BASIC Cotton Manual

Practical Lessons Learned from the Sustainable Cotton Project's
Biological Agriculture Systems in Cotton (BASIC) Program

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Sustainable Cotton Project

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San Joaquin Valley, California
2001 to 2004

Abstract: This publication describes management and marketing options for cotton production systems that use bio-intensive, integrated pest management to reduce chemical inputs.

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This manual is dedicated to
Everett "Deke" Dietrick

For his tireless persistence in helping farmers recognize the importance of biological management systems.

A pioneer in biological control,
Deke has been offering
environmentally sound solutions
to growers for over 30 years
through his company,
Rincon- Vitova Insectaries.

Thanks, Deke!

"Deke" Dietrick and fellow entomologist Stefan Long check their sweep net for beneficial and pest insects in the mowed section of an alfalfa strip surrounded by a San Joaquin Valley Westside cotton field.

Sustainable Cotton Project Overview

Cotton is an important fiber crop in California, grown on roughly 1,400 farms — almost 700,000 acres in 2003, according to the California Agricultural Statistics Service. Nearly 7 million pounds of chemicals are applied annually to this acreage. A significant portion of these chemicals are toxic insecticides, herbicides, and chemical fertilizers. There is increasing pressure on California's farmers to become better stewards of the land and better neighbors by reducing applications of agrichemicals. As the population of California's Central Valley continues to expand into agricultural areas, regulatory control of chemical use is likely to increase.

The Sustainable Cotton Project's BASIC program has been actively working with cotton growers in the Firebaugh, Mendota, and Dos Palos areas from 2001 through 2004, encouraging them to enroll a test block of cotton into the program. By enrolling, growers have helped to refine a system that will enable all cotton growers to reduce their dependence on pesticides. The results of those three years are compiled into this manual. It is hoped that cotton growers can apply these better management practices to their cotton acreage, successfully reducing their applications of toxic chemicals.

A private nonprofit, the Sustainable Cotton Project has been funded over the past three years by the California State Water Resources Control Board. This funding has enabled the Sustainable Cotton Project to coordinate with participant growers, pest management consultants, University of California Cooperative Extension, and Agricultural Experiment Station researchers to bring biointensive management practices and proven BASIC techniques to California cotton.

BASIC as a system is built on Integrated Pest Management (IPM) practices developed through 30 years of research and field research supported by the cotton industry and public institutions. The key to BASIC is bringing together all the parties to implement and demonstrate these strategies in a participatory process. This process and commitment is the unique contribution of BASIC.

The BASIC system incorporates biointensive IPM practices. Biointensive IPM builds on existing IPM practices, but takes the system farther by better integrating ecological and economic factors into the cropping system. Benefits include: reduced environmental impacts, decreased costs of inputs, and more sustainable pest management systems.

The Consumers Union defines biointensive IPM as the highest level of IPM. "Biointensive IPM is a systems approach to pest management based on an understanding of pest ecology. It begins with steps to accurately diagnose the nature and source of pest problems, and then relies on a range of preventative tactics and biological controls to keep pest populations within acceptable limits. Reduced-risk pesticides are used if other tactics have not been adequately effective, as a last resort, and with care to minimize risks." (Benbrook. 1996)

The goal of the BASIC program is to develop a working knowledge of chemical reduction techniques that can be successfully and economically applied in California. BASIC offers strategies designed to save the grower money by reducing the need for insecticides, miticides, chemical fertilizers and water. To share this information with local growers, the program offers field days, demonstrations, and on-farm trials as well as highlighting new ways for cotton farmers to save money and control pest outbreaks.

Growers enroll before planting, and team up with other growers to field-test the effectiveness of the BASIC strategy. The main program components are:

- ✓ an April planting date and use of Plant Degree Forecasts*
- ✓ cotton fields located near alfalfa or planting beneficial habitat along field margins
- ✓ intensive scouting to monitor pests and beneficial insects
- ✓ early releases of natural enemies within cotton fields
- ✓ limiting or eliminating pesticide applications in the spring or using softer targeted chemicals
- ✓ soil fertility and nutrient monitoring

These program elements can help cotton growers find a good balance by encouraging soil building, increasing beneficial habitat, and reducing the need for expensive chemical sprays.

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* *Growers have utilized Plant Degree Forecasts for over 15 years to help schedule planting (Munier et al., 2004).*

BASIC growers plant habitat along field edges to provide food and shelter for beneficial insects that prey and feed on pest insects in the cotton plants.

BASIC growers have shown that a significant percentage of the chemicals applied to cotton can be eliminated through better management practices. Improved soil management practices, combined with planting habitat for beneficial insects and monitoring for both pests and beneficial insects, have been proven to reduce pesticide use by up to 73% of the county average, saving the farmer time and money as well as reducing the environmental impacts of these chemicals. However, farmers who are pursuing an environmentally beneficial system, such as use of reduced risk materials that may be more costly, or loss of crop land devoted to beneficial hedgerows, may not see lower production costs.

On the demand side, consumers are becoming more educated about the environmental costs of cotton production. Companies such as Cutter and Buck, Nike, and Timberland are responding to this by seeking cotton that is produced in a more environmentally friendly manner. This represents a marketing opportunity for growers to sell their cotton at a premium price. The combination of market demand and environmentally friendly production practices are a win-win situation for the farmer, consumers, and the environment.

Many thanks to the California State Water Resources Control Board for funding this important work.

Soil Fertility, Soil Quality, and Plant Health

The soil is where plant health begins and ends. Healthy soils have a buffering capacity that allows balanced uptake of nutrients, creating a healthy plant that is less attractive to pests and more resistant to pest damage.

Soil components—minerals, air, water, and organic matter—vary widely in California, depending on geography and climate. The challenge in the semi-arid and constantly tilled farmland of cotton-growing areas is to maintain healthy soils with adequate levels of organic matter. Healthy soils will possess the following characteristics:

- good tilth
- water retention (a function of organic matter)
- a sweet, "earthy" smell
- ability to buffer salts and pH
- habitat for numerous and diverse microorganisms
- resistance to erosion by either wind or water
- ability to produce healthy crop

Organic matter is the soil component primarily responsible for these traits. Various soil organisms break down organic matter, creating humus. Humus in turn provides nutrients to the plants as they are producing crops. Sustainable soil management is the practice of maintaining soil health and productivity by maintaining or increasing the soil's organic matter. Cultural practices such as the application of manures and compost, the use of cover crops, and crop rotations are methods to achieve this. Healthy soils are, in fact, a complex living system that must be nurtured in order to sustain its life and productivity.

One Grower's Experience Using Manure and Minimum Tillage

BASIC grower Gary Martin has been utilizing a minimum tillage system on his cotton for the past few years and has found that it has many advantages. The biggest advantage is that it saves him money. With his system, he is able to utilize a smaller tractor that uses less fuel and causes less soil compaction. He makes fewer passes over the field, increases his organic matter, reduces air quality emissions, and has seen better yields—all at the same time.

Here is how it works: Gary purchases fresh poultry manure which is delivered to the farm in the spring. He lets it sit until the fall. After harvest, he spreads 5 tons/acre on his cotton fields. Gary does not take down his cotton beds, but rather goes through after harvest and first shreds the stalks, then comes through with a knife which cuts and dislodges the roots. This is done with a small knife on the bed disc bar, which cuts the stalk off underground. He then applies the manure and again uses the bed disc which incorporates the trash and manure. He makes up to three more passes to create the kind of beds he likes. This puts the trash and manure in the early root zone and increases the organic matter of his soil.

Gary then leaves his cotton beds up for a period of three to four years, which gives him another great advantage. He is always able to get in the field and plant cotton in the spring, regardless of the weather. The beds may not be in perfect shape, but he doesn't miss a planting date by not being able to get in and build his beds. Each fall he goes in with the same procedure: shredding stalks, cutting the old plant roots, and spreading manure. This system eliminates chiseling or discing the ground flat, eliminates the four passes of a 200 hp tractor, reduces fuel costs and emissions that harm air quality.

Turning windrows of compost

Cotton Plant Nutrition

Throughout its life cycle, the cotton plant requires nutrients in varying quantities to support its growth, and most importantly its reproductive system, which is responsible for boll and fiber production. Each stage in the development of cotton requires certain elements for optimal growth and production. Nitrogen, sulfur, molybdenum, and manganese are associated with vegetative growth. A deficiency in any of these elements will restrict vegetative growth and fruiting. Elements specifically needed for fruiting are phosphorus, potassium, calcium, magnesium, boron, and zinc. A deficiency in these elements will limit fruit or boll production more than vegetative growth (Joham, H.E. 1986). On the other hand, excess nutrients not only waste money, but cause pest and nutrient runoff problems, so application of nutrients should not exceed plant requirements.

Nitrogen (N) is the nutritional element that is required in the greatest amounts by most cultivated crops. It is used in the plant to form proteins, chlorophyll, protoplasm, and enzymes. In cotton, N is needed for overall growth. Adequate amounts are important in order to obtain desired yields. Cotton removes 50 to 55 lbs. of N from the soil per bale of cotton (Mullins et al., 1990; Unruh et al., 1996). So a yield of three bales per acre will require 150 to 165 lbs. of N per acre. To calculate the amount of N needed to produce cotton, growers should test their soil to determine its base N level. Then other sources of

N should be considered, such as those in the water and air. In the San Joaquin Valley, the extensive use of synthetic fertilizers, the concentration of industrial dairies and feedlots, the new urban development, and the rising fossil fuel combustion have increased the supply of reactive N in the environment (Galloway and Cowling, 2002). At least 20 lbs. of N/acre are deposited through rainfall each year (Cowling et. al., 2001). According to Nichols and Green, about 50 lbs. of N are available to the plants from every 1% of organic matter in the top foot of soil. These calculations and others are available on the Cotton Inc. agricultural research Web page, "Estimating Cotton's Nitrogen Needs," www.cottoninc.com/AgResearch/homepage.cpm?PAGE=3728.

Too much N can increase costs by delaying plant maturity, by increasing pests such as boll rot, aphids, and whiteflies, and by making defoliation more difficult. For example, in California, experiments showed that cotton aphids reached higher densities in fields with high levels of synthetic N fertilization (200 lbs. N/ac.) than in fields that received lower rates of N fertilization (50 lbs. N/ac.) (Cisneros and Godfrey, 2001). High aphid populations in cotton fields have resulted in increased insecticide use, from a previous average of two or three applications per season to four to six or more applications in recent years in many areas (Godfrey et al., 1999). In addition, over-fertilization can add nitrates to surface and ground water through N leaching (Harris and Smith, 1980; Hodgson and MacLeod, 1988).

Potassium (K) is a nutrient that growers must evaluate because of cotton's great demand for it during boll formation. Yield and quality of the fiber are determined by potassium. The critical period for potassium uptake is during flowering, about two to three months after planting. Researchers have found that production of a bale of cotton requires about 52 lbs. of K_2O (43 lbs. K) in the soil (Abaya. 1996). Potassium requirements of cotton can be met by preplant soil application of K and/or mid-season sidedress applications of K.

When present in adequate amounts, organic matter supplies most of the nutrients that cotton needs. This is seldom the case in cotton-cotton rotations. If the system is not providing sufficient nutrients to the plants, then supplemental nutrition with fertilizers is required. These can be applied to the root zone or through foliar applications. Once the soil's organic matter is increased and the farmer understands how to maintain it, the need for supplemental chemical fertilization is reduced.

In a fertility study in India on a cotton-sorghum-soybean rotation, it was found that when 50% of N was supplied by organic fertilizers, such as compost or manure, as well as 50% conventional fertilizers, the yields were the same as the crops with 100% conventional fertilizers. Researchers concluded that the soil fertility was improved, providing sustainable yields while maintaining fertility (Ravankar et al., 2000). Other trials in Alabama found that poultry litter can be used effectively as a source of N for cotton. Total N in broiler litter is almost as effective as N from ammonium nitrate fertilizer. High rates of broiler litter resulted in greener plants and slightly later maturity, but did not reduce yields (Mitchell, C., no date).

Good cotton boll formation requires adequate potassium. Here BASIC field scout Uriel Hernandez checks the cotton in a BASIC field.

Crop Rotation

Crop rotation is a traditional agricultural practice involving the sequencing of different crops on farm fields; it is considered fundamental to successful sustainable 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 the cycles of many insect pests, plant diseases, and plant parasitic nematodes. Even basic corn-cotton rotations have been found to be effective in reducing some species of nematodes (Anon., 1993). Rotation crops that help to reduce cotton root knot nematodes in California include alfalfa, winter small grains, resistant cowpea cultivars, California Blackeye CB 5, CB 27, and CB 46, and root-knot resistant cultivars of processing tomatoes (Roberts et al., 2001). 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 N for subsequent crops. In Australia legumes were used in rotation with irrigated cotton. Levels of N fixation and yield achieved on-farm were measured in commercial fava beans (*Vicia faba*) and other winter and summer legume crops sown after cotton over three years to assess the relative inputs of fixed N into this system. Fava beans contributed up to 240 lbs./acre, while winter crops of field peas, lentils, lupine, and green manure pasture species fixed up to 214 lbs./acre (Rochester et al., 1998).

A long-term cotton study at Auburn University in Alabama showed that using winter annual legumes as green manures produced cotton yields equivalent to those grown using fertilizer nitrogen. In addition, the study found that adding a third crop to the rotation (cotton-legume-corn) provided an 11% yield increase to the following cotton crop compared to the two-crop rotation (cotton-legume-cotton). Adding conventional N fertilizer boosted the two-year rotation cotton lint yields in this study another 79 lbs./ acre. In the same Alabama study, a three-year rotation of cotton-vetch, corn-rye (fertilized with 60 lbs. of conventional N/acre), followed by soybeans, produced about the same cotton yields as the two-year cotton-legume-corn rotation (Mitchell, 1988).

Conservation Tillage

Conservation tillage includes a number of strategies and techniques for establishing crops in the residues of the previous crop, which are purposely left on the soil surface. The principal benefits of conservation tillage are:

- reduced wind and water erosion
- multiple cropping
- ability to produce crops on marginal and erodible lands
- improved soil moisture management
- flexible time for field operations
- improved soil structure
- increased soil organic matter
- reduced soil compaction
- reduced CO_2 and nitrogen oxide emissions
- reduced particle emission (dust)
- reduced fuel cost
- improved water quality
- increased equipment savings
- increased profitability

In other parts of the United States and the world, conservation tillage has been widely adopted, principally due to its ability to reduce erosion and lower production costs. California's Central Valley growers have been slow to adopt this technology: only 0.3% of the farmed acreage in the San Joaquin Valley uses conservation tillage practices. Conventional pre-plant tillage operations account for 18 to 24% of total cotton production cost (Mitchell et al., 2002). With production costs increasing and heightened public concern over air, water, and soil quality, this technology offers an opportunity to improve cotton-growing conditions in the San Joaquin Valley.

Growing N and Using Strip Tillage
Saves Money and Reduces Plant Stress

These are comments from Wayne Parramore, who farms 1,200 acres of cotton, lupine, and clover in Georgia, discussing N concentrations in cotton petiole (leaf stem) samples taken from cotton strip-tilled into lupines, compared to conventionally fertilized cotton (Dirnberger, 1995).

Taking petiole samples every week to monitor plant nitrogen, the Parramores discovered an amazing difference between fields fertilized with commercial N and fields where lupine was the N source. "The commercial fertilizer graph (of plant nitrogen) changed each time," Parramore said, "going way up to the housetop and falling right back off! In the lupine field, it didn't do that. That's the first time I've ever seen one [N concentration levels] stay between the graph lines where it is supposed to be." Parramore reported they would start off with 19.5 parts per million N on the petiole samples of the cotton that was strip-tilled into the lupine field. The N would come down slowly, leveling off at 4 or 5 ppm N and remaining there the rest of the season.

Types of Conservation Tillage

No Till or Strip Till **—** In this operation the soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width. Planting is accomplished using disc openers, coulter row cleaners, in-row chisels, or rototillers. Weed control is done primarily with herbicides; cultivation may be used for weed control, if required.

Ridge Till **—** Ridge tillage is characterized by the maintenance of permanent or semi-permanent ridge beds. The ridge beds are established and maintained through the use of specialized cultivators and planters designed to work in heavy crop residues. The typical features of high residue cultivators are large coulters followed by large sweeps mounted on single shanks. The coulters cut through residue in the middle of the inter-row area to assure that the residue will not hang up on the sweep shanks. The sweeps are run shallow, yet deep enough so that the flow of the soil helps carry crop residues over the sweep during cultivation. Furrowing wings are used in conjunction with the sweeps to aid in rebuilding ridges.

Mulch Till — In mulch tillage, a significant portion of the crop residue is left on the soil surface. It is usually done with the moldboard or disc plow in primary tillage. Because the residues are not buried deep, good aerobic decomposition is encouraged.

Killed-Mulch System — Systems are being developed, centered on the concept of growing a dense cover crop, killing it, and planting or transplanting into the residue. The dense residue provided by the killed cover crop not only protects and builds the soil, it also provides substantial weed control. Herbicides or mechanical technology such as mowing, undercutting, rolling, or roll chopping can be used (Kuepper, 2001).

Many cotton growers in California will find flaws or hurdles with some of these conservation tillage systems. The principal challenge is fitting these practices into the current production system as well as the initial expense to develop much of the technology. The University of California's Conservation Tillage Workshops — by Jeff Mitchell, UC Cooperative Extension Vegetable Crops Specialist at the Kearney Ag Center in Parlier — conducting research trials throughout the Central Valley, addressing many of these issues. Some of the drawbacks are:

- non-uniform stands due to irregular soil moisture causing skips in seeding
- increased irrigation caused by restricted water movement in furrows, slowing water runs
- lower air temperatures above surface mulches, which may reduce early season growth and can increase the risk of frost damage
- escaped weeds and difficulty cultivating weeds through high levels of residues
- regrowth of off-season cover crops during the summer crop season
- increased potential for gopher/rodent problems (Mitchell and Miyao, 2002)

The pink bollworm is a major pest of cotton that has been excluded from the San Joaquin Valley by a mandatory host-free period from December 21 through March 10. After harvest and prior to this host-free period, cotton plants are shredded, cut from their roots, and incorporated into the soil in compliance with the plowdown requirements enforced by counties' Agricultural Commissioners. In some conservation tillage equipment, such as a Terratil, a bent leg shank with a rotary harrow is used to form beds in a single pass operation. This procedure is successful in killing the cotton plants and judged in compliance with the plowdown requirements. Growers are required to request a variance from the county Agricultural Commissioners before engaging in these practices.

Plowdown Variances

A listing of all County Agricultural Commissioners, who will know plowdown requirements and what variance is required, can be found at: www.cdpr.ca.gov/docs/county/caclist.htm. Also, Jim Rudig, (559) 445-5472, Supervisor of CDFA's Pink Bollworm program, can provide additional information.

The use of conservation tillage in cotton production involving multiple crops in the year- round systems is considered a best management practice by many USDA agencies. These best management practices can substantially reduce farm contributions to non-point source pollution of water and air. These practices also benefit farm productivity, sustainability and profitability by improving soil characteristics and crop performance. In a study conducted in Riverdale, California, conservation tillage planting and stalk management systems produced yields comparable to those of standard till practices in two back-to-back cotton crops. These reduced till systems decreased the number of tractor operations by 41 to 53%, fuel use by 48 to 62% and overall production costs by 14 to 18% (Mitchell et al. 2003)

Conservation tillage practices are encouraged by Department of Agriculture agencies such as National Resources Conservation Service (NRCS) and Risk Management Agency (RMA). NRCS has conservation programs that partly fund innovations like conservation tillage. More information can be obtained from your local NRCS office, listed in the phone book under U.S. Government.

A newly planted BASIC cotton field showing rows of planted habitat adjacent to a roadway.

Pest Management: Let Bugs Do the Work

Sunflowers (right) shelter beneficial insects along the edge of a BASIC field near Dos Palos.

For every cotton pest, there are several species of parasites and predators that are only too happy to eat the pest or lay their eggs in it and destroy it. However, like all animals, these parasites and predators require habitat and sources of food — nectar and pollen in this case — in order to thrive and do their good work. If these beneficials, which are essentially mini-livestock, are managed correctly, they can save the grower both time and money by reducing pesticide applications. Especially in these times of high fuel prices, reducing pesticide applications can be very cost-effective. Reducing pesticide use can also help avoid problems associated with pesticide-contaminated water (both irrigation and rain water) running off the farm. Farm runoff is now being more closely monitored for pesticides, nitrates, and sediments. And using these beneficial-insect friendly practices may open up some new markets for cotton grown with fewer pesticides.

To obtain maximum plant protection, beneficials should be managed like mini-livestock by providing them with food (nectar and pollen) and shelter. Here lady beetles congregate in native deergrass. (Photo courtesy KC Dufour)

The BASIC program has demonstrated that beneficial insects can be protected, and applications of toxic pesticides can be reduced, by the relatively simple and low-cost practice of planting habitat for beneficial insects. This habitat serves two primary purposes: first, to provide pollen and nectar for populations of beneficial insects before, during, and after the commercial crop is grown. Secondly, the habitat provides shelter, an "island" of unsprayed area from which beneficials can quickly repopulate a cotton field after a pesticide application. Some pests, such as alfalfa and lygus, may prefer the habitat to the cash crop and pest management operations can take advantage of this.

Habitat Options

Most of the habitat discussed here is annual habitat. Perennial habitat can also provide an over-wintering spot for beneficials.

A BASIC enrolled field with planted habitat for beneficial insects in an unused corner. The cotton also benefits from the native perennial habitat along the San Joaquin River, shown in rear.

The bottom line is that almost any habitat planted around your cotton is better than none, if it's managed correctly. Most growers will agree that it is best to grow cotton next to alfalfa in neighboring fields to provide a food source for beneficial insects. When there is no alfalfa, planting two rows of habitat along ditches or furrows (about 1% of the field) on the upwind side of the cotton field can be an effective tool for managing pest populations. Remember, this habitat will require some water. Suggested habitat species are corn (90-, 120-, or 150-day), alfalfa, mustard, sunflower, yarrow, fennel, milo, grains, cilantro, dill, velvet beans, buckwheat, black-eyed peas, and radish.

Habitat planted along road edges will protect the cotton crop from the dust of passing vehicles, which will reduce mite damage.

Planting habitat ahead of the cotton crop will give beneficial insect populations a chance to build up, preventing pest infestations later in the season.

On the Westside of the San Joaquin Valley, a BASIC field is planted with rows of mustard, sunflowers, corn, and sudan grass. These plantings reduce dust blowing into the field from road traffic and they also provide nectar and pollen for beneficial insects.

Habitat Planting Times

Annual habitat can be planted at different times relative to the crop and in different ways.

1. Plant habitat before planting cotton. This may be difficult due to water considerations, but by having the habitat planted ahead of the cotton, the habitat will generally be more noticeable and attractive to aphids and other pests and help keep them from moving to the cotton.

2. Plant with the cotton. This may be the easiest way to add habitat. Unfortunately you do lose the advantage of having the habitat up and growing to attract the natural enemies of pests prior to the crop.

3. Plant after the cotton. Growers can go back along the field margins after planting and add habitat. Another effective practice is to fill in any bare spots in the field with habitat to provide small pockets of beneficial plants that may lure pests from the cotton to the habitat. This can be done by hand.

Perennial habitat might be a choice when a barrier between a cotton field border and a school or housing development is desired. Habitats of this type can provide not only a pesticide drift barrier, but also a dust barrier and a pleasing landscape feature.

There is no right way to plant. Growers have used many methods, for example, putting the seed all together in a planter, or planting the corn, sunflowers and sorghum in the outside row and the smaller seeded plants in the next row, planting by hand, whatever works for you. Growers will need to ensure that habitat plantings are not sprayed with herbicides, which would kill the plants, or with insecticides, which would kill the beneficial insects.

To separate a cotton field from a schoolyard, this BASIC grower planted barrier rows of habitat, reducing the likelihood of pesticide drift.

Whichever planting scenario is chosen, the habitat will need to be irrigated.

Sprinkler irrigation of habitat planted to shelter beneficial insects.
The plants also act as a dust barrier, reducing mite problems in the cotton field.

Strips left unmowed in an alfalfa field.

Alfalfa Habitat Planting: An Idea Whose Time Has Come

Lygus is a key insect pest in California cotton. The insects pierce the stems and suck plant juices, causing damage to flower buds, young bolls, and terminal buds. Lygus can be managed with minimal pesticide use if a grower is willing to plant some alfalfa habitat in or adjacent to cotton, as well as being willing to strip-harvest the alfalfa. This management strategy is based on the fact that cotton is not the preferred host of lygus. In fact, lygus prefer alfalfa to cotton, which is why strip-harvesting alfalfa will keep lygus in their preferred crop. Once the surrounding vegetation starts to dry up (or is mowed, in the case of alfalfa), the insects will move into irrigated cotton and feed on the plants. Through habitat manipulation, such as the use of alfalfa strips, it has been demonstrated that lygus can be kept away from the cotton during critical square formation.

Lygus feeding on native sage. (Photo courtesy Rex Dufour)

It is important to manage lygus before they move into a cotton field and cause damage. Once they have migrated into the cotton, it often requires chemical treatment to control them, which results in the reduction of natural enemies and potential disruption by secondary pests. In a paper written by UC Cooperative Extension Specialist Pete Goodell and J.W. Eckert, they found that “this disruption can lead to multiple pesticide applications, excessive production costs, and destabilization of the cotton ecosystem” (Goodell and Eckert, 1998).

These strips of alfalfa are already flowering as cotton plants emerge in the surrounding field.

The left half of this alfalfa strip was mowed earlier, leaving the right side to flower, keeping Lygus in the alfalfa, and providing continuous habitat for beneficial insects.

The use of alfalfa strips in cotton fields was introduced in the 1960s as an alternative method to broad-spectrum insecticide applications (Stern et al., 1969), and recently revived by UC entomologists in the *Encyclopedia of Pest Management* (Summers et al., 2004). Alfalfa is not only favored by lygus, but can also serve as a refuge for natural enemies. Widespread adoption of the practice has not occurred, probably because of the difficulty in maintaining production practices for the two different crops.

Within a Westside cotton field, the right half of this alfalfa strip has just been mowed. Alternating sections are mowed over the season, keeping Lygus in their preferred crop. The alfalfa also provides constant nectar and pollen for beneficial insects.

How Farmers Interplant Alfalfa and Cotton

BASIC growers Frank Williams and Mark Fickett were intrigued by the idea of interplanting alfalfa and thought the benefits might outweigh the management challenges. They decided to give it a try. The following is a brief outline of the practices they used on their cotton in 2003.

Planting Scheme – Six rows of alfalfa and two rows of fava beans (on the outside of the alfalfa) were planted on December 10, 2002, at a rate of 5 to 6 lbs./acre. The alfalfa was planted between two 80-acre cotton fields. The planting was done using standard equipment.

Irrigation — When the alfalfa was planted, there was no pre-irrigation, as the rain took care of the germination process. However, during the summer season, the alfalfa habitat was irrigated four times. The first irrigation took place while pre-irrigating for cotton planting, on February 19. The second alfalfa irrigation took place with the first irrigation of cotton on June 10, the third on July 10, and the final irrigation on August 4. Sprinkler irrigation was used for the alfalfa habitat trial.

Mowing — A mowing scheme was set up to keep the alfalfa green and lush and prevent migration of lygus into cotton. This was done by using a rotation system. Only a portion of the habitat was mowed at a time, leaving a strip of alfalfa as a hosting zone. Every 30 days a portion of the habitat was mowed. When the alfalfa habitat was mowed, D-Vac samples were taken from the habitat as well as the cotton adjacent to the habitat. The volume and number of beneficial species were sizeable.

Monitoring — Throughout the season, BASIC field staff monitored the alfalfa habitat along with the cotton. Using a D-Vac, they took 17 samples during the season, from May 26th through September 12th.

Pest Pressure — The cotton adjacent to the alfalfa strips had no significant changes in pest pressure from the rest of the field and most importantly, there were no signs of pests moving out of the habitat.

Conclusions — The alfalfa habitat was considered a success since there were no significant changes in pest pressure coming into the cotton from alfalfa. The habitat provided a ready food source and refuge for the lygus, which had no reason to move out of their preferred host. As the season progressed, we saw a continual increase in the diversity of species and large numbers of beneficial insects in the D-Vac samples.

UC IPM entomologist Pete Goodell taking a closer look at a BASIC field day.

BASIC Soil and Insect Monitoring Program

Soil Sampling

BASIC begins each season with a soil sample from the enrolled field. This sample is submitted to a laboratory for analysis and the results are then distributed to the grower. At this point, the grower and BASIC staff discuss what, if any, changes need to be made to the grower's soil program. With an accurate soil evaluation, growers can be more efficient with their fertilizer use, which in turn can increase yields, reduce costs, and potentially decrease environmental pollution from excess nitrogen runoff. Excessive nitrogen can pose problems in cotton. Studies in cotton and many other crops show a correlation between excessive nitrogen and pest outbreaks. Also high nitrogen levels at defoliation can make it difficult to completely desiccate the field.

BASIC field scout Luis Gallegos checking the level of insect activity in the alfalfa strip left after strip cutting.

Weekly Field Monitoring

Once the cotton emerges, BASIC field staff begin their weekly monitoring of the field for both pests and beneficials. Sweep net and D-Vac are two sampling techniques used by BASIC to determine pest and beneficial levels. Sweep net sampling consists of 50 sweeps across a single row of cotton, using a standard net with a diameter of 15 inches. All pests and beneficials and their stage of development are recorded.

The D-Vac operates like a vacuum and it works a lot like the sweep net, except it is better at extracting extremely small insects and insects in their nymphal and larval stages of development. The last sampling technique employed by BASIC is leaf sampling. Mites, aphids, thrips, and certain beneficials are sampled with this technique. 100 leaves are randomly selected throughout the field and checked for those insects. Through the use of the sweep net, D-Vac, and leaf sampling, the BASIC management team determines if biological control is working.

The scouts observe both the field and adjacent habitat (if planted) and record all their observations on a GPS (Global Positioning Satellite) system. This allows the scouts to keep close track of any hot spots or problem areas that might arise. Generally, 50 sweeps are taken and numbers of green lacewings, assassin bugs, big-eyed bugs, lady bugs, and minute pirate bugs are tracked. Along with the beneficials, scouts record the numbers of mites, whitefly, worms, aphids, loopers, and any other pests that threaten the cotton. The weekly report is left behind for the grower to examine and share with his staff and PCA. Every two weeks the data is compiled for all enrolled fields and distributed to growers as *Field Notes*. This publication allows growers to look at the conditions in other areas and to see what kinds of pest pressures their neighbors are facing.

Entomologist Stefan Long and farmers check the contents of the D-Vac vacuum sweeper to see what insects are in the field.

Petiole Analysis

BASIC field staff take two petiole (leaf stem) nitrate samplings from each enrolled field. The first sample is usually taken in early July and the second in mid-August. The first sample is submitted about a week before the first bloom, just when the white tip of the first blooms emerge from the oldest squares. Only primary leaves on the main stem are sampled, avoiding leaves from fruiting or vegetative branches. Staff take 25 to 35 leaf petioles (leaves are discarded) from four different quadrants in the field. Analysis consists of chemically monitoring the nitrate-nitrogen and phosphorus content of cotton petioles.

Growers receive a computer printout that graphically shows the nitrogen and phosphorus content along with any appropriate recommendations. Petiole nitrate-nitrogen and phosphorus levels serve as indicators of the relative amounts of unused nitrogen and phosphorus in the plants. In densely fruiting cotton through about the fifth week of bloom, there is an inverse relationship between the nitrate and phosphorus levels. As nitrates increase, phosphorus tends to decrease. And as phosphorus increases, nitrates tend to decrease. When nitrates are decreasing and phosphorus in increasing, this is an indication of adequate moisture, heavy fruiting, and rapid use of nitrogen. When both nitrates and phosphorus are decreasing, this is an indication of drought stress. When there is a sharp increase in both nitrates and phosphorus, this is a response to above-normal moisture conditions. Fruiting may or may not be good in these conditions, which are conducive to insect damage. When nitrates are increasing and phosphorus is decreasing, it indicates that moisture is adequate, fruiting is poor, and fruit loss is possible.

Petiole analysis will indicate a need for nitrogen about two weeks prior to the appearance of plant symptoms. If petiole nitrate-nitrogen is low during the first three weeks of bloom, a soil application, a foliar application, or both, would be recommended. Urea has been found to be an effective and safe source of nitrogen to apply to a developing cotton plant. Leaf and petiole analyses are most reliable when moisture and other stress-related factors are not influencing growth. BASIC scouts note recent growing conditions along with the sampling.

Plant mapping

Plant mapping is another tool utilized by the BASIC team. Plant mapping provides an indication of the cotton plant’s growth and development. Plant mapping programs have been developed to aid growers in determining if their plants are growing at a normal pace for good yield. Plant mapping allows the farmer to make management decisions on irrigation practices, nitrogen fertilization, and defoliation. Plant mapping also allows the farmer to see what his/her square and boll retention is. For more information on how to do plant mapping, see Appendix 1, Plant Mapping for Vigor Management by Richard Plant, Bob Hutmacher, & Dan Munk from the *California Cotton Review*, Volume 47, April 1998.

Syrphid flies—beneficial insects that resemble honey bees— are often seen hovering in the field.

Augmenting Beneficial Insects

Conserving beneficials by providing habitat is perhaps the easiest and least costly way of reducing pesticide use. However, there may come times when the population of beneficial insects is not large enough to effectively control pest outbreaks. Regular monitoring of both pest and beneficial populations should provide advance notice of these situations, and a supply of the appropriate beneficial insects can be ordered from commercial suppliers to reinforce the natural population of beneficials.

Sources of Beneficial Insects
The most comprehensive listing of sources of beneficial organisms is still the 1997*Suppliers of Beneficial Organisms in North America* from the California's Department of Pesticide Regulation: www.cdpr.ca.gov/docs/ipminov/bscover.htm

Compared to simply spraying a pesticide to control the pest populations, beneficial augmentation conserves native beneficials and pest problems are less likely in the near future. Use of pesticides will eliminate the majority of beneficials, requiring additional applications and cost anywhere from $20 to $35 per acre. New products may be more pest-specific in their action and less disruptive to beneficials, but at least as expensive as "old" products. When selecting a treatment, check the UC Pest Management Guidelines and reference the Selectivity Chart, www.ipm.ucdavis.edu/PMG/r114303211.html, to learn the relative impacts of pesticides on pests and their natural enemies.

Factors to consider when deciding about augmenting beneficials

- Cost of augmentations vs. cost of pesticide applications — Some studies (Collier and Van Steenwyk, 2004) have shown that successful augmentation efforts cost only 1% of total production costs. It should be noted that these costs may be difficult to quantify if, for example, a single pesticide application must be followed by repeated applications due to destruction of beneficial populations. The same is true for beneficial releases. A single release might require follow-up releases.
- Environmental requirements of beneficials — Beneficial organisms are like mini-livestock: unfavorable weather conditions and/or lack of beneficial habitat (pollen and nectar sources) will decrease likelihood of survival and success.
- Quality of beneficials — Quality control is an important issue on several levels: simply having the beneficials alive and in good shape is important. The beneficials must also be the correct ecotype or species of parasite/predator for the pest.
- Timing of release — Knowledge of pest population levels and trends is an important component of successful management, so regular monitoring of pest populations, particularly early in the pest cycle, is important.

Assassin Bugs are beneficial insects that eat the larvae and adults of many pest insects. These generalist predators, here seen on California native buckwheat, are especially fond of the larvae of Lepidoptera — moth and butterfly worms. (Photo courtesy Rex Dufour)

Managing Beneficial Insects

Beneficial	Preys/Parasitizes	Release Comments
Trichogramma is a very small wasp that parasitizes the eggs of 200 species of insects	This wasp is generally released in cotton to control specific caterpillars attacking cotton	Release the wasps into crops adjacent to cotton, such as corn, or on field margins containing annual habitat. The wasp numbers will then increase and migrate into the cotton in high numbers. Make sure that the type of *Trichogramma* being released is the ecotype most effective against the target pest, which in cotton is likely to be beet armyworm and cabbage looper. Probably not effective as a single control strategy, but inundative augmentation may be effective. There is some debate about efficacy of *Trichogramma* releases because egg destruction by predators also destroys *Trichgramma* larvae. (Knutson. 1998). A good reference is the University of California Integrated Pest Management publication *Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control*, M.L. Flint et al.
Minute Pirate Bug (*Orius tristicolor*) Oval-shaped, about 3 mm long (or 1/8"), very flat, and are black colored with white wing patches	Feeds on thrips, spider mites, aphids, and small caterpillars	To encourage their presence year-round, field margin plantings in the carrot family are recommended, such as fennel, dill, Queen Anne's lace, as well as yarrow, sunflower, buckwheat, coyote brush, alfalfa, corn, clover, and vetch. Overwinters as an adult in leaf litter (think perennial habitat) both inside and outside orchards, under tree bark or boards, around homes and other buildings. They are most common where there are spring- and summer-flowering shrubs and weeds, since they feed on pollen and plant juices when prey are not available.
Predatory mites	Spider mites	Predatory mites must be released early in the season in order to achieve control. Spider mites are usually controlled by a predator complex of Omnivorous Western Flower Thrips, *Frankliniella occidentalis,* and generalist predatory bugs Big-Eyed Bugs (*Geocoris spp*.), and Minute Pirate Bugs (*O. tristicolor*). (Colfer et al. 2001) Insecticides often cause outbreaks of mites by destroying their predators. There is generally no significant natural control of mites for about a month following chemical treatment for lygus bugs, aphids, or other insect pests. Managing spider mites requires preserving natural controls as long as possible each season. Mites are also associated with dusty or dirty cotton along frequently traveled dirt roads.

Spray Options for Reduced Risk Pest Management

When beneficial insects don't do the job, even when augmented by releases of commercially raised beneficials, then some action must be taken to avoid economic damage. Use of reduced risk pesticides can often decrease economic injury of the cotton crop while at the same time conserving the beneficials. As biocontrol pioneer Carl Huffaker noted years ago, "When we kill off the natural enemies of a pest we inherit their work"—not to mention additional costs of pesticide applications!

Besides the use of reduced-risk pesticides, there are several techniques the cotton grower can use to minimize the negative impacts of pesticide applications, such as avoiding early season pesticide applications, use of targeted spraying, and use of economic thresholds when deciding about the need for pesticide applications. These techniques are generally most effective if used in combination. For example, early season pesticide applications can be especially problematic, since they tend to wipe out beneficials at a time when their populations are low, but may be expanding in response to increases in pest populations. It seems to be a law of nature that pest populations bounce back more quickly than beneficials populations do, probably because there are more pests surviving in the field as well as migrating into the field from elsewhere.

> **When we kill off the natural enemies of a pest we inherit their work.**
>
> ***—Carl Huffaker, biocontrol pioneer***

Knowing the field history—where "hot spots" of pest infestations occur—combined with monitoring of pest and beneficial populations, and use of economic thresholds, may provide sufficient information for the grower to decide to apply pesticides on only a portion of the field, avoiding destruction of beneficial populations elsewhere in the field. This will ultimately save the grower money, and many of these practices can be cost-shared through the Natural Resource Conservation Service (NRCS) EQIP program if the grower has not previously implemented them. If growers are presently using these practices, then they might qualify to receive ongoing payments to support these practices through NRCS's Conservation Security Program if they live in an NRCS-CSP watershed.

Microbial Pesticides

Reduced-Risk Pesticide	Pests Controlled	Comments on Use and Efficacy
Bacillus thuringiensis (Bt) is a bacterium, and has many commercially available formulations	Very effective against tobacco budworm *(Heliothus virescens)* and moderately effective against cotton bollworm *(Heliothus zea* or *Helicoverpa armigera)*, (Layton. 1996), cabbage looper, cottonleaf perforator, saltmarsh caterpillar, soybean looper, yellowstriped armyworm	Bt 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. Applications are most effective when timed so that the bollworm larva is in its early stages of development (1st or 2nd instar). Spray formulations are most effective against armyworms and those species feeding on exposed leaf surfaces. Night spraying will prolong the exposure to the Bt, since ultraviolet rays of the sun break it down.
Beauveria bassiana is a fungus available in commercial formulations such as Mycotrol®.	Whiteflies (*Bemisia tabaci, Trialeurodes sp., Sphonius phillyreae*), aphids, lygus bugs, cotton fleahopper (*Pseudatomascelis seriatus*), and cotton boll weevil (*Anthonomus grandis*)	This fungus requires adequate humidity to be effective, so is not well suited to California conditions, but can be effective in southeastern US. Mycotrol® is OMRI-listed. Dr. Mike McGuire (USDA/ARS) (see Cotton Contacts) is working on isolates of *B. bassiana* in California to control cotton pests.
Spod-X, a naturally occurring virus in a liquid concentrate. Manufactured by Certis	Beet armyworms	Causes a fatal infection when ingested by beet armyworm larvae. OMRI listed
Gemstar is beneficial virus, isolated from the bollworm. Formulated in a liquid for application on cotton and vegetables. Manufactured by Certis.	Gemstar controls budworm *(Heliothus virescens*), and corn earworm/bollworm *(Heliothus zea* or *Helicoverpa armigera)*	OMRI-listed

Cotton Defoliation and Harvest

Prior to harvesting a cotton crop, synthetic growth regulators and defoliants are applied to fields to stimulate uniform boll maturation and leaf drop. These practices increase the efficiency of mechanical harvesting and ginning. Plant leaves (trash) clog mechanical pickers, slow harvest, and stain cotton lint. Gin costs rise with increased trash levels because a greater amount of seed cotton is required to make a bale of cotton lint. Stained lint reduces the grade of cotton.

Cotton harvest at a BASIC field.

A basic knowledge of crop development and maturity along with an understanding of the physiology of harvest aids is necessary in making decisions concerning the effective application of these materials. Successful preparation of a cotton crop for harvest must consider the complexities of crop leaf senescence, boll maturation, and the many kinds of chemical and mechanical harvest aids. For information on plant mapping, refer to UC's *Cotton Production Manual* (see Resources section).

Deciding when to apply the chemical can be difficult. Above all else, the decision should be based on the maturity of the plants and field. Harvest schedules, prevailing weather conditions, and weather forecasts are also prominent considerations. For all practical purposes, the maturation process stops when the leaves are taken off a cotton plant. Anytime that the decision is made to apply a defoliant or harvest aid chemical, there will probably be some immature bolls on the plant. However, a grower cannot wait until 100% of the bolls are mature. Some will have to be sacrificed.

As a rule of thumb, the last boll to be picked will probably be the first-position boll on the fourth or fifth node down from the top of the plant. The maturity of this boll should be used as the key for timing an application of defoliant. The yield and quality of the bottom crop and middle crop is far more important than those last small bolls on the top of the plant. Field examination is critical for defoliation decisions.

University of California Cooperative Extension Farm Advisor Ron Vargas recommends that growers count the number of fruiting positions with harvestable bolls above the highest first position open or cracked boll. Defoliation can begin without sacrificing yield or quality when Alcala is four to five nodes above the cracked boll and when Pima is three nodes above the cracked boll.

Defoliation decisions need to be made on a field-by-field basis in order to do the best job and make the fewest mistakes that could end up costing the grower money. Use the "sharp knife" technique to assess boll maturity. (Cut an unopened boll in half crosswise. If the seed coats are brown and the fiber "strings" out, the boll is probably mature and can be defoliated.) If defoliants are applied too early, there is a possibility of compromising yield and some aspects of fiber quality.

All of these concepts and terms are reviewed in the "Harvest Aid Management Guidelines" available on the University of California Cotton Web site at: http://cottoninfo.ucdavis.edu. The site also includes an extensive list of conventional growth regulators and defoliants. At the same Web site you can review or print out a copy of Volume 68 (Sept. 2003) of the *California Cotton Review* newsletter, which has detailed comments on the characteristics of specific chemicals and relative performance of a range of materials in UCCE harvest aid trials in recent years. To learn more about the timing of defoliant applications, see *Cotton Defoliation*, from Alabama A&M and Auburn Universities, which is included as an appendix of this publication.

For growers reducing their use of chemicals or growing cotton organically, the choices at defoliation time are few. Some organic growers choose to rely on nutrient and water management to assist in boll maturation, opening, and plant defoliation. Growers supply only enough nitrogen to ensure fruit set and boll development on a yearly basis. Petiole analysis is sometimes used to determine the level of plant nitrogen and to manage growth.

Organic Options for Defoliation

Material or practice	***Comments***
Zinc sulfate, zinc plus citric acid, zinc sulfate plus Chilean nitrate, magnesium chloride	These materials can only be applied if the soil is deficient in these minerals. Magnesium chloride can leave a brown granular residue on the lint.
Effective microbes	This product was applied on the cotton field in the BASIC program in 2003. The product had no impact on the cotton and may have stimulated additional growth.
Citric acid/Clove oil Matran 2™ (commercial preparation of citric acid and clove oil and other proprietary materials)	This product was applied on the cotton field in the BASIC program in 2004. After waiting for two weeks, the product had no impact on the cotton and a chemical defoliant was applied. No data could be found on generic mix.
Thermal defoliation	Still in the testing stages, thermal defoliation was tested in several states including California on both Alcala and Pima varieties. Defoliation was not as great as that obtained with chemical treatment. Desiccation was more pronounced and in some cases, almost instantaneous (USDA - ARS, Shafter, CA). The current prototype is a one-row, tractor-pulled “oven” with an enclosed propane burner.

Opening cotton flower

Marketing BASIC Cotton

Along with its BASIC program, the Sustainable Cotton Project has operated the Cleaner Cotton Campaign (CCC) since 1998. The long-term objectives of CCC were to build market demand for organic cotton, while simultaneously helping growers learn to implement organic and other environmentally sound practices on their farms. The immediate objective was to dramatically reduce human and environmental exposure to toxic farm chemicals. The ultimate objective was to spark the development of a growing and self-sustaining global organic cotton industry centered in the United States, and to make organic and bio-intensive integrated pest management (IPM) mainstream options for cotton growers.

At the time CCC was launched in 1998, organic cotton was almost completely ignored by the apparel industry, Today as a direct result of CCC's work, organic cotton is a serious subject of discussion throughout the apparel industry. Some of the industry's most important players—including Parkdale Mills (the largest yarn spinner in the U.S.), Franzonni (the largest yarnspinner in Europe), Nike, (the largest athletic wear company in the U.S.), and international trendsetter Armani—now routinely use organic cotton in their apparel.

Different stages and qualities of cotton—with seed and bolls—at the Panoche Gin, Firebaugh.

In 2002, 15 companies made significant progress in either launching or expanding organic cotton programs. Timberland, Sweat-X, and IKEA made new commitments to use organic cotton, while Nike, Norm Thompson Outfitters, Hanna Anderson, and others continued—with CCC encouragement and support—to build and expand their organic cotton programs. In total, 25 companies are now using organic cotton, and many others are seriously researching or testing organic cotton blends. According to data collected by the Organic Trade Association, organic cotton use has grown at a rate of about 22% per year since CCC was launched. Without the work of CCC, this kind of progress simply would not have been possible.

A significant factor in the rapid increase in demand for organic cotton has been CCC's success at popularizing organic cotton blending. The blending model, pioneered by Nike, encourages companies to set percentage goals across their entire product lines, rather than taking the riskier, and more limited, step of launching small 100% organic lines. Nike, for example, which began with very low percentage blends in selected lines, now uses 6% organic cotton in all cotton products produced in the U.S.

Surrounded by cotton modules waiting to go through the Panoche Gin, Ed Wandzell explains the ginning process to apparel industry representatives on the 2004 Sustainable Cotton Project Tour.

College Campuses

For several years, the CCC also had a program that worked on college campuses, encouraging student bodies to pass resolutions requesting that organic cotton collegiate wear be on sale in their campus bookstores. The movement has declined due to lack of funding and product availability, but organic clothing is still an important issue for many students. Through these efforts, it is clear that there is a market on college campuses for organic or biologically grown cotton clothing.

Design Schools

Through outreach to fashion design schools, the CCC has succeeded in positioning organic cotton and environmentally sound growing practices as a long-term trend. Four of the most influential design schools in the world—the Royal College of Art and Saint Martins School of Design (both in the UK), and the Academy of Art and the California College of Arts and Crafts (both in San Francisco)—now emphasize information on sustainable design and the impacts of choosing environmentally sound fiber.

One exciting event was the choice by the 2002 graduating class of the Academy of Art College to focus their senior collections on organic cotton and the Sustainable Cotton Project. This focus demonstrates an increasing awareness of ecological issues in the fashion industry and their importance as a part of the future of design. Fashion experts view this as a long-term trend and not a short-term fashion fad. Nike and Timberland are considering using the images and marketing ideas produced by the students as part of their future marketing strategies.

The 2003 SCP Farm Tour was sponsored by American Apparel Tour

Farm Tours

SCP's tours of California cotton country have attracted over 80 company representatives, members of the press, and the academic community over the past six years. Participants from the apparel industry are given a chance to see how cotton is grown, talk directly with cotton farmers, and see a cotton gin in action. The tours remain a popular and influential part of CCC efforts.

Current Trends

Since the start of CCC in 1998, worldwide organic cotton use has grown at 22% annually. However, with each passing year, less and less organic cotton is grown in California or the United States. Organic cotton acreage in California rapidly decreased from its high in 1995 of 24,625 acres to 160 acres in 2004.

CCC marketing staff observed this trend, and in 2002 began to focus on expanding their outreach to include a market for BASIC (environmentally sound) cotton as well as organic cotton. Through this approach, SCP still maintains its original goal of reducing chemical use in rural California.

In 2003, CCC retooled its marketing materials and actively began to promote BASIC cotton as a value-added agricultural product. SCP has targeted companies that use organic blends as companies that might consider adding BASIC cotton to their blends. This is an effective strategy for finding markets for BASIC cotton. Our question to these companies has been "What about the other 95%?" This process continues to push for the use of organic cotton as well as supporting the efforts of BASIC growers who are producing cleaner cotton.

In many ways, BASIC proposes going beyond organic, since BASIC cotton is grown on many more acres in California than are devoted to organic cotton. While BASIC guidelines do not entirely eliminate pesticide use, the total reductions are impressive. BASIC growers might find it difficult to follow organic production practices, but they are happy to achieve a compromise, particularly if it saves them money.

There is some textile industry resistance to the use of BASIC cotton due to the complexity of integrating it through the supply chain along with the organic cotton. Some companies feel that the message is unclear for marketing programs.

However, SCP is encouraged about the prospects for marketing BASIC cotton. In 2004, Cutter and Buck sponsored the SCP farm tour. They are now seriously considering using BASIC as the other 95% in their organic blend. Other companies and a spinning mill have also shown an interest in using BASIC cotton. Work on this market is ongoing.

On the organic side, Martin Kagi and Paul Schnepf, of Buhler Swiss cotton spinning mill, met in December 2004 with BASIC growers and SCP marketing representative Lynda Grose to discuss forward contracts for growing organic Pima cotton. Buhler feels that organic Pima from California is the best cotton for their mill and they look forward to working directly with growers to produce that cotton.

Working together, BASIC and CCC are helping to make a difference for California and its cotton growers.

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Web Sites

Sustainable Cotton Project
Information on the BASIC program and better management practices used to reduce pesticide use.
www.sustainablecotton.org

National Center for Appropriate Technology (NCAT)
NCAT manages ATTRA, the National Sustainable Agriculture Information Service, which provides information free of charge to commercial farmers and those who work with them around the country.
www.attra.ncat.org

University of California Integrated Pest Management Program
Do a search for cotton and find a multitude of resources, from cotton planting forecasts, to pest management guidelines for cotton, pest identification, and much more.
www.ipm.ucdavis.edu

Cotton Incorporated
The marketing board of the cotton industry, Cotton Inc. works for all cotton growers to increase the demand for and profitability of cotton through research and promotion. Their Web site includes technical, research, and consumer information.
www.cottoninc.com

Community Alliance with Family Farmers
Offers resources to farmers on sustainability and technical resources
www.caff.org

UC Davis Cost Studies on Cotton
Do a search for cotton and find cost comparisons on different varieties and practices.
www.coststudies.ucdavis.edu

USDA – Agricultural Marketing Service
Market News Reports - Cotton Reports: up-to-date information on cotton markets.
www.ams.usda.gov/cotton/mncs

Cotton Facts from the California Cotton Ginners and Growers Association
www.ccgga.org/cotton_information/calif_cotton.html

Auburn University and Alabama Cooperative Extension article on using broiler litter as a source of N in cotton.
http://hubcap.clemson.edu/~blpprt/pdf/ChickManure.pdf

American Society of Agronomy has articles on cotton, including:
Agronomy Journal on response of irrigated Alcala and Pima cotton to nitrogen
http://agron.scijournals.org/cgi/content/abstract/95/1/133

Virginia Cooperative Extensions has articles on cotton and specifically on Potassium Fertilization of Cotton
www.ext.vt.edu/pubs/rowcrop/418-025/418-025.html

Cotton page from Texas A&M Lubbock
Texas A & M University System Agricultural Research and Extension Center has extensive resources on cotton, including general production, weeds, fertility, insects, nematodes, and disease
http://lubbock.tamu.edu/cotton/

UC Conservation Tillage Work Group
Extensive resources on conservation tillage in many agricultural systems, including a cotton farming page on conservation tillage
http://groups.ucanr.org/ucct/index.cfm

Cotton Farming Magazine
www.cottonfarming.com/home/2003_OctCF-TT.html

Western Region Sustainable Agriculture and Education
Information on conservation tillage in cotton using only post-emergence herbicides
http://wsare.usu.edu/projects/2003/SW01-056A.pdf

Louisiana State Ag Center Research and Extension
Information on conservation tillage, crop rotation, & best management practices
www.lsuagcenter.com/Communications/LouisianaAgriculture/agmag/46_2_articles/conservation.asp

Agroecology News from Clemson University in South Carolina
Information on conservation tillage in South Carolina
http://agroecology.clemson.edu/spring01.pdf

University of California Cooperative Extension cotton production information
California Cotton Publications
http://cottoninfo.ucdavis.edu/pubs.htm

The University of Georgia College of Agricultural and Environmental Sciences
Workshop information, newsletters, cotton production guide, Georgia Ag statistics, and much more.
www.griffin.peachnet.edu/caes/cotton/

Texas Cotton links
This very useful site is a complete page of resources on cotton production. It has links to industry, government, and university sites as well as information on pathology, taxonomy and other related topics.
http://algodon.tamu.edu/htdocs-cotton/othercot.html

Cotton Insects from Texas
A very compete pictorial of insects found on cotton.
http://lubbock.tamu.edu/ipm/AgWeb/cotton/cottonpestimages/index.htm

UC Pest Management Guidelines and Selectivity Chart
www.ipm.ucdavis.edu/PMG/r114303211.html

Suppliers of Beneficial Organisms in North America (1997)
www.cdpr.ca.gov/docs/ipminov/bscover.htm

Appendix 1

Plant Mapping for Vigor Management

By Richard Plant, Bob Hutmacher, & Dan Munk

California Cotton Review, Volume 47, April 1998

There are four quantities that provide the most information in the plant mapping process. These are the plant height, the number of main-stem nodes, the number of vegetative nodes below the first fruiting branch, and the percent retention of first position squares in the bottom five fruiting branches (FB)(first position is the position closest to the main stem). To record the data you should select twenty plants in four groups of five. Pick the four groups from different parts of the field and try to pick plants that represent the whole population.

If your field is very heterogeneous you will have to map separate parts and decide which part to manage for. Record the height, number of main-stem nodes, number of vegetative nodes, and number of retained squared in the bottom five nodes for each plant. In recording the number of vegetative and total main-stem nodes, the node with cotyledons is counted as node zero, with node 1 next up the stem form the cotyledons. Your calculations will be made easier if you have a spreadsheet or if you use software supplied by the University of California, but you can get by without either of these.
In summary, these four parameters combine to provide an indication of the crop's balance between carbohydrate supply and demand. The objective is to maintain this balance and maximize the boll load. One possible problem is a low boll load with a high vegetative growth, indicated by high HNR, low retention, and/or high number of vegetative nodes. The opposite situation is a high boll load and inadequate supply, indicated by a low HNR, high retention, and/or low number of vegetative nodes.

For more information, refer to page 237 in the Cotton Production Manual, UC DANR Publication 3352. Do not confuse NAWF with nodes above cracked boll (NACB). You can use NACB to schedule your defoliation. For information on how to do this, see p. 352 of the Cotton Production Manual.

Following the program above is a good way to get started in plant map data collection by trying it out. There are many advantages to collecting in-season plant map data on a regular basis since it gives you the opportunity to spot trends in crop behavior. If you wish to do more detailed or extensive plant mapping, you should get copies of the software made available by the University of California for this purpose. Some of this software requires Microsoft Excel and some runs independently. Software is available for both the palmtop and the desktop computer, and for in-season and end-of-season plant mapping. You can obtain this software from your county Farm Advisor, or, if you are connected to the Internet, you can download some of it from the World Wide Web site http://agronomy.ucdavis.edu/plant.

Appendix 2
Cotton Defoliation

Alabama Cooperative Extension System
ALABAMA A&M AND AUBURN UNIVERSITIES
Publication ANR-715

Defoliation notes

Cotton producers make harvest-aid application decisions based mainly on these four factors:
- The maturity of the crop
- The condition of the crop
- The prevailing weather conditions
- The desired harvest schedule

Once producers decide that defoliation is needed, they must determine the following:
- When the materials should be applied
- Which material(s) will be applied
- How much material(s) to apply

Crop condition and air temperatures will determine which defoliation materials and rates are appropriate. These factors vary a great deal during the season, and the choice of materials and application rates varies as well. The appropriate time for defoliation depends mainly on crop maturity and the desired harvest schedule.

Timing for Defoliant Applications

Cotton defoliation is a sensitive process. For a successful harvest, defoliation must be carefully timed and carried out. Poor defoliation can lower fiber quality, while defoliating too early lowers yield and micronaire. Defoliating too late increases the likelihood of boll rot and lint damage or loss due to weathering. Late defoliating also increases the possibility that defoliant activity will be inhibited by lower temperatures. Many people use the rule that it is safe to defoliate cotton when about 60 percent of the bolls are open. Although this strategy may work well in most situations, defoliation errors may occur where the crop is set more quickly or more slowly than normal.

Figure 1 shows a fruiting "gap'' that may occur in a crop set over a long period. The gap is caused by fruit loss due to stress or insect pressure at peak bloom. This type of crop may have a high proportion of immature bolls at 60 percent open. Defoliation at this time would cut short the development of the top bolls and lower yield and micronaire.

On the other hand, Figure 2 shows a crop that is set in a short period, such as 3 weeks. This crop could safely be defoliated at 40 to 50 percent open boll.

The safest way to determine when to defoliate is to choose the bolls you intend to harvest and to make sure that those bolls are mature. Bolls need 40 to 60 days from setting (flower pollination) to mature, depending on the temperature. In cool weather, bolls will need extra time. A boll that is set in July or early August will mature in about 40 to 45 days, while a boll set in late August or early September may require about 50 to 60 days.

Figure 1. At 60 percent open boll, this crop would not be fully mature and safe to defoliate.
Figure 2. Even at 45 percent open boll, this crop would be mature enough for safe defoliation.

As you walk each field, examine the bolls you intend to harvest to determine if they are mature. The younger bolls will be those toward the top and outer portions of the plant.
Bolls are mature enough for defoliation when:
- They are hard (when squeezed) and difficult to slice in cross sections with a sharp knife. The fibers should string out when the boll is cut. If the fibers do not string out, the boll is not mature.
- The seed coat is a light brown color and the kernel completely fills the seed cavity with no jelly in the center. The seed coat is a pearly white in young bolls and turns from white to black as the boll

matures. When the seed coat becomes light brown, the boll is mature enough to tolerate harvest- aid chemicals.

Another method of evaluating crop maturity is termed "nodes above cracked boll" (NACB). This involves searching the plant for the uppermost cracked boll (already cracked when found) on the first fruiting position. Bolls located 4 to 5 nodes above this point are generally considered mature, and defoliation at that time should not decrease yield or lint quality. Growers should find the uppermost first position boll they expect to harvest and make sure there is not more than 4 to 5 nodes below it to a cracked or open boll. Otherwise, cotton yield and quality may be lowered by defoliation.

A significant increase in the percentage of harvested cotton that is stored in modules has made good defoliation even more important than for cotton that is stored in wagons.

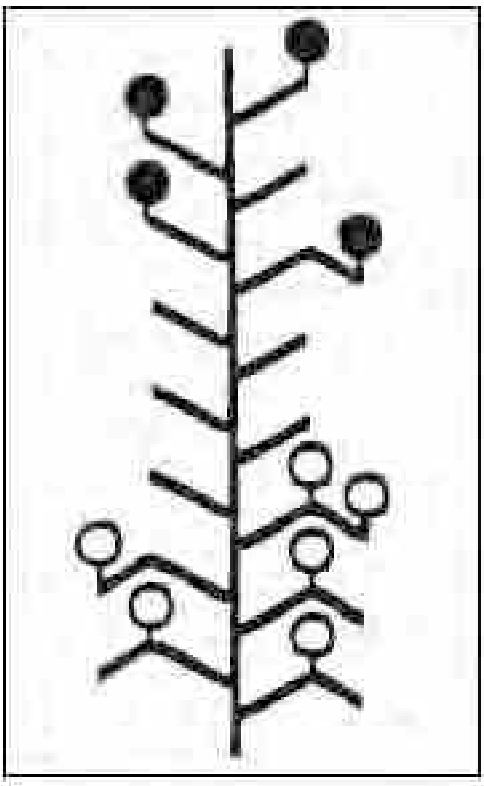

Figure 1. At 60 percent open boll, this crop would not be fully mature and safe to defoliate.

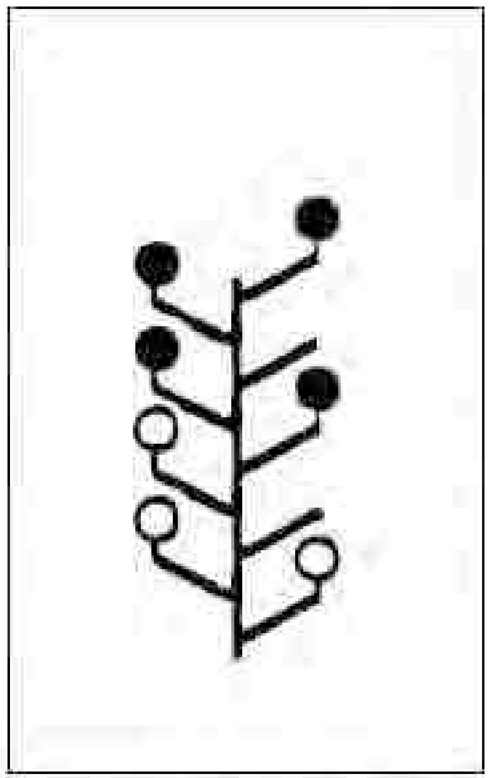

Figure 2. Even at 45 percent open boll, this crop would be mature enough for safe defoliation.