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ORGANIC COTTON PRODUCTION

CURRENT TOPIC

Abstract: *Cotton sold as "organic" must be grown according to the federal guidelines for organic crop production. Soil fertility practices that meet organic certification standards typically include crop rotation, cover cropping, animal manure additions, and use of naturally occurring rock powders. Weed management is accomplished by a combination of cultivation, flame weeding, and other cultural practices. A wide variety of insects attack cotton. Management options include trap cropping, strip cropping, and managing border vegetation to encourage high populations of native beneficials. Certain biopesticides using bacteria, viruses, and fungal insect pathogens are available as insect control tools. We discuss specific insect management strategies for cutworm, cotton bollworm, tobacco budworm, pink bollworm, armyworm, loopers, thrips, fleahoppers, lygus bugs, aphids, whitefly, spider mite, and boll weevil. Seedling disease, soil disease, and foliar disease management is also discussed. Pre-harvest defoliation methods that meet organic certification are mostly limited to citric acid, flamers and frost. The publication concludes with sections on marketing organic cotton and the economics and profitability of organic cotton production.*

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July 2003

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Introduction

Organic cotton has provided significant price premiums for growers willing to meet the many challenges inherent in its production without the aid of conventional pesticides and commercial fertilizers. Growing organic cotton is demanding, but with commitment, experience, and determination, it can be done. This publication covers the major steps in organic production of cotton. It covers soil fertility, weed control options, and alternative pest controls for the many insect problems that plague cotton. Finally, marketing of organic cotton is discussed as well.

ATTRA is the national sustainable agriculture information service operated by the National Center for Appropriate Technology, through a grant from the Rural Business-Cooperative Service, U.S. Department of Agriculture. These organizations do not recommend or endorse products, companies, or individuals. NCAT has offices in Fayetteville, Arkansas (P.O. Box 3657, Fayetteville, AR 72702), Butte, Montana, and Davis, California.

Organic cotton acreage declined 18% from 2000 to 2001 in the seven states where most of it is grown (Marquardt, 2002). Most of this decline came from one large organic cotton farmer in New Mexico who lost it all to drought and withdrew from organic cotton farming altogether. A total of 11,459 acres of either certified organic or transitional organic cotton was produced in 2001. Texas produced the most organic cotton—8,338 acres—with Arizona and California being the next two highest producing states.

World production of organic cotton amounts to 6,000 tons of fiber annually, or about 0.03% of global cotton production. Turkey produces the most at 29%, with the U.S. being second at 27% and India third at 17% (Ton, 2002). Demand for organic cotton is highest in Europe (about 3,500 tons or 58% of the total) and the U.S. (about 2,000 tons or 33%) (Ton, 2002). Demand in the U.S. increased at an annual rate of 22% between 1996 and 2000 (Organic Trade Association, 2001; cited by Ton, 2002).

Overview of Organic Production

Growing cotton organically entails using cultural practices, natural fertilizers, and biological controls rather than synthetic fertilizers and pesticides. A systems approach to organic production involves the integration of many practices (cover crops, strip cropping, grazing, crop rotation, etc.) into a larger system. Through good soil and biodiversity management, farms can become increasingly self-sufficient in fertility, while pest problems are diminished, and some pests are even controlled outright. A diverse rotation, using legumes and other cover crops, is at the heart of good humus and biodiversity management in an organic cropping system. Cotton, for example, would be but one of several crops an organic farmer would grow. For more complete coverage of general organic crop production, we recommend the ATTRA publication *Overview of Organic Crop Production*.

Throughout this publication, we use examples from conventional farming that illustrate principles relevant to organic cotton production.

In order to market a crop as "organic," a grower must be certified through a third party. This process involves several on-farm inspections and paying a certification fee. More on this subject can be found in the ATTRA publication *Organic Farm Certification and The National Organics Program*. Applicants for certification are encouraged to become familiar with provisions of the Final Rule posted on the USDA's National Organic Program Web site, http://www.ams.usda.gov/nop.

Organic production begins with organically grown seed. If certified organic seed cannot be located, untreated seed may be used as long as it is not derived from genetically modified plants. Most certifiers will accept proof that growers have tried unsuccessfully to buy organic material from at least three different suppliers as evidence of unavailability. Federal organic regulations also address composting and the use of raw manures. These may have implications for cotton production when used as fertilizer.

Soil Fertility

Mineral nutrition of crops in organic systems comes from proper management of soil organisms that are responsible for releasing nutrients. Rather than feeding plants with fertilizer, organic farmers feed the soil and let the soil organisms feed the plants. The biological activity in the soil can be likened to a digestive process whereby organic food sources are applied to the soil and then digested by soil organisms to release nutrients for the crop. Soil mineral levels are built up through the application of animal manure, compost, soluble rock powders, and deep-rooted cover crops that bring up nutrients from deep within the soil. Plant nutrition is supplemented with foliar fertilization in some situations. Soil fertility, levels of organic matter, minerals, pH, and other measurements can be monitored with regular soil tests. The overall cropping sequence fosters a system in which a previous crop provides fertility benefits to a subsequent crop—such as a legume cover crop providing nitrogen to a following corn crop. Much more detailed soil-fertility information is available from ATTRA in these publications: *Sustainable Soil Management*, *Manures for Organic Crop Production*, *Sustainable Management of Soil-borne Plant Diseases*, and *Sources of Organic Fertilizers and Amendments*.

Crop Rotation

Crop rotation is a traditional agricultural practice involving the sequencing of different crops on farm fields; it is considered fundamental to successful organic farming. Rotations are a planned approach to diversifying the whole farm system both economically and biologically, bringing diversity to each field over time.

Rotations can benefit the farm in several ways. Planned rotations are one of the most effective means of breaking many insect pest and plant disease cycles in the soil. Likewise, many problem weeds are suppressed by the nature and timing of different cultural practices. Rotations also affect the fertility of the soil in significant ways. The inclusion of forage legumes, in particular, may serve as the primary source of nitrogen for subsequent crops.

Rotation is an important means of controlling a number of cotton pests, including nematodes. Even basic corn-cotton rotations have been found effective in reducing some species of nematodes (Anon, 1993). A minimum of two years planted to non-host species is the standard recommendation.

A long-term cotton study at Auburn, Alabama, showed that using winter annual legumes produced cotton yields equivalent to those grown using fertilizer nitrogen. The study found an 11% yield increase for a 2-year cotton-legume-corn rotation compared to continuous cotton grown with legumes each year. Adding conventional nitrogen fertilizer boosted the two-year rotation cotton lint yields in this study another 79 pounds per acre. A three-year rotation of cotton-vetch, corn-rye (fertilized with 60 pounds of conventional N/acre), followed by soybeans, produced about the same cotton yields as the two-year rotation (Mitchell, 1988).

Cover Cropping

Cover crops are crops grown to provide soil cover and erosion protection. At the same time, cover cropping may accomplish a number of other objectives, including providing nitrogen to the subsequent cotton crop when tilled into the soil, improving tilth by adding organic matter, and serving as a catch crop when planted to reduce nutrient leaching following a main crop.

Fast, dense-growing cover crops are sometimes used to suppress problem weeds as a "smother crop" or allelopathic cover. The mere presence of most cover crops reduces the competition from weeds. Sometimes crops are no-till planted into such covers. If the cover crop is not killed, it is referred to as a "living mulch." Some cover crops that have been used successfully for weed suppression include small grains (particularly grain rye), several brassica species, hairy vetch, and forage sorghums.

For the humid Cotton Belt, crimson clover, field peas, and hairy vetch are excellent winter cover crops for nitrogen production. Also, a mixture of hairy vetch and rye works well for overall biomass production. When flowering, these provide nectar and pollen as alternate food for beneficials. Hairy vetch is noted for its dense spring cover and weed suppression. Cereal rye provides an enormous amount of biomass to the soil and is known to attract and shelter beneficial insects. It also suppresses germination of small-seeded weeds when left as a mulch cover on the soil surface. Natural allelopathic chemicals leach from the rye residue and inhibit weed germination for about 30-60 days (Daar, 1986). Weed suppression effectively ends once the rye residue is incorporated. Weed suppression has made rye attractive as a cover crop/mulch in no-till and ridgetill systems. Mowing or a burndown herbicide is often used in conventional systems to kill the rye cover crop so that no-till plantings of field crops can be established. An effective organic no-till system for cotton has yet to be developed, but early indications are that it will be. For more information on the potential for organic no-till see the ATTRA publication *Pursuing Conservation Tillage Systems for Organic Crop Production*, which discusses progress in this area. It is important to mow rye at the flowering stage when the anthers are extended, and pollen falls from the seed heads when shaken. If mowing is done earlier, the rye simply grows back. As allelopathic weed suppression subsides, a no-till cultivator may be used for weed control. This is not a proven system for organic cotton production but only presented here as food for thought about the development of future organic no-till systems.

In addition to producing nitrogen, cover crops often provide excellent habitat for predatory and parasitic insects and spiders. Some good insectary plants often used as cover crops include alfalfa, buckwheat, sweet clover, vetch, red clover, white clover, mustards, and cowpeas. Migration of beneficials from the cover crop to the main crop is sometimes associated with the post-bloom period of the cover crop. In these instances, mowing the cover crops in alternate strips may facilitate their movement, while the remaining strips continue to provide refuge for other beneficial species. Sickle-bar mowers are less disruptive to beneficials than flail mowers, rotary mowers, and mower conditioners with crimpers.

Long-term cotton cover-crop studies have also been done in Louisiana (Millhollon and Melville, 1991) and Arkansas (Scott, 1990). The Arkansas study spanned 17 years, from 1973 to 1988. Cotton grown after winter cover crops of rye + hairy vetch produced an average of 234 pounds more seed cotton per acre than a control treatment of winter fallow. Cotton following pure vetch showed a 129-pound increase, while yields after rye + crimson clover had a 72-pound yield improvement.

In the long-term Louisiana study, cotton yields declined for the first nine years when cover crops were used, but increased steadily thereafter. In the final four years of the study, cotton yields were 360 pounds-per-acre higher following vetch, compared to fallow + 60 pounds of fertilizer N per acre. Averaged over the 30-year study period, the highest cotton yields followed wheat + 60 pounds of fertilizer N, hairy vetch alone, common vetch alone, or vetch + 40 pounds of N. For additional information on cover crops, see the ATTRA publication *Overview of Cover Crops and Green Manures*.

Weed Management

Cotton germinates at a soil temperature of 61° F at a depth of about 2 in. With planting delayed until the soil temperature reaches 66°, the crop emerges rapidly and uniformly and is more vigorous (Head and Willians, 1996), giving it a competitive edge on weeds. The delay in operations also allows additional growth of winter cover crops where used. The downside of this strategy may include risks of increased damage from certain insect pests such as boll weevil, tobacco budworm, and cotton bollworm.

Cultivation

Tillage and cultivation are the traditional means of weed management for organic crops. Some specific tillage guidelines and techniques for weed management include the following:

- Preplant tillage. Where weeds such as johnsongrass are a problem, spring-tooth harrows and similar tools can be effective in catching and pulling the rhizomes to the soil surface, where they desiccate and die. Disking, by contrast, trends to cut and distribute rhizomes and may make the stand even denser.

- Blind tillage. Blind cultivation employs finger weeders, tine harrows, or rotary hoes during the pre-emergent and early post-emergent phase. These implements are run at relatively high speeds (6 mph plus) across the entire field, including directly over, but in the same direction as, the rows. The large-seeded crops like corn, soybeans or sunflower survive with minimal damage, while small-seeded weeds are easily uprooted and killed. Post-emergent blind tillage should be done in the hottest part of the day when crop plants are less turgid, to avoid excessive damage. Rotary hoes, not harrows, should be used if the soil is crusted or too trashy. Seeding rates should be increased 5-10% to compensate for losses in blind cultivation (Anon., 1991; Doll, 1988).

- Inter-row cultivation. When annual weeds are the concern, cultivation is best kept as shallow as possible to bring as few weed seeds as possible near the soil surface. Where perennial, rhizomaceous weeds are a problem, the shovels set furthest from the crop row may be set deeper on the first cultivation to bring rhizomes to the surface. Tines are more effective than sweeps or duck feet for extracting rhizomes. Later cultivations should have all shovels set shallow to avoid excessive pruning of crop roots. Earliest cultivations should avoid throwing soil toward the crop row. This places new weed seed into the crop row where it may germinate before the crop canopy can shade it out. As the crop canopy develops, soil should be thrown into the crop row to cover emerging weeds.

Inter-row cultivation is best timed to catch weeds as they are germinating—as soon as possible after rain or irrigation, once the soil has dried enough to avoid compaction or surface crusting.

Flame Weeding

Prior to the 1950s, before modern herbicides became available, flame weeders were used in the U.S. to control weeds in cotton, sugar cane, grain sorghum, corn, and orchards. Interest in flame weeding has resurfaced in recent years with rising herbicide costs. Weeds are most susceptible to flame heat when they are young seedlings 1–2 inches tall or in the 3–5 leaf stage. Risk of damaging the cotton plants diminishes as the cotton grows and forms a bark on the stem. Broadleaf weeds are more susceptible to flaming than grasses. Grass seedlings develop a protective sheath around the growing tip when they are about 1 in. tall (Drlik, 1994). Consequently, repeated flamings may be necessary on grassy weeds for effective control. Searing the plant is much more successful than charring. Excessive burning of the weeds often stimulates the roots and encourages regrowth, in addition to using more fuel.

Preplant flaming has commonly been referred to as the stale seedbed technique. Prepared seedbeds are flamed after the first flush of weeds has sprouted. Cotton planting follows the flaming without any further disturbance to the seedbed. Assuming adequate moisture and soil temperature, germination should occur within two weeks. Note that a fine-to-slightly-compacted seedbed will germinate a much larger number of weeds.

Costs associated with flame weeding can vary. Flamers have been built for $1,200 for an eight-row unit (Anon., 1993) and for as much as $1,520 for a 12-row unit (Houtsma, 1991). Commercial kits cost around $1900 for an eight-row from Thermal Weed Control Systems (see **References**). These kits do not include hoses, a tank, or a tool bar. It is more cost-effective to pick these items up locally from a gas dealer or salvage operation. An Arkansas cotton grower uses a "water shield" to help protect the cotton plants, but still feels flaming should be delayed until the crop has developed a woody bark on the stem (Vestal, 1992). Adapting flame technology requires careful implementation. Thermal Weed Control Systems (TWCS), Inc. of Neillsville, Wisconsin, and Flame Engineering, Inc. (FEI), of Lacrosse, Kansas, are two flame-weeding companies that can provide technical assistance and equipment (see **References**). LP gas usage depends on ground speed but generally runs from 8-10 gallons per acre, according to sources at Thermal Weed Control. For an overview of weed management strategies and options for agronomic crops, please request the ATTRA publication *Principles of Sustainable Weed Management*.

Insect Management Practices

Biological and cultural insect control involves understanding the ecology of the surrounding agricultural systems and the cotton field and making adjustments to production methods that complement the natural system to our benefit. To realize the full benefits of a biological approach we need to move beyond asking how to kill bugs and ask the larger question: Why do we have bugs in our cotton fields in the first place?

In a nutshell, we invite pest problems by planting large expanses of a single susceptible crop. When cotton is the only food available, bugs are going to eat cotton. When we have a more diverse farmscape involving many types of plants and animals, the likelihood of severe pest outbreaks diminishes. For more information on farmscaping, request the ATTRA publication *Farmscaping to Enhance Biological Control*.

Many types of insects feed on cotton plants and threaten yields. Proper identification of these pests as well as their natural enemies is the first step in successful management of pests. State Extension services typically have Internet based information that can help with pest and beneficial insect identification. Once the pest is properly identified, a scouting program with regular monitoring can help determine the pest pressures and the densities of beneficial insects. When pest pressures reach the economically-damaging threshold, control actions become necessary. If biological controls are to be used, they must be started before the pests reach critical levels. That is why monitoring is so important.

The use of beneficial insect habitats along crop field borders has shown to increase the presence of beneficial insects. These habitats provide shelter, pollen and nectar sources, and refuge if the fields are treated with a pesticide. In the event you are releasing purchased beneficial insects, these field-edge habitats will encourage the beneficials to remain and continue their lifecycle in that location, helping reduce the pest population. Some pests may also inhabit the field-edge habitats; therefore, these habitats should be monitored along with the crop field. For additional information, request ATTRA's *Biointensive Integrated Pest Management* and *Farmscaping to Enhance Biological Control*.

Though not completely organic, the Sustainable Cotton Project's BASIC program (Biological Agriculture Systems in Cotton) offers California growers strategies designed to save money and reduce the need for pesticides, chemical fertilizers, and water. The BASIC program utilized the following strategies in their 2002 program that showed a 73% reduction in pesticide use over the Fresno County average (Figure 1). In Figure 1, the "enrolled acreage" had the free monitoring, habitat plantings, and insect releases provided to them. "Basic growers" had implemented the principles on their own fields but without the direct involvement of the basic program staff. Regular IPM, intensive monitoring, beneficials, and beneficial habitat can reduce pesticide use whether you are organic or conventional. For pesticide use questions or analysis questions, contact Max Stevenson at: maxstevenson@yahoo.com

1. *Intensive Monitoring*
   Fields enrolled in the program were monitored weekly. Monitoring included an overall picture of the field and the local conditions, the levels of pests and beneficials, farmscape observations, the status of the adjacent beneficial habitat, and any unusual sightings or areas for concern. Farmers were

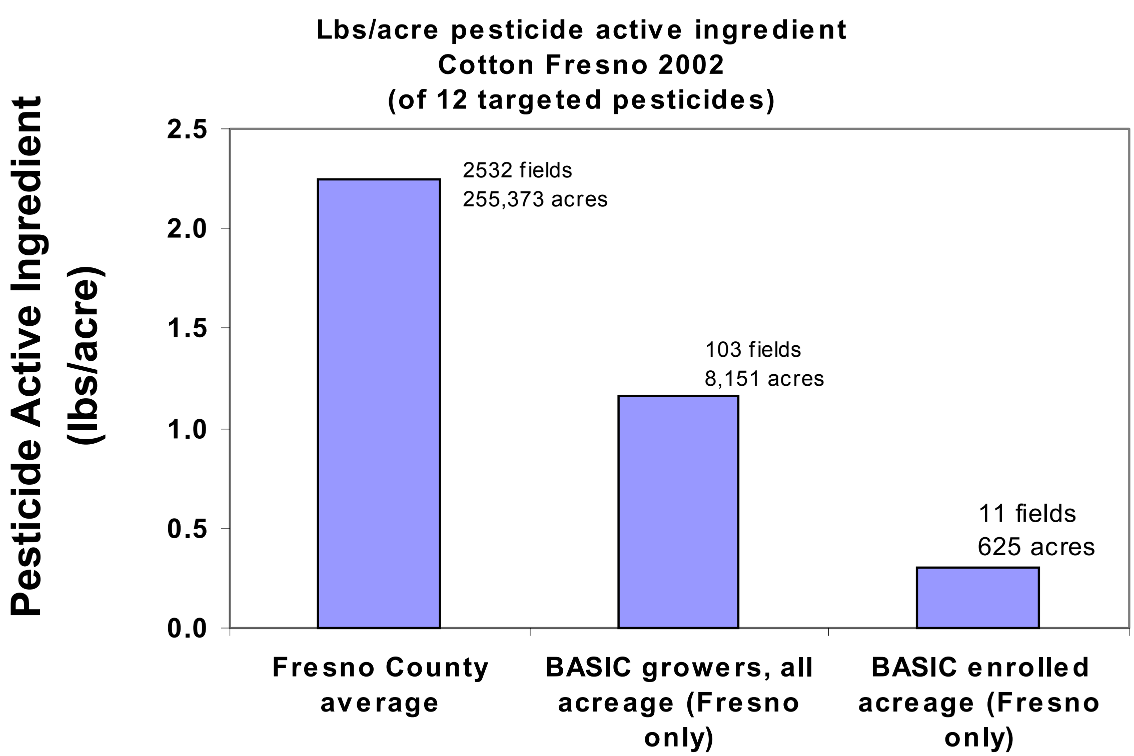

Figure 1. Pesticide reductions resulting from the BASIC program in California.

given a copy of the monitoring form, and the overall results were published bi-weekly in a newsletter.

2. *Strip Cutting of Alfalfa Intercropped with Cotton*
One of the "best management practices" promoted by the BASIC program has been the strip cutting of alfalfa. This practice prevents the immigration of certain species at harvest time and keeps one of the main cotton pests, *Lygus Hesperus,* from moving out of the alfalfa (its preferred host) into the adjacent cotton. BASIC field staff and mentor growers were also able to provide technical support for growers wanting to implement a system of strip cutting.

3. *Bezzerides Weed Cultivator*
A Bezzerides cultivator was tried by a BASIC grower during the 2002 season. The cultivator works in the planted row where conventional cultivators can't reach. Traditionally, this is the area where chemical herbicides are used to eliminate competing weeds. The trial was not considered a success, since the cultivator also removes cotton plants along with the weeds, and the growers who tested the equipment felt that it was not significantly better than their existing cultivators.

4. *Beneficial Habitat Planting*
Seventy percent of the growers enrolled in the 2002 BASIC program planted beneficial habitat adjacent to their enrolled fields. The habitat was intended to attract and hold naturally occurring beneficials. The remaining thirty percent of the enrolled fields were adjacent to alfalfa fields where strip cutting was practiced.

5. *Beneficial Insect Releases*
Releases of beneficial insects were also utilized during the growing season. Thousands of lacewings and predatory mites were released to augment the naturally occurring insects. When growers see a pest problem starting to develop in their fields they want fast action and so will often turn to a chemical spray. Releasing insects helped them feel like something was being done, while the natural enemies took over the pest control.

For additional information on the Sustainable Cotton Project or the BASIC program, contact Marcia Gibbs at marcia@sustainablecotton.org, or see the Web site at http://sustainablecotton.org.

Trap Cropping

A trap crop is planted specifically to attract pest insects. It is then sprayed with some type of insecticide, in conventional management, or left to detain the pests from the cotton crop, or the entire trap crop is tilled under to kill the pest insects. Early-sown cotton has been used as a boll-weevil trap crop. Using fall-planted-cotton trap crops to reduce the number of over-wintering boll weevils was first proposed as early as the late 1800s (Javaid and Joshi, 1995). Both early and fall cotton trap crops are effective at attracting boll weevil adults and can be enhanced by adding pheromones such as Grandlure™ to the trap crop. The concentrated weevils can then be killed with organically accepted insecticides, which are limited to a few botanicals and biologicals. Crop consultants James and Larry Chiles were able to reduce the cost of boll weevil control by 30% using trap crops of early and late-planted cotton. Even with the cost reduction, they were able to maintain good yields of 1000 to 1200 pounds per acre. They planted a trap crop of cotton in early April, 30 days before the normal cotton planting time, and a late-planted trap crop on August 10. A weevil attractant pheromone was used to lure boll weevils to the cotton trap crops. The trap crops were sprayed for weevils whenever populations were high. This technique reduced the number of early emergent weevils infesting the main crop and reduced the number of weevils overwintering to attack the next year's crop. In a Mississippi study, Laster and Furr (1972) showed sesame (*Sesamum indicum)* to be more attractive than cotton to the cotton bollworm. Robinson et al. (1972) reported more *predators* on sorghum than on cotton in his Oklahoma strip cropping study. Lygus bug may also be kept out of cotton by using nearby alfalfa as a trap crop. Unmowed or strip-mowed alfalfa is preferred by that pest over cotton (Grossman, 1988).

Strip Cropping

Strip cropping takes place when harvest-width strips of two or three crops are planted in the same field. The most common strip crop grown with cotton is alfalfa. Increasing the diversity of crops increases stability in the field, resulting in fewer pest problems, due to natural biological controls. Crop rotation is one means of introducing diversity over time. Strip intercropping creates biodiversity in space.

Strip cropping cotton fields with alfalfa generally increases beneficial arthropod populations. Among the most notable are carabid beetles that prey on cutworms and armyworms (Grossman, 1989). Alfalfa has been found to be one of the best crops for attracting and retaining beneficial insects. Strip-cutting alfalfa (i.e., cutting only half of the crop in alternating strips at any one time) maintains two growth stages in the crop; consequently, some beneficial habitat is available at all times. In some cases alfalfa is mixed with another legume and a grass.

In a conventional cotton management study, Stern (1969) interplanted 300–500 foot cotton strips and 20-foot wide alfalfa strips to compare pest control needs with monoculture cotton. The intercropped field required only one insecticide application, while the monoculture cotton had to be sprayed four times. The practice was abandoned in this specific case, however, due to modifications to irrigation systems and extra labor to cut alfalfa, which did not compensate for the reduced pesticide costs.

Dr. Sharad Phatak of the University of Georgia has been working with conventional cotton growers in Georgia testing a strip-cropping method (Yancy, 1994). Phatak finds that planting cotton into strip-killed crimson clover improves soil health, cuts tillage costs, and allows him to grow cotton without any insecticides and only 30 pounds of commercial nitrogen fertilizer per acre. Working with Phatak, farmer Benny Johnson reported saving at least $120/acre on his 16-acre clover-system test plot. There were no insect problems in the trial acres, while beet armyworms and whiteflies were infesting nearby cotton and required 8 to 12 sprayings. This system may have some applicability in an organic cotton system. In the study, cotton intercropped with crimson clover yielded 5,564 pounds of seed cotton per acre, compared with 1,666 pounds of seed cotton in the rest of the field (Yancy, 1994). Boll counts were 30 per plant with crimson clover and 11 without it. Phatak identified up to 15 different kinds of beneficial insects in these strip-planted plots.

Phatak used a crimson clover seeding rate of 15-pounds per acre that produced around 60 pounds of nitrogen per acre by spring. By late spring, beneficial insects were active in the cover crop. At that time, 6- to 12-inch planting strips were killed with Roundup™ herbicide (not allowed in an organic system). Fifteen to 20 days later the strips were lightly tilled and the cotton planted. The cover crop in the row-middles was left growing to maintain beneficial insect habitat. Even early-season thrips, which can be a problem following cover crops, were limited or prevented by beneficial insects in this system. When the clover is past the bloom stage and less desirable for beneficials, they move readily onto the cotton. The timing coincides with a period when cotton is most vulnerable to insect pests. Following cotton defoliation, the beneficials hibernate in adjacent non-crop areas.

Phatak emphasizes that switching to a whole-farm focus while reducing off-farm inputs is not simple. It requires planning, management, and several years to implement on a large scale. It is just as important to increase and maintain organic matter, which stimulates beneficial soil microorganisms.

Managing Border Vegetation

Weedy borders are particularly infamous as sources of insect pests. Current recommendations suggest mowing them prior to establishment of cotton. Mowing after weeds have formed flower buds will tend to drive plant bugs into the cotton field (Layton, 1996).

Grassy weed species harbor lepidopterous pests generally. A specific weed, wild geranium, is an important spring host of tobacco budworm and should be discouraged in border areas.

More diverse field borders with habitat plant species support some crop pests but also sustain beneficial insects that prey on pest populations, particularly during non-crop seasons. Managing the vegetation in these areas as habitat for beneficial insects counterbalances the threat from insect pests. The strategy entails planting or otherwise encouraging the growth of plants that provide alternative food sources (nectar, pollen, alternate prey), moisture, shelter, and perching sites preferred by beneficials. Plant species that are aggressive and invasive, or are known hosts to major crop diseases or insect pests, should be avoided. Descriptions of crops, cover crops, and wild plants that are known to attract certain beneficial insects and information on designing landscapes to attract beneficial organisms can be found in ATTRA's *Farmscaping to Enhance Biological Control*, which is available on request.

Natural Disease Organisms as Pest Control

A naturally occuring fungal disease of aphids is known to occur under conditions of high infestation. In Mississippi, this historically occurs between July 10-25 (Layton, 1996). Fungal diseases commonly attack and suppress populations of lepidopterous pests, most notably the cabbage looper and beet armyworm. Suppression of these pests by natural disease organisms is encouraged by developing dense crop canopies, which also assists in weed control. However, these are also conditions that encourage plant diseases and may not be desirable where cotton diseases are rampant.

Early Crop Maturation

Early maturing crops are more likely to escape damage from late-season infestations of boll weevil, tobacco budworm, cotton bollworm, armyworms, loopers, and other pests. The use of short-season cotton is the most obvious means of doing this. Excessive nitrogen use, late irrigation, and excessive stand density can result in delayed maturity and increased exposure to these pests, and should be avoided (Layton, 1996).

Biopesticides

B.t. (*Bacillus thuringiensis*) is a naturally occurring bacteria that produces a toxin effective in controlling many caterpillars. The toxin causes paralysis of the worm's digestive tract. Worms may continue to live for some hours after ingestion, but will not continue to feed. B.t. strains have been formulated into a number of commercial products under various trade names. *B.t.* degrades rapidly in sunlight, requiring careful timing or repeated applications.

B.t. must be ingested in sufficient amounts by the caterpillar to be effective. Consequently, an understanding of the feeding habits of the pests is necessary, so that proper formulations are used and timing of applications is optimal. Spray formulations are most effective against armyworms and those species feeding on exposed leaf surfaces. B.t. sprays are very effective against tobacco budworm and moderately effective against cotton bollworm (Layton, 1996). Because of their feeding habits, granular bait formulations are more effective for control of cutworms. Careful inspection of specific product labels will assure that the product has been formulated for the pest to be controlled.

HNPV (*Heliothis* nuclear polyhedrosis virus) is a commercially produced disease organism that attacks budworms and bollworms. It has less of a track record in the Southeast than B.t., but based on preliminary observations it appears to be a viable biological pesticide (Steinkraus, 1992; Anon., 1996). When using any biopesticide, be certain the formulation is cleared for use in organic production.

Beauveria bassiana is an insect-disease causing fungus that has been formulated and is available commercially. It works on several insect larvae, including cutworms and budworms. It works best during periods of high humidity. More on this natural control method can be found below in the Specific Insect Management Strategies section.

Insecticidal Soap

Evolved from a traditional organic gardening technique, insecticidal soaps control insect pests by penetrating the cuticle and causing cell membranes to collapse and leak, resulting in dehydration. Several commercial formulations of insecticidal soap have been successfully used to control aphids, spider mites, white flies, thrips, leaf hoppers, plant bugs, and other pests. Soaps have limited effects on chewing pests such as beetles or caterpillars. Applied as sprays, these biodegradable soaps work by contact only and require excellent coverage to be fully effective (Harmony Farm, 1996; Ellis and Bradley, 1992).

Insecticidal soaps will kill many beneficial insects and must be used with that in mind. Phytotoxicity has also been demonstrated, particularly on crops with thin cuticles (Ellis, 1992). Different varieties of cotton will have different plant characteristics. Therefore, it is advisable to test the soap solution on your plants on a small strip to determine whether any harm will result. Avoid application of soap during the heat of the day, because the plant is then under extreme stress, and you want the soap to remain on the plant as long as possible, not evaporate rapidly. Late day applications will stay on the plant longer, increasing the chances of contact with target pests. Water hardness will affect the efficacy of soap, because calcium, iron, and magnesium will precipitate the fatty acids and make the soap useless against the target insects. The best way to determine how well your water will work is the soap-jar test. Let a jar full of your spray solution sit for 20 minutes, then look for precipitates in the soapy-water solution. Product labeling must be studied to determine suitability to crop and pest in each particular state and region.

Specific Insect Management Strategies

Cutworms

Cutworms wreak havoc during seedling establishment in many cotton-growing areas. Cutworm species include the variegated cutworm, *Peridroma saucia;* black cutworm, *Agrotis ipsilon;* granulate cutworm, *Feltia subterranea*; and army cutworm, *Euxoa auxiliaris.* They are active at night, feeding and chewing through the stems of the seedlings. In the day they burrow underground or under clods to avoid detection. To inspect for cutworms, dig around the damaged areas during the day or come out at night with a flashlight to catch the culprits in the act. Problem areas are usually found near field borders and in weedier areas.

Cutworms have many predators and parasites that can help control their numbers. Some of these parasites and predators can be purchased or harnessed naturally through planting or conserving habitat for them.

Understanding the biology of beneficial organisms is imperative in order to use them effectively as pest control agents. For example, insect parasitic nematodes like *Steinerema carpocapsae* or insect-infecting fungi like *Beauveria bassiana* require adequate humidity to be effective. Other predators include spiders, minute pirate bugs, damsel bugs, and lacewing larvae. Birds also prey on cutworms, so do not assume that the birds in the field are causing the seedling damage.

If natural pesticide applications are necessary, choose one that is least disruptive to the natural enemies. The application of a rolled oats with molasses bait containing *Bacillus thuringiensis* or nighttime spraying of *Bacillus thuringiensis* is effective. Again, early detection and application during the early developmental stages of the larvae (1st and 2nd instar) make these biorational pesticides more effective. Pheromone traps will indicate when mating flights are occurring, and through degree-day calculations one can estimate egg laying and hatching. For information on degree-day calculations contact your local Extension agent.

Thyme oil serves as a toxicant, insect growth regulator, and antifeedant to cutworms (Hummelbrunner and Isman, 2001). Mock lime or Chinese rice flower bush, *Aglaia odorata,* inhibits larval growth and is insecticidal to the cutworms *Peridroma saucia* and *Spodoptera litura* (Janprasert et al,1993). No commercial products using tyme oil, mock lime, or Chinese rice flower are known to us at this time. Azadirachtin, the active ingredient in neem, has similar effects on various insects and is used in the form of neem cakes to control soil pests in India. Certis USA produces Neemix Botanical Insecticide. Its active ingredient, Azadirachtin, is registered for cutworm, looper, armyworm, bollworm, whitefly, and aphid control on cotton.

Cotton bollworm and tobacco budworm

The tobacco budworm, *Heliothus virescens,* and cotton bollworm, *Heliothus zea* or *Helicoverpa armigera,* attack cotton in similar ways, damaging bolls, squares, and blooms, and feeding on plant terminal buds, causing branching that delays maturity. On mature damaged bolls, one finds holes with excrement or frass surrounding the boll. These holes provide entry to secondary organisms that can cause decay. Besides cotton, other bollworm hosts include alfalfa, beans, corn, peanuts, sorghum, soybeans, peppers, sweet potatoes, tobacco, and tomatoes. Wild hosts include toadflax, deergrass, beggarweed, groundcherry, geranium, and sowthistle. In feeding preference tests, 67% of females preferred common sowthistle, about 5% preferred cotton, and 28% did not discriminate. Common sowthistle was also the most preferred by newly hatched larvae among the five host plant types presented in a multiple-choice test. (Gu and

Walter, 1999). This suggests some possible management strategies using sowthistle as a trap crop.

This bollworm "complex" has many natural enemies that can be harnessed through the use of beneficial habitats or purchased from insectaries. Generalist predators such as assassin bugs, bigeyed bugs, damsel bugs, minute pirate bugs, lacewing larvae, collops beetles, and spiders will feed on the eggs of bollworm or on the larvae that are in early stages of development. Parasites like the wasps *Trichogramma spp., Chelonus texanus,* and *Hyposoter exiguae,* and the parasitic fly *Archytas apicifer,* parasitize eggs, larvae and pupae. These groups of natural enemies are usually enough to keep bollworms below economically damaging thresholds. In conventional fields where broad-spectrum insecticides are used, these natural enemies are so depleted that continuous spraying is required to keep bollworms and other pests in check.

Cultural practices that keep bollworm numbers down include managing the cotton field to obtain an early harvest and avoiding over-fertilizing or over-watering. Tillage significantly lowers bollworm populations by disrupting emergence from the overwintering stage. Minimum tillage operations may favor bollworm populations, except in the South, where minimum tillage favors fire ant colonization (Monks and Patterson, no date). Fire ants are effective predators of many cotton pests, including bollworm.

For sprays of *Bacillus thuringiensis* (B.t.) to be effective, they need to be timed so that the bollworm larva is in its early stages of development (1^{st} or 2^{nd} instar). Night spraying will prolong the exposure to the B.t., since ultraviolet rays of the sun break it down. The use of *Beauveria bassiana* as a biopesticide can be effective against bollworm only when temperature and humidity requirements are met. Research from China indicates that the ideal temperature and humidity for high bollworm kill using *Beauveria bassiana* is 77°F with humidity between 70-95%. Mortality drastically decreased when humidity dropped below 70% (Sun et al., 2001). Nuclear polyhedrosis virus, another biopesticide, is a disease-causing virus for use on the bollworm complex and is available commercially in a product call Gemstar LC™ from Certis USA. Azadirachtin, the principal active ingredient in many neem-based products, also shows promise as a growth regulator and anti-feedant against the cotton bollworm (Murugan et al., 1998).

Pink bollworm

Pink bollworm, *Pectinophora gossypiella*—or pinkies, as they are commonly called—is a significant cotton pest in the Southwest. They have also been found in Texas, Oklahoma, Arkansas, and Florida. Pinkies damage cotton by feeding on buds and flowers and on developing seeds and lint in bolls. Under dry conditions, no measurable yield reduction occurs until 25 to 30% of the bolls are infested; at this level the infested bolls have more than one larva. With high humidity, it takes only one or two larvae to destroy an entire boll, because damaged bolls are vulnerable to infection by fungi that cause boll rot (Rude, 1984). Damaged bolls will have a pimple or wart that develops around the hole where pinkies have entered. Unlike cotton bollworm or tobacco budworm, pinkies do not deposit frass or feces at the base of the entrance hole.

Cultural practices to reduce pink bollworm numbers consist of ceasing irrigation sooner than normal, early crop harvest, shredding crop residue after harvest, plowdown of cotton residue to six inches, and winter irrigation if cotton will follow cotton on the same field (not a wise practice in organic production). Okra and kenaf are alternate hosts to pink bollworm and must also be eliminated from an area. These techniques are used in area-wide eradication efforts. Area-wide sterile release programs through the Animal and Plant Health Inspection Service (APHIS) of the USDA is a biological control method also used in eradication efforts.

Pink bollworm eggs are very small, making them susceptible to many natural enemies, including mites, spiders, minute pirate bugs, damsel bugs, bigeyed bugs, and lacewing larvae. A number of parasitic wasps such as *Trichogramma bactrae, Microchelonus blackburni, Bracon platynotae,* and *Apanteles ornone* attack pink bollworm. Studies have shown that the use of the insect-feeding nematodes *Steinernema riobravis* and *S. carpocapsae* on pink bollworm larvae in the fields achieved a larval mortality rate of 53 to 79% (Gouge et al., 1997).

The success of insect-killing fungi like *Beauveria bassiana* depends on the timing of the application to correlate with hatching and early stages of development of the pink bollworm, as well as optimum humidity for the fungi to infect.

Other strategies to reduce pink bollworm populations include the use of mating pheromone disruptors. Several products, such as Biolures®, Checkmate®, Frustrate®, and PB Rope®, are available in the U.S. Pink bollworm mating disruption trials recorded higher yields (1864 lbs/acre) than control fields with no mating disruption (1450 lbs/acre) (Gouge et al., 1997).

Armyworms

Beet armyworm, *Spodoptera exigua,* and fall armyworm, *Spodoptera frugiperda,* can both feed on cotton and on rare occasions cause yield reductions. Beet armyworms can cause yield reductions in cotton if populations are high enough near the end of the season. Armyworms hatch in clusters, with the small worms spreading through the plant over time, feeding on leaves, squares, flowers, and bolls. They skeletonize leaves and bracts, trailing frass and spinning small webs as they go. The egg clusters are covered with white cottony webbing, making them easy to spot. Outbreaks are attributed to favorable weather conditions and the killing off of natural enemies.

Natural enemies are assassin bugs, damsel bugs, bigeyed bugs, lacewing larvae, spiders, the parasitic flies *Archytas apicifer* and *Lespesia archippivora,* and the parasitic wasps *Trichogramma ssp., Hyposoter exiguae, Chelonus insularis,* and *Cotesia marginiventris.*

Nuclear polyhedrosis virus is a disease-producing virus that infects beet armyworm. It is available in the product Spod-X LC (Certis). *Bacillus thruingiensis* on young worms is effective if application is thorough. Laboratory and greenhouse tests showed that caffeine boosted the effectiveness of the B.t. against armyworms up to 900 percent (Morris, 1995). Its use is most promising against pests that are weakly susceptible to B.t. itself. Recipe: dissolve 13 oz. pure caffeine in water; add the solution to 100 gallons of standard B.t. spray; apply as usual. (Morris, 1995). Caffeine can be obtained from most chemical-supply houses and is also available in pill form from most pharmacies. Organic growers interested in this approach should ask their certifying agency about the appropriateness of this treatment in a certified organic system.

Many other crops are hosts to armyworms, as are the weeds mullen, purslane, Russian thistle, crabgrass, johnsongrass, morning glory, lambsquarters, nettleleaf goosefoot, and pigweed. These last three are preferred hosts that can serve as indicators of the populations or be managed as trap crops.

Loopers

The cabbage looper, *Trichoplusia,* feeds on leaf areas between veins causing a net-like appearance but rarely cause significant damage, because natural enemies control them. If the enemies are lacking in number, severe defoliation of cotton plants by loopers may cause problems with boll maturation. Defoliation before bolls mature can reduce yields drastically.

Loopers feed on all the crucifers, crops and weeds, and on melons, celery, cucumbers, beans, lettuces, peas, peppers, potatoes, spinach, squash, sweet potatoes, and tomatoes. Other hosts include some flowers, like stocks and snapdragons, and tobacco. Some weed hosts include lambsquarters, dandelion, and curly dock.

Natural enemies are assassin bugs, bigeyed bugs, damsel bugs, minute pirate bugs, lacewing larvae, spiders, and numerous parasitic wasps, such as *Trichogramma pretiosum, Hyposoter exiguae, Copidosoma truncatellum,* and *Microplitis brassicae.* The parasitic fly *Voria ruralis* also contributes to looper control. *Trichoplusia ni* NPV (nuclear polyhedrosis virus) sometimes is responsible for sudden looper population decline, especially after rainfall. *Bacillus thruingiensis* is effective when the problem is detected early.

Thrips

Thrips damage seedlings by rasping and sucking the surface cells of developing leaves, resulting in twisted and distorted young leaves. They are rarely a problem and are usually kept in check by minute pirate bugs, parasitic wasps, predacious mites, and other thrips. The western flower thrip can be a beneficial insect when it feeds on spider mites on a full-grown plant. The bean thrip, *Caliothrips fasciatus,* feeds on older cotton leaves and sometimes causes defoliation. Insecticidal soap is the least toxic pesticide for thrips but should not be applied on hot sunny days because it may burn the plants. Research has demonstrated that cotton varieties with hairy leaves are less injured by thrips than smooth-leaf varieties (Muegge et al., 2001)

Wayne Parramore of Coolidge, Georgia, strip crops cotton into lupine, providing him with nitrogen, soil erosion control, and a beneficial insect habitat to control thrips (Dirnberger, 1995). When the lupine is 36 inches tall, a strip is tilled 14 inches across the seedbed. A Brown plow in front of the tractor with a rotovator in the back exposes the center strip, warming it up for the planting of cotton. The remaining lupine is host to aphids, thrips, and their natural enemies. It prevents weeds and grasses from growing up and it reduces soil erosion. The remainder of lupine that is tilled in later provides a second shot of nitrogen to the cotton. The Parramores report that strip tilled cotton-lupine required only two insecticide applications. They later determined that they could have done without the second spraying in the lupine field, based on a check-plot comparison. Neighboring conventional fields took five spray applications.

In Parramore's own words:

"By having these crop strips in my field, I have insects evenly distributed – nonbeneficials feeding beneficials. Now when the cotton gets big enough for the legume to die, where are the beneficials gonna be? They're not going to be all around the edges of the field and slowly come across the field; they're all over the field already. They're in the middle where lupine is still growing inches away from cotton plants. We're looking at a savings and increase in production of approximately $184.50 per acre."

Fleahoppers

The cotton fleahopper, *Pseudatomoscelis seriatus,* is a small bug measuring about 1/8 inch, with black specks covering its yellowish-green body. The whitemarked fleahopper, *Spanagonicus albofasciatus,* is the same size and resembles the predatory minute pirate bug, *Orius sp.* and *Anthocoris sp.*. Fleahoppers cause damage by stinging the squares, which then drop from the plant, reducing yields. In 1999 the cotton fleahopper was the most damaging insect in cotton, responsible for nearly a third of the total reduction in yield caused by all insect pests in the U.S. Total U.S. insect losses represented more than two million bales that year. (Williams et al., 2000). Fleahopper infestations usually occur in fields near weedy and uncultivated ground or near weedy borders. Some of these weeds, like false ragweed, *Parthenium hysterophorus,* wolly croton or goatweed, *Croton capitatus,* and horsemint, *Monarda punctata,* release volatile compounds that have been shown to be preferred by fleahoppers over cotton (Beerwinkle and Marshall, 1999). Once the weeds start to mature and dry out, the pests will move to the cotton. This information can help with monitoring and establishing a trap crop system. Natural enemies of fleahoppers include assassin bugs, bigeyed bugs, damsel bugs, lacewing larvae, and spiders. A study done in east Texas showed that spiders were three times better than insects as predators of the cotton fleahopper (Sterling, 1992).

Lygus or tarnished plant bug

These bugs are represented by the species *Lygus hesperus, L. elisus, L. desertinus,* and *L. lineolaris.* The first three species are found in the Southwest, and *L. lineolaris* is found in the rest of the cotton belt. They pierce stems and suck plant juices, causing damage to flower buds (squares), young bolls, and terminal buds. Because almost any plant that produces a seed head can be a lygus host, this pest has a wide range. Cotton is not the preferred host of lygus, but once the surrounding vegetation starts to dry up, they will move into irrigated cotton and feed on succulent plant parts. Alfalfa is a preferred host to lygus and can be grown in strip intercrops with cotton to assist in lygus control. The classic habitat manipulation system where alfalfa is strip harvested or where borders are left uncut demonstrates that lygus can be kept away from cotton during critical square formation. The alfalfa also harbors numerous natural enemies of lygus, keeping their populations in check. These natural enemies include the tiny wasp *Anaphes iole,* which parasitizes lygus eggs, and predators like damsel bugs, bigeyed bugs, assassin bugs, lacewing larvae, and spiders. If lygus populations are reaching economically damaging levels, then a pesticide application is warranted. Check with your organic certifier to determine which pesticides are allowed. Botanical insecticides such as pyrethrum, sabadilla, and rotenone are options but may be prohibitively expensive. Insecticidal soaps can reduce the lygus nymph population. Keep in mind that these treatments will also affect the natural enemies and may cause secondary outbreaks of pests like aphids and mites.

Boll weevil strategies

The boll weevil, *Anthonomus grandis*, is considered by some as the primary deterrent to growing cotton organically. In weevil eradication zones, the boll weevil may be less of a concern. Conventional controls consist of applying pesticides to target the adults when they start feeding and laying eggs. For organic systems, using this approach with organically accepted pesticides would be too costly and only moderately effective.

The use of short-season cotton may be part of an overall strategy to control boll weevils with little or no sprayed insecticides. The objective of short-season cotton is to escape significant damage caused by the second generation of weevils, through early fruiting and harvest. For this to occur, the population of first generation weevils must also be low. Crop residue management and field sanitation is essential. Destruction of cotton stalks soon after harvest has long been recognized as a useful practice for reducing the number of overwintering weevils (Sterling, 1989).

Early harvest, sanitation, and immediate plowdown are strategies that keep the overwintering populations low for the following season. In order for these strategies to be effective, they must be practiced by all cotton growers in an area. Any volunteer cotton plants that are missed can be the source of infestation for the following crop season.

The boll weevil has two effective insect parasites, *Bracon mellitor* and *Catolaccus grandis. Bracon mellitor* occurs naturally in North America and can contribute to boll weevil control if conditions are favorable and suitable habitats are available.

Catolaccus grandis is originally from tropical Mexico but has been effective in controlling boll weevils in augmentative releases done in USDA cooperative studies. The researchers achieved from 70 to 90% boll weevil parasitism (King et al., 1995). Releases began on July 19 at 350 females per acre per week over a nine-week period. The objective was to suppress or eliminate weevil reproduction in six organic cotton fields. Similar work done in Brazil resulted in *Catolaccus grandis* inflicting significant mortality on third instar weevils. The use of augmentative releases of *C. grandis* has a very high potential for supplementing and enhancing available technology for suppressing boll weevil populations (Ramalho et al., 2000). *Catolaccus grandis* is currently not commercially available.

Other alternative methods used by organic cotton growers in Texas against the boll weevil are pyrethrum used with diatomaceous earth, garlic oil and fish emulsion as repellants, and pheromone traps for early detection. For more information on Texas organic cotton growers and the boll weevil eradication zones, check the Web site: http://www.texasorganic.com/BollWeevil.htm

Aphids

Aphid problems in conventional cotton are usually the result of secondary pest flair ups caused by excessive spraying for a primary pest like lygus or bollweevil, because the broad-spectrum insecticides also kill the beneficial insects. Aphids are usually kept below economically damaging levels by predators like the ladybug, syrphid fly larva, lacewing larva, minute pirate bug, and the parasitic wasp *Lysiphlebus testaceipes.* The damage caused by aphids and other homopterans, like whiteflies, comes from their honeydew excretion that contaminates the lint and causes sticky cotton. A study conducted in Georgia's coastal plain indicates that aphids are initially suppressed by the insect-eating fungus *Neozygites fresenii*, and were kept at low levels thereafter by parasitoids and predators, most notably the small lady beetles of the Scymnus spp., preventing further outbreak (Wells, 1999).

The choice of cotton varieties influences the abundance of cotton aphids and their associated biological-control agents. A study comparing cotton varieties found lower aphid densities on cotton varieties exhibiting the smooth-leaf characteristics. Parasitism and predation may have reduced cotton aphid population growth early in the season. Disease-causing fungal infection was the primary cause of an aphid population reduction that occurred during the week after peak aphid abundance, and continued disease activity combined with predation maintained aphids at a low density for the remainder of the season (Weathersbee and Hardee, 1994).

Nitrogen management is an important tool in controlling aphid infestations, though less easily done without commercial fertilizers. Studies have shown that excessive or poorly timed fertilizer-N application will promote tender and succulent plant growth that attracts aphids. In California, experiments showed that cotton aphids reached higher densities in high nitrogen fertilized plants (200 lbs. N/ac.) than in low nitrogen fertilized plants (50 lbs. N/ac.) (Cisneros and Godfrey, 2001). This increase in aphid pressure has also increased insecticide application, from an average of 2-3 to 4-6 or more per season in recent years in many areas (Godfrey et al., 1999).

The concept of induced resistance in plants has generated much interest in alternative pest control circles recently. Plants can be treated with substances that induce resistance to plant pests. One of these substances, jasmonic acid, has been used on cotton to determine the effect it has on cotton aphid, two spotted spider mites, and western flower thrips. Preference was reduced by more than 60% for aphids and spider mites, and by more than 90% for thrips on jasmonic-acid-induced leaves compared with control leaves (Omer et al., 2001). The effective ingredient from jasmonic acid is an essential oil isolated from the extracts of the jasmine plant, *Jasminum grandiflorum.* The release of plant volatiles associated with the application of jasmonic acid also attracts natural enemies. Other plant resistance inducers include salicylic acid (aspirin) and salts like potassium phosphate and potassium silicate. Amino acids such as beta-aminobutryic acid and botanicals such as the extract of giant knotweed, *Reynoutria sachalinensis,* can produce systemic resistance (Quarles, 2002). Milfana® is a commercial product made from giant knotweed extract. Check with your certifier before applying any of these products.

Whitefly

Whiteflies are similar to aphids in that they pierce stems and suck plant sap then excrete honeydew that contaminates the lint. The adult whiteflys resemble tiny white moths, the nymphs are more like scale insects. They are found on the undersides of cotton leaves, and when their numbers are high enough, the honeydew falls to leaf surfaces below where sooty mold forms, turning the leaf black. Whiteflies are usually kept in check by natural enemies, unless broad-spectrum pesticides are applied for a key pest. If most predators and parasites are killed, then the potential for devastating outbreaks exists. Beneficial insects that prey on whiteflies are lacewing larvae, lady beetles, minute pirate bugs, and bigeyed bugs. Parasites include *Ecarsia formosa, Ecarsia meritoria, Encarsia luteola, Encarsia pergandiella*, *Eretmocerus haldemani,* and *Eretmocerus californicus.* Some of these parasites are specific to the greenhouse whitefly, *Trialeurodes vaporariorum,* or the sweetpotato whitefly, *Bemisia tabaci,* or the bandedwing whitefly, *Trialeurodes abutilonea,* or the silverleaf whitefly, *Bemisia argentifolii*. Some of these beneficials parasitize more than one whitefly species. These nymphs are what most predators and parasites attack.

If whitefly populations near threshold levels, use insecticidal soap or "narrow range" oil (check with your certifier to determine which oils are allowed) to reduce primarily the nymph and pupa stage of the whitefly. Botanical insecticides like neem can reduce adult populations and also act as an insect growth regulator affecting the pupal stage. Other botanical insecticides such as pyrethrum can help reduce the adult population. Insect-eating fungi such as *Beauveria bassiana* are slow acting and require adequate humidity. An effective sprayer that has enough power to cover both sides of the leaf surface is needed, and at least 100 gallons of water per acre is necessary to have sufficient coverage.

In conventional cotton, nitrogen fertilizer management is also a factor in whitefly population levels and the amount of honeydew produced. A California study demonstrated that increasing levels of nitrogen fertilizer increased densities of both adult and immature whiteflies during their peak population growth on cotton. Higher nitrogen treatments also resulted in higher densities of honeydew drops produced by the whiteflies (Bi et al., 2000).

Spider mite

Spider mites, *Tetranychus spp.*, are tiny arachnids (related to spiders, ticks, and scorpions) that live in colonies, spinning webs and feeding under cotton leaves. Spider mites have modified mouth parts that pierce the cells of the leaf to consume its contents. On the leaf's upper surface yellow spots appear when the feeding is moderate. Once the plants are infested, the yellow spots turn reddish brown. If the infestation is severe, mites can cause defoliation and affect yields. Spider mite populations are usually suppressed by natural enemies, unless a broad spectrum insecticide application occurs to disturb this balance. Insect predators of spider mites include minute pirate bugs, damsel bugs, bigeyed bugs, some midges, lacewing larvae, dustywings, spider mite destroyers, lady beetles, sixspotted thrips, and western flower thrips. Other mites that prey on spider mites are *Amblyseius ssp., Galendromus spp., Metaseiulus spp.,* and *Phytoseiulus ssp.* When scouting for mites, a hand lens is necessary to distinguish the pest mites from the predatory mites. Spider mites tend to be sedentary, while their predators are very active.

Insecticidal soaps, "narrow range" oils, neem-based products such as Trilogy®, and sulfur are acceptable miticides in organic production (check with certifier regarding specific products). Application instruments must thoroughly cover the leaves' undersides, and products that are diluted must be applied in high volumes (more than 100 gallons of water per acre) to achieve complete coverage.

Cultural controls include keeping dust down along roads that border cotton fields. This is usually done by reducing traffic along those roads or watering down the roads. Reducing water stress on the cotton plants helps prevent mite build up. Pima cotton varieties are less susceptible to mites than highland varieties (Anon. 2001).

Diseases of Cotton

Diseases in plants occur when the pathogen is present, the host is susceptible, and the environment is favorable for the disease to develop. Eliminating any one of these three factors will prevent the disease from occurring. Organisms responsible for cotton diseases include fungi, bacteria, nematodes, and viruses. If these organisms are present, then manipulation of the environment and the host, to make it less susceptible, helps to better manage diseases on cotton in a sustainable manner.

Soil health and management is the key for successful control of plant diseases. A soil with adequate organic matter can house uncountable numbers of organisms such as bacteria, fungi, amoebae, nematodes, protozoa, arthropods, and earthworms that in conjunction deter harmful fungi, bacteria, nematodes and arthropods from attacking plants. These beneficial organisms also help in creating a healthy plant that is able to resist pest attack. For more information, see the ATTRA publication *Sustainable Management of Soil-Borne Plant Diseases*.

The leaf surface can also host beneficial organisms that compete with pathogens for space. A disease spore landing on a leaf surface has to find a suitable niche for it to germinate, penetrate, and infect. The more beneficial organisms on the leaf, the greater the competition for the spore to find a niche. Applying compost teas adds beneficial microorganisms to the leaf, making it more difficult for diseases to become established. For more information on foliar disease controls, see the ATTRA publications *Notes on Compost Teas*, *Use of Baking Soda as a Fungicide*, *Organic Alternatives for Late Blight Control on Potatoes*, and *Powdery Mildew Control on Cucurbits*.

Seedling diseases

These diseases are soil-borne fungi and are associated primarily with *Rhizoctonia solani, Pythium spp.,* and *Thielaviopsis basicola*. Cool wet soils, deep seed placement, soil compaction, and cool temperatures contribute to seedling disease development. Spreading compost and using green manure crops, especially grasses, can reduce the pathogen levels in the soil. Various organisms have been researched as potential biological controls, these include *Burkholderia cepacia, Gliocladium virens, Trichoderma hamatum, Enterobacter cloacae, Erwinia herbicola,* rhizobacteria, and fluorescent pseudomonads as seed treatments. (Zaki et al., 1998; Lewis and Papavizas, 1991; Howell, 1991; Nelson, 1988; Demir et al., 1999; Laha and Verma, 1998).

Of these organisms, *Burkholderia cepacia* is available commercially in a product called Deny®. Another microorganism, *Bacillus subtilis,* sold under the trade name Kodiak®, is recommended as a seed inoculant for controlling damping off fungi. The following organisms have been used as soil treatments with varying levels of success: *Stilbella aciculosa, Laetisaria arvalis, Gliocladium virens,* and *Trichoderma longibrachiatum* (Lewis and Papviazas, 1993; Lewis and Papviazas, 1992; Sreenivasaprasad and Manibhushanrao, 1990).

Soil diseases

The three most important fungal soil diseases that cause economic damage are *Fusarium oxysporum, Phymatotrichum omnivorum,* and *Verticillium dahliae.* Nematodes are soil-dwelling, microscopic, worm-like animals. Only a few species are damaging to cotton. They will be classified in this publication as a soil disease.

Fusarium alone rarely causes economic problems, but when associated with nematodes, it forms a complex in which the nematode damage weakens the plant, making it susceptible to the fungus. Organic matter and its associated microorganisms can serve as an antagonist to this disease. The use of *Bacillus subtilis* products (Kodiak®) as a seed inoculum is recommended. The strategies for nematode control will be discussed further on in this publication.

Texas root rot, caused by *Phymatotrichum omnivorum,* is found in the alkaline soils of Texas and the Southwest. It is difficult to control and occurs on more than 2,300 broadleaf plants (Goldberg, 1999). This fungus is active in high temperatures and in low organic-matter soils, so adding compost or incorporating green manure crops will increase organic matter and microorganism competition. Avoid growing cotton on ground that is known to harbor this disease.

Verticillium wilt caused by *Verticillium dahliae* is widespread, attacking many other agronomic, horticultural, and ornamental crops, as well as some weeds. It is persistent in the soil because of survival structures called microsclerotia. These microsclerotia are produced throughout the infected plant and when the crop is disked, these seed-like structures are also incorporated into the soil. Cultural controls include resistant varieties (Pima cotton is tolerant), rotation with grass crops, management for short season production, and avoiding excessive nitrogen and irrigation. Soil solarization done 6-11 weeks before planting was effective in one study where the pathogen was reduced to negligible levels (Basalotte et al., 1994).

There are many types of nematodes in soils, most are beneficial, and a few are cotton pests. Where nematode infestations are heavy, sampling and laboratory analysis can be used to determine the length of rotations and the non-host crops to use. If the problem is root-knot nematodes, rotation to resistant soybean varieties or sorghum is a possibility. Rotation to wheat, corn, grain sorghum, or resistant soybeans is possible if the nematodes are the reniform species (Lorenz, 1994; O'Brrien-Wray, 1994). Nematodes that attack cotton are the root knot nematode, *Meloidogyne incognita,* reniform nematode, *Rotylenchulus reniformis*, and the Columbia lance nematode, *Hoplolaimus columbus.* In sustainable production systems, nematodes can be managed by crop rotation, resistant varieties, and cultural practices. Eventually a "living soil" will keep harmful nematodes and soilborne fungi under control (Yancy, 1994). Crop rotation is a good strategy, but make sure to identify the type of nematode you have and rotate with a crop that is not an alternate host for that nematode. For example, the reniform nematode also feeds on vetch, tobacco, soybeans, tomatoes, and okra, so these crops are not suitable for rotation with cotton for reniform nematode reduction. Check with your seed supplier to identify varieties resistant to the nematodes present in your field. Cultural practices include cover cropping with plants that are antagonistic to nematodes, such as rapeseed or marigolds, planting cotton on soils that are less sandy, controlling weeds, incorporation of chicken litter and other manures, and solarization. For more information, see the ATTRA publication *Alternative Nematode Control*.

Boll rots

Boll rots are a problem in areas with high humidity and rainfall and where bolls are starting to open or have been damaged by insects. Most pathogens are secondary invaders relying on insect damage for access. *Diplodia spp., Fusarium spp*., and other fungi have been associated with a basal type of rot where bracts are infected first, followed by invasion through nectaries and the base of the boll (Anon., 1981). Other organisms that infect cotton bolls are *Alternaria macrospora, Puccinia cacabata,* and *Xanthomonas,* which are also responsible for foliar diseases. The boll-rot organism of most concern is *Aspergillus flavus*, which produces aflatoxins in the cottonseed. Aflatoxins are carcinogens to some animals and to humans. It contaminates cottonseed oil and cottonseed meal, which then cannot be used for feed. If *Aspergillus* is a problem in your area, consider cultural practices that reduce humidity, such as lower density seeding to allow more air circulation. Avoid tall, vegetative cotton growth—often a result of late planting, excessive nitrogen fertilizer, fertile soils, and/or excessive moisture. Rank growth often renders cotton plants more attractive and susceptible to late season insects, more susceptible to boll rot, and more difficult to defoliate (Bacheler, 1994).

Foliar diseases

Bacterial blight caused by *Xanthomonas campestris* pv *malvacearum* is common in areas with warm, wet weather during the growing season. It causes defoliation and reduces lint quality. Leaf spots are angular, restricted by leaf veins, water-soaked when fresh, and eventually turning brown before defoliation. Boll symptoms are small, round, water-soaked spots that become black. Affected bolls may shed or fail to open and have poor-quality lint. Quick plow down of crop residues after harvest to give ample time for decomposition will assist in the control of the disease. Crop rotation and using resistant varieties are also effective strategies.

Alternaria leaf spot caused by *Alternaria macrospora* starts off as a tiny circular spot that enlarges to half an inch. Concentric rings form as the spot enlarges, with the center sometimes falling out to form a shothole. Spots can also be found on bolls. High humidity increases the incidences of the disease, causing defoliation in severe cases. Controls include using resistant varieties and avoiding prolonged leaf wetness.

Southwestern cotton rust, *Puccinia cacabata*, first appears as small, yellowish spots on leaves, stems, and bolls, usually after a rain. These spots enlarge, developing orange-reddish to brown centers. Later, large orange spots appear on the lower leaves and discharge orange spores. Rust diseases require more than one host in order to complete their life cycle. For *Puccinia cacabata* the alternate host is grama grass, *Bouteloua spp*., and its proximity to the cotton field may determine the severity of infestation. If there is grama grass near your field, removal by burning, plowing, or grazing is recommended. A season of heavy rains and high humidity with grama grass close by has the potential for problems with cotton rust.

Cotton leaf crumple virus is transmitted by the silverleaf whitefly, *Bemisia argentifolii.* Control of the vector and stub cotton, which serves as an overwintering site for the virus, and the use of resistant varieties are strategies for disease reduction. Symptoms include wrinkled leaves that are cupped downward and plants that are small or stunted. This disease causes economic losses if the plants are infected when young.

Defoliation

Defoliation is a significant obstacle to organic production. The organic options available to defoliate cotton include flame defoliation and waiting for frost. Vinegar has not been cleared for use as a defoliant under the NOP rules. Ceasing irrigation can assist in leaf drop and boll maturation in low rainfall areas. Citric acid has been used by at least one Missouri cotton farmer (Steve McKaskle). Citric acid is organically approved if it comes from natural sources. Otherwise, the only alternatives are to wait for a frost or hand harvest.

Research reports from the 1960s show that considerable work was devoted to developing butane-gas flame defoliators. Several models were developed by engineers in various parts of the cotton belt. To our knowledge no such equipment is available on the market today, having been replaced by chemical defoliation methods.

Marketing Organic Cotton

As previously mentioned, marketing cotton as "organic" requires certification of the field production practices. Certification also must continue throughout the manufacturing process, from the ginner, yarn spinner, and cloth maker, to the garment manufacturer. Each step of the process must use only materials (dyes, bleaches, etc.) that meet organic specifications. Manufactured products that are not already on the National Organic Program's approved list must go through a lengthy process to gain approval. If any unapproved product is used in the processing of cotton, the fiber cannot be labeled as organic (Spencer, 2002).

Organic cotton farmers usually sell either to a mill or a manufacturer. It is usually up to the farmer to negotiate the price with his buyer. Buyers of organic cotton are limited. Parkdale Mills (see **References**) is perhaps the largest organic cotton buyer in the U.S. Located in Belmont, North Carolina, Parkdale makes yarn from organic cotton. They buy mostly from the southern states and occasionally from California. They purchase organic cotton when demand from a garment maker warrants. They buy from farmers, co-ops, and merchants.

Sandra Marquardt of the Organic Trade Association's Fiber Council (see **References**) says price premiums range from around $.95 to $1.25 per pound, depending on the quality and staple length. This premium may decline as stiff competition from foreign organic cotton increases. The Organic Fiber Council lists companies that could be approached as potential buyers of organic cotton, especially the mills.

The International Organic Cotton Directory offers an extensive listing of people, companies, and farmers involved in the organic cotton industry. They are dedicated to the sustainable production, processing, and consumption of organic cotton worldwide. They have directories listed by product type, business type, and alphabetically. There are a number of U.S. merchants/brokers and eight U.S. mills listed that could be potential buyers of organic cotton. As well, there are several farmers and farm organizations listed that are involved with organic cotton. See this Web site at: http://www.organiccottondirectory.net

Economics and Profitability

Results from a six-year study in the San Joaquin Valley of California (Swezey, 2002) showed organic cotton production costs running approximately 50% higher than those of conventional cotton. The researchers found no difference between fiber length, strength, or micronaire between conventional and organic cotton. They concluded that organic cotton production was feasible in the northern San Joaquin Valley and that effective marketing of organic cotton must include a price premium to offset higher production costs.

Costs that typically differ from conventional cotton production include fertilizer materials such as manure, compost, or cover crop seed and their associated application and establishment costs; mechanical weed control costs; organically-acceptable insect and disease management materials, such as compost tea and beneficial insects; additional hand weeding labor; and costs associated with being certified organic.

A detailed organic cotton budget is available from The University of California Extension Service. To locate this publication on the Web go to: http://www.sarep.ucdavis.edu/pubs/costs/95/cotton.htm

Summary

Prospective growers should be aware that growing organic cotton is not quite the lucrative proposition it sounds and that there may be more money made, and less risk involved, in growing other crops instead. Cotton has many pests that must be controlled without conventional pesticides under an organic system. Weed control options are limited to those done without synthetic herbicides. Defoliation can be a major challenge, with limited options to accomplish the task. Transitioning from conventional crop production to organic cotton is fraught with risk, not to mention that the transition process takes three years before the fields can be certified as organic. Additionally, in the absence of institutional support and infrastructure, organic growers are unable to move organic cotton around as easily as do conventional growers. Markets for organic cotton are limited, and demand plus foreign supplies influence prices. Finally, most organic cotton is grown in the northern fringe of the Cotton Belt, out of the main range of the boll weevil. With weevil eradication programs, however, organic cotton may have a better chance than before to produce well throughout the Cotton Belt.

References

Altieri, M.A., and M. Leibman.(ed.). 1986. Insect, weed, and plant disease management in multiple cropping systems. In: Francis, C.A. (ed.). Multiple Cropping Systems. Macmillan Publishing Company. New York. 383 p.

Anon. 1996. New biological insecticide out. Arkansas Farmer. June. p. 14.

Anon. 1993. Corn-cotton rotations. Acres USA. April. p. 5.

Anon. 1991. Non-chemical weed control for row crops. Sustainable Farming News. September. p. 1-8.

Anon. 1993a. Arkansas farmer builds flame weed cultivator. Farm Show. March-April. p. 16.

Anon. 2001. UC Pest Management Guidelines, Cotton, Webspinning spider mites. University of California Statewide Integrated Pest Management Program Web site. Accessed September 2002. http://www.ipm.ucdavis.edu/PMG/r114400111.html

Anon. 1981. Insect and Disease Identification Guide for IPM in the Southeast. The University of Georgia, Cooperative Extension Service Bulletin 849.

Bacheler, J. S.. 1994. A Scout's Guide to Basic Cotton Terminology. North Carolina State University Web page. Accessed October 2002. http://ipmwww.ncsu.edu/cotton/glossary/glossary.html

Basallote, M.J., J. Bejarano, M.A. Blanco, R.M. Jimenez-Diaz, and J.M. Melero. 1994. Soil solarization: a strategy for the control of diseases caused by soil borne plant pathogens and reducing of crop rotations. Investigación Agraria, Producción y Protección Vegetales. 1994, Fuera de Serie No. 2. p. 207-220.

Beerwinkle, K.R., and H.F Marshall. 1999. Cotton fleahopper (Heteroptera: Miridae) responses to volatiles from selected host plants. Journal of Cotton Science. Vol. 3, No. 4. p. 153–159.

Bi, J.L., G.R. Ballmer, N.C. Toscano, M.A. Madore, P. Dugger (ed.) and D. Richter. 2000. Effect of nitrogen fertility on cotton-whitefly interactions. 2000 Proceedings Beltwide Cotton Conferences, San Antonio, Texas. Vol. 2. p. 1135-1142.

Cisneros, J.J., and L.D. Godfrey. 2001. Midseason pest status of the cotton aphid (Homoptera: Aphididae) in California cotton: is nitrogen a key factor? Environmental Entomology. Vol. 30, No. 3. p. 501-510.

Daar, Sheila. 1986. Suppressing weeds with allelopathic mulches. IPM Practitioner. April. p. 1–4.

Demir, G., A. Karcilioglu, and E. Onan. 1999. Protection of cotton plants against damping-off disease with rhizobacteria. Journal of Turkish Phytopathology. Vol. 28, No. 3. p.111-118.

Dirnberger, J.M. 1995. The bottomline matters—You can laugh at him on the way to the bank. National Conservation Tillage Digest. October-November. p. 20–23.

Doll, J.D. 1988. Controlling weeds in sustainable agriculture. University of Wisconsin—Extension. Madison, Wisconsin. 3 p.

Drlik, Tanya. 1994. Non-toxic weed control. IPM Practitioner. October. p. 20.

Ellis, Barbara W., and Fern Marshall Bradley. 1992. The Organic Gardener's Handbook Of Natural Insect And Disease Control. Rodale Press, Emmaus, Pennsylvania. 534 p.

Flame Engineering Inc.
P.O. Box 577
Lacrosse, KS, 67548
800-225-2469

Godfrey, LD, K, Keillor, R.B. Hutmacher, J. Cisneros, P. Dugger (ed.), and D. Richter. 1999. Interaction of cotton aphid population dynamics and cotton fertilization regime in California cotton. 1999 Proceedings Beltwide Cotton Conferences, Orlando, Florida. Volume 2. p. 1008-1011.

Goldberg, Natalie P. 1999. Phymatotrichum Root Rot, Guide A-229. College of Agriculture and Home Economics, New Mexico State University Web page. Accessed Sept. 2002. http://www.cahe.nmsu.edu/pubs/_a/a-229.html

Gouge, Dawn H, Kirk A. Smith, Charlie Payne, Linda L. Lee, Jamie R. Van Berkum, Daniel Ortega, and Thomas J. Henneberry. 1997. Control of pink bollworm, *Pectinophora gossypiella*, (Saunders) (Lepidoptera: Gelechiidae) with biocontrol and biorational agents. TEKTRAN. United States Department of Agriculture, Agricultural Research Service. Accessed September 2002. http://www.nalusda.gov/ttic/tektran/data/000008/22/0000082251.html

Grossman, Joel. 1989. Enhancing natural enemies. IPM Practitioner. November–December. p. 10.

Grossman, Joel. 1988. Lygus. IPM Practitioner. April. p. 11–12.

Gu, H., and G. H Walter. 1999. Is the common sowthistle *Sonchus oleraceus* a primary host plant of the cotton bollworm, *Helicoverpa armigera* (Lep., Noctuidae)? Oviposition and larval performance. Journal of Applied Entomology, Vol. 123, No.2. p. 99-105.

Harmony Farm. 1996. Harmony Farm Supply Catalogue: Spring–Summer 1996. Graton, A. 128 p.

Head, Robert B., and Michael R. Williams. 1996. Pests, Thresholds, and the Cotton Plant. Publication 1614. Mississippi State University. Mississippi State, Mississippi. 15 p.

Houtsma, J. 1991. Fighting weeds with fire. The Farmer. June. p. 10-11.

Howell, C.R. 1991. Biological control of Pythium damping-off of cotton with seed-coating preparations of *Gliocladium virens*. Phytopathology. Vol. 81, No.7. p. 738–741.

Hummelbrunner, L.A., and M.B. Isman. 2001 Acute, sublethal, antifeedant, and synergistic effects of monoterpenoid essential oil compounds on the tobacco cutworm, *Spodoptera litura* (Lep.,Noctuidae). Journal of Agricultural and Food Chemistry. American Chemical Society. Vol. 49, No. 2. p. 715–720.

Janprasert, J., C. Satasook, P. Sukumalanand, D.E. Champagne, M.B. Isman, P. Wiriyachitra, and G.H.N. Towers. 1993. Rocaglamide, a natural benzofuran insecticide from *Aglaia odorata*. Phytochemistry. Oxford: Pergamon Press. Vol. 32, No. 1. p. 67–69.

Javaid, I., and J.M. Joshi. 1995. Trap cropping in insect pest management. Journal of Sustainable Agriculture. Vol. 5. p. 1–2, 117–136.

King, E. G., R. J. Coleman, L. Woods, L. Wendel, S. Greenberg, and A. W. Scott. 1995. Suppression of the boll weevil in commercial cotton by augmentative releases of a wasp parasite, *Catolaccus grandis*. Proceedings Beltwide Cotton Conferences 1995. p. 26–30.

Laha, G.S., and J.P. Verma. 1998. Role of fluorescent pseudomonads in the suppression of root rot and damping off of cotton. Indian-Phytopathology. Vol. 51, No. 3. p. 275–278.)

Laster, M.L., and R.E. Furr. 1972. Heliothis population in cotton-sesame intercroppings. Journal of Economic Entomology. Vol. 65. p. 1524–1525.

Layton, Blake. 1996. Cotton Insect Control Guide 1996. Publication 343. Mississippi State University. Mississippi State, Mississippi. 36 p.

Lewis, J.A., and G.C. Papavizas. 1991. Biocontrol of cotton damping-off caused by *Rhizoctonia solani* in the field with formulations of *Trichoderma spp*. and *Gliocladium virens*. Crop Protection. Vol. 10, No. 5. p. 396–402.

Lewis, J.A., and G.C. Papavizas. 1993. *Stilbella aciculosa*: a potential biocontrol fungus against *Rhizoctonia solani*. Biocontrol Science and Technology. Vol. 3, No. 1. p. 3–11.

Lewis, J.A., and G.C. Papavizas. 1992. Potential of *Laetisaria arvalis* for the biocontrol of *Rhizoctonia solani*. Soil Biology and Biochemistry. Vol. 24, No.11. p. 1075-1079.

Lorenz, Gus. 1994. Nematodes: Producers' unseen enemy. Delta Farm Press. April 8. p. 26–27.

Marquardt, Sandra. 2002. 2002 Beltwide presentation: Organic cotton: production and marketing trends in the U.S. and globally – 2001. From The Organic Cotton Site: http://www.sustainablecotton.org/NEWS007/news007.html

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Millhollon, E.P., and D.R. Melville. 1991. The long-term effects of Winter Cover Crops on Cotton Production in Northwest Louisiana. Louisiana Experiment Station Bulletin No. 830. 35 p.

Mitchell, C.C., Jr. 1988. New information from old rotation. Reprinted from Highlights of Agricultural Research. Vol. 35, No. 4. Alabama Experiment Station. 1 p.

Monks, Dale C. and Michael G. Patterson (eds.). No date. Conservation Tillage, Cotton Production Guide, Insect Control. Alabama Cooperative Extension System. Circular ANR-952. Accessed September 2002. http://hubcap.clemson.edu/~blpprt/constill.html#insectcontrol

Murugan, K., D. Jeyabalan, N.S. Kumar, R. Babu, S. Sivaramakrishnan, and S.S. Nathan. 1998. Antifeedant and growth-inhibitory properties of neem limonoids against the cotton bollworm, *Helicoverpa armigera* (Hubner). Insect Science and its Application. Vol.18, No 2. p. 157-162.

Morris, O. 1995. Caffeine jolts worms. New Farmer. January. p. 42

Muegge, Mark A., Brant A. Baugh, James F. Leser, Thomas A. Doederlein, and E. P. Boring III. 2001. Managing cotton insects in the high plains, rolling plains and trans Pecos areas of Texas. Texas Cooperative Extension Bulletin E-6. p. 8. http://TcEBookstore.org/\tmppdfs\552089-E6.pdf

Nelson, E.B.. 1988. Biological control of pythium seed rot and preemergence damping-off of cotton with *Enterobacter cloacae* and *Erwinia herbicola* applied as seed treatments. Plant Disease. Vol. 72, No.2. p. 140-142.

O'Brien-Wray, Kelly. 1994. Nematode nemesis challenges cotton. Soybean Digest. December. p. 6–7.

Omer, A.D., J. Granett, R. Karban, and E.M. Villa. 2001. Chemically-induced resistance against multiple pests in cotton. International Journal of Pest Management. Vol. 47, No. 1. p. 49-54.

Parkdale Mills
Jean Frye
PO Box 856
Selmont, NC 28012
704-825-7993
http://www.parkdalemills.com

Quarles, William. 2002. Aspirin, compost, talking plants and induced systemic resistance. The IPM Practioner. Vol. 24, No. 5/6. p 3-4.

Ramalho, F. S., R. S. Medeiros, W. P. Lemos, P. A. Wanderley, J. M. Dias, and J. C.Zanuncio. 2000. Evaluation of Catolaccus grandis (Burks) (Hym., Pteromalidae) as a biological control agent against cottonboll weevil. Journal of Applied Entomology. Vol. 124, No. 9-10. p. 359.

Robinson, R.R., J.H. Young, and R.D. Morrison. 1972. Strip-cropping effects on abundance of predatory and harmful cotton insects in Oklahoma. Environmental Entomology. Vol. 1. p. 145-149.

Rude, Paul A. (senior writer). 1984. Integrated Pest Management for Cotton in the Western Region of the United States. University of California. Division of Agriculture and Natural Resources Publication 3305. p. 49.

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Scott, H.D., et al. 1990. Effects of Winter Cover Crops on Cotton and Soil Properties. Arkansas Agriculture Experiment Station Bulletin No. 924.

Spencer, Marty T. 2002. NOP Scope document sends personal care, fibers spinning. Natural Foods Merchandizer. July. p. 1.

Sreenivasaprasad, S., and K. Manibhushanrao. 1990. Biocontrol potential of fungal antagonists Gliocladium virens and *Trichoderma longibrachiatum*. Zeitschrift-fur-lanzenkrankheiten-und-Pflanzenschutz. Vol. 97, No 6. p. 570-579.

Stern, V.M. 1969. Interplanting alfalfa in cotton to control lygus bugs and other insect pests. p. 55-69. In: Proceedings of the Tall Timbers Conference on Ecological Animal Control by Habitat Management, February 27-28. Tallahassee, Florida.

Steinkraus, D.C., et al. 1992. Biological control of bollworms and budworms. Arkansas Farm Research. July–August. p. 18–19.

Sterling, W.L., L.T. Wilson, A.P. Gutierrez, D.R. Rummel, J.R. Phillips, N.D. Stone, and J.H. Benedict. 1989. Strategies and tactics for managing insects and mites. In: R.E. Frisbie, K.M. El-Zak, and L.T. Wilson (eds.). Integrated Pest Management Systems and Cotton Production. John Wiley & Sons, Inc. New York, NY. p. 267-325.

Sterling, W.L., A. Dean, and N.M. Abd-El-Salam. 1992. Economic benefits of spider (Araneae) and insect (Hemiptera: Miridae) predators of cotton fleahoppers. Journal of Economic Entomology. Vol. 85, No. 1. p. 52-57.

Sun, LuJuan, Wu Kong Ming, Guo YuYuan. 2001. The pathogenicity of *Beauveria bassiana* to *Helicoverpa armigera* under different temperatures and humidities. Acta Entomologica Sinica.Vol 44, No 4. p. 501-506.

Swezey, Sean L. 2002. Cotton yields, quality, insect abundance, and costs of production of organic cotton in the northern San Joaquin Valley, California. p. 257 In: Robert Thompson, (compiler) Proceedings of the 14th IFOAM Organic World Congress. Canadian Organic Growers, Ottawa, Ontario, Canada.

Thermal Weed Control Systems, Inc.
Rt 1, Box 250
Neillsville, WI, 54456
715-743-4163

Ton, Peter. 2002. The International market for organic cotton and eco-textiles. p. 258 In: Robert Thompson (compiler), Proceedings of the 14th IFOAM Organic World Congress. Canadian Organic Growers, Ottawa, Ontario, Canada.

Vestal, Joe. 1992. Flame cultivation makes comeback. Delta Farm Press. August 7. p. 24.

Wells L. J., R Ruberson, R. M. McPherson, G. A. Herzog, P. Dugger (ed.), and D. Richter. 1999. Biotic suppression of the cotton aphid (Homoptera: Aphididae) in the Georgia coastal plain. Proceedings Beltwide Cotton Conferences, Orlando, Florida. Volume 2. p. 1011-1014.

Weathersbee III, A.A., and D.D. Hardee. 1994. Abundance of cotton aphids (Homoptera: Aphididae) and associated biological control agents on six cotton cultivars. Journal of Economic Entomology. Vol. 87, No 1. p. 258-265.

Williams M.R., P. Dugger (ed.) and D. Richter. 2000. Cotton insect loss estimates—1999. 2000 Proceedings Beltwide Cotton Conferences, San Antonio, Texas. Volume 2. p. 884–913.

Yancy, Cecil, Jr. 1994. Covers challenge cotton chemicals. The New Farm. February. p. 20–23.

Zaki, K., I.J Misaghi, and M.N. Shatla. 1998. Control of cotton seedling damping-off in the field by *Burkholderia* (Pseudomonas) *cepacia*. Plant Disease. Vol. 82, No. 3. p. 291-293.

Web Resources

The Organic Cotton site:
http://www.sustainablecotton.org/

Details on a Texas organic cotton farm:
http://www.sosfromtexas.com/

International Organic Cotton Directory:
http://www.organiccottondirectory.net/

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Edited by Paul Williams and David Zodrow
Formatted by Cynthia Arnold

July 2003

The electronic version of **Organic Cotton Production** is located at:
HTML
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