect complexes can be influenced by a reduction in tillage, seeding of winter cover crops, and delays in winter/spring vegetation management. Currently, weed management strategies place a higher reliance on herbicides than tillage in many conservation tillage systems. The resulting increase in surface residue from crops and weedy vegetation provides a favorable microenvironment for soil-dwelling insects. In some instances, insect densities increase to higher than expected levels in these fields before cotton is available as a host. Producers have experienced occasional, but severe problems with insect pests in conservation tillage systems in the Mid-South region of the U.S. The reduction of tillage and use of winter cover crops has made cutworms (Noctuidae), cotton aphids, and false chinch bug, *Nysius raphanus* Howard, more common problems that require insecticides for their control.

The availability of transgenic technologies incorporating herbicide tolerance in cotton varieties (BXN and Round-up Ready) has increased the adoption of conservation tillage practices by providing an effective and economical weed management tool. Many producers utilize the herbicide, Round-up, in a pre-plant application to 'burndown' or terminate vegetation on seedbeds prior to planting. This treatment provides satisfactory control of most native weed species found in cotton fields if properly timed. However, applied too early or against weeds larger than the susceptible stage, Round-up is an ineffective treatment. Spring plant species not controlled by Round-up can be non-crop hosts for cutworm, tarnished plant bug, false chinch bug, thrips, and cotton aphid.

In addition, the general timing of pre-plant herbicide applications in cotton has shifted closer to the time of planting compared to the timing of tillage practices. With herbicides, producers can delay fieldwork for vegetation management much longer than if tillage is used. This delay in terminating some weed species provides a refuge for insects until cotton becomes available. Therefore, insect pests have another opportunity to increase population densities.

Multiple Cropping Systems

Producers are changing from a monoculture system of cotton production to a diversified multi-cropping system. Historically, crop rotation has been promoted by agronomists for yield stability, as well as, soil improvement in crop management practices. In recent years, crop rotation has been more driven by economics than by any other factor. Cotton producers have diversified operations to include more corn, rice, grain sorghum, and soybeans to distribute the risk of production costs and yield variability across a number of crops, rather than relying solely on cotton. Crop rotation strategies are not limited to fields on a single farm and may be on adjacent farms. Multiple cropping systems can influence insect populations across an entire region over which an individual producer has little control. Crop rotation and multiple cropping strategies modify the area-wide landscape ecology compared to that in a cotton monoculture.

The impact of area-wide crop rotation on the dynamics of insect populations has not been well studied in the Southern United States. Except for the boll weevil, most cotton insect pests are capable of moving among different hosts. Many of the crops (cotton, soybean, field corn, grain sorghum) used in annual sequential rotations serve as non-sprayed refuges for insect pests that will subsequently infest cotton fields. Field corn can serve as an alternate host for insect pests such as cutworm, bollworm, stink bug, and tarnished plant bug similar to the non-crop plants within cotton fields and on field margins (Bradley et al. 1986, Boethel et al. 1986). In the Southeastern United States, field corn provides an alternate mid-season host for bollworm, prior to populations immigrating to cotton fields (Bradley et al. 1986). Bollworm densities in cotton fields usually are much higher in those states with appreciable acreages of field corn than in areas that have little field corn acreage. Stink bugs typically prefer soybeans over cotton and usually significant stink bug migration into cotton does not occur when reproductive stage soybeans are available (Bundy and McPherson 2000). However, cotton could potentially become a more frequent host for stink bugs due to the decline in acres planted to soybean. Since 1990 in Louisiana, soybean acreage has decreased from approximately 1,800,000 to 700,000 in 2001 (Anonymous 2001). A similar situation can be observed in some areas with field corn.

Another effect of crop rotations on insect ecology relates to heavy residue from the previous field corn harvest and its impact on soil-dwelling insect pests. Conservation tillage systems also are used for field corn production and usually little or no tillage is performed following harvest. Heavy residue from the previous corn crop covers the soil surface and mediates soil temperature and moisture levels. The probability of insect pests successfully over wintering increases in those fields. Bollworm and stink bug species are common cotton pests that can over winter in corn fields.

Landscape Diversity in Agricultural Communities

A general increase in the density and diversity of non-cultivated native plant species that can function as hosts for insect pests is occurring. The transformation of cropland into the Federal subsidized Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP) provides alternate non-crop hosts for many cotton insects. Other areas in a cotton ecosystem including marginal land not being farmed (fallow) or reverted to livestock pastures also may provide alternate hosts. In some instances, these areas may act as trap crops and reduce pest migration to cotton fields. However, for several species, ditch banks, fallow fields, un-improved pastures, and WRP/CRP areas are potential refuges. Pest population densities can actually increase on hosts in these areas. When plants in these areas are no longer attractive, continuous immigration or one mass migration of insect pests to cotton fields may occur. Cotton fields in close proximity to such areas are subject to a higher probability of pest immigration than fields not located near WRP/CRP fields or other uncultivated areas.

The ability of secondary insect pests such as cutworm, tarnished plant bug, stink bug, and cotton aphid to utilize a wide range of hosts may have an impact in cotton ecosystems where the CRP/WRP has been embraced by many land owners. In Louisiana, the parishes of greatest cotton production also are the same parishes in which large amounts of acreage are devoted to CRP. Fifty-six percent of the total acreage planted to cotton occurs in five parishes (Tensas, Morehouse, Franklin, Richland, and Madison). These same parishes account for 42.3% of the CRP acres in the state (Anonymous 2001).

Summary

The emergence of specific pest problems is not likely the result of a single change in production practices or in the environment surrounding cotton fields. The sum total of changes in a local area and complex interactions among biotic and abiotic components in a cotton production region likely contribute to changes in the diversity and density of pests. Many of the previously discussed changes in cotton production are occurring concurrently across large acreages and impacting numerous pest species. A current example of a change in pest status can be that for stink bugs. During the late 1990s', stink bugs were mentioned only as an occasional pest. Stink bugs infested 5,294,862 acres across seventeen states of the cotton belt, ranking the complex fifth among all pests in 2000 (Williams 2001). In Louisiana, the number of acres infested in 1995 through 2000 has risen from 8,367 to 374,699, respectively (Williams 1996, Williams 2001). Cotton IPM strategies must become more holistic and consider pest control decisions not only within individual field units but also across farm landscapes.

"Low spray" environments are now a reality in many cotton ecosystems due to changes in pest management strategies and cropland use patterns. Changes in pest status and increases in pest diversity emphasize the need for improved sampling plans and decision-making tools. Furthermore, spatially variable treatments against selected arthropod pests are more likely to be successful in the absence of primary pests that have historically dictated the need to spray entire fields.

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Table 1. Effects of Production Practices and Agronomic Systems on Cotton Insect Pests.

	Agronomic System[1]				
Insect Pests	**Conservation Tillage**	**CRP/WRP Land**	**Crop[2] Rotation**	**Transgenics (BG/RR[3])**	**Boll Weevil Eradication**
Cutworms	X[4]	X	X	0	0
Thrips	X	X	X	X	0
Cotton Aphid	X	X	0	X	X-0
Tarnished Plant Bug	X	X	X	X	X-0
Stink Bugs	0	X	X	X	X-0
Bollworm/T. budworm	X	0	X	X	X-0
Armyworms	0	X	X	X	X-0

[1]Available data suggests changes in pest density/diversity compared to a conventional cotton monoculture system.
[2]Refers to a cotton and field corn rotation.
[3]Bollgard/Round-Up ready.
[4]X=positive effect; 0=no measured or anticipated effect; X-0=effects vary based stage of program.