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Insecticide and Miticide Resistance Management

in San Joaquin Valley Cotton for 2001

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INTRODUCTION AND PURPOSE

Effective management of pest arthropods' development of resistance to pesticides is important for the future profitability of cotton. New registrations for pest control products are difficult to obtain and costly to develop. Pesticide applications that do not provide adequate control waste money, unnecessarily increase the overall pesticide load on the environment, and expose other insects to these products.

This publication presents an organized approach to maintaining pesticide susceptibility in five key insect and mite pests of cotton: spider mite, lygus bug, cotton aphid, beet armyworm, and silverleaf whitefly. While the importance of managing resistance in a single species is widely understood, up until now little attention has been paid to the management of resistance across several species. The publication is arranged by individual pest, but the pest manager is urged to consider what implications a control measure intended for a single pest may have on others that might be present at or below levels that are economically significant to the crop. For example, pyrethroids applied for lygus control will also affect silverleaf whitefly and spider mites in the same field. When implementing your resistance management program for silverleaf whitefly, it is important that you note any earlier pesticide applications intended for other pests.

The guidelines presented here are to be used in conjunction with IPM for Cotton in the Western United States (ANR Publication 3305), which gives more information on sampling, pest identification, and the roles of natural enemies. For additional management information, please refer to Cotton Pest Management Guidelines, available in UC IPM Pest Management Guidelines (ANR Publication 3339) or online at http://www.ipm.ucdavis.edu.

IMPORTANT: Read and follow label directions when using any pesticide. Check with your local Agricultural Commissioner concerning the status of any Section 18 requests.

FREQUENTLY ASKED QUESTIONS ON PESTICIDE RESISTANCE

What is pesticide resistance?

Pesticide resistance is the ability of an insect or mite to survive a pesticide treatment applied at a rate that other individuals in the pest population cannot survive. This is an inherited characteristic, so the survivors pass the genetic resistance on to the next generation. The more often we spray, the more quickly we remove susceptible individuals from the pest population and select for a population that is made up mostly of resistant individuals (Figure 1).

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Key steps to slow the development of resistance

- Monitor pest populations and use economic thresholds as a basis for timing and application decisions.
- Maintain good plant health.
- Limit selection pressure all season long. Remember that when you spray for one pest you may affect another.
- Limit your use of each pest control chemistry.
- Rotate chemistries and/or modes of action from application to application.
- Use appropriate application rates.
- Use all available tactics to manage the target insect or mite, including chemical, cultural, and biological means.

Why should we be concerned about pesticide resistance?

Pesticide resistance costs growers money. In addition, when insects develop resistance, the grower needs to apply higher rates and more frequent applications of the pesticide to kill the pests, and eventually needs a new pesticide when the old one becomes essentially ineffective. Pesticides are extremely expensive to develop and register, so those replacement pesticides do not come along very quickly. We have to be careful stewards of the pesticides that are currently registered to make them last as long as possible.

How do arthropods resist the killing action of pesticides?

When we spray, we kill a large portion of the pest population, but at the same time we select for survivor insects with genes for resistance. Genetics for resistance can be manifested in a variety of ways. The most common resistance mechanism provides the insect with specialized enzymes that break the pesticide down into less-toxic chemicals.

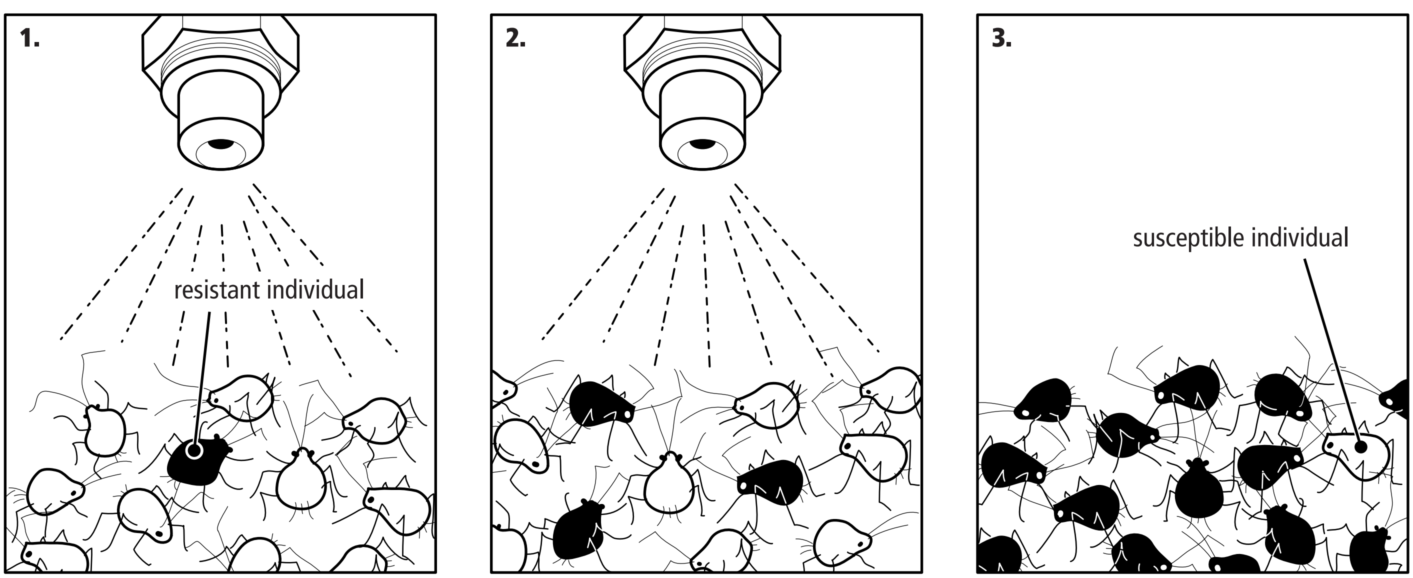
Are resistant arthropods stronger than susceptible ones?

When pesticides are sprayed, the resistant arthropods are more likely to survive. There is often a cost to the insect for the specialized enzymes that resist the pesticide, however, so in the absence of the pesticide spray susceptible individuals may reproduce faster or survive better. There may be a biological trade-off that means that a resistant arthropod may not be stronger in all situations.

What is cross-resistance?

If an arthropod develops resistance to one pesticide, it has a gene that may allow it to be resistant to another closely related pesticide, or in some cases to one that is not so closely related, even if the population has not yet been exposed to to that second pesticide. This is cross-resistance. For example, insects that become resistant to one organophosphate tend to be resistant to all organophosphates. Also, insects that develop resistance to organophosphates usually have partial cross-resistance to

Figure 1. Pesticide resistance can build up in the pest population when a change in the genetic characteristic of the pest population is inherited from one generation to the next. Increased or frequent use of pesticides often hastens resistance.



1. Some individuals have genetic traits that allow them to survive a pesticide application.
2. A proportion of the survivors' offspring inherit the resistance traits. At the next spraying, these individuals will survive.
3. If pesticides are applied frequently, the pest population will soon consist of resistant individuals.

carbamates. Insects that became resistant to DDT many years ago often have some resistance to pyrethroids. It is important to understand the concept of cross-resistance. If you spray pesticides from groups that share cross-resistance, you are essentially spraying the same pesticide over and over, and you will select more quickly for resistance.

What is multiple resistance?

An arthropod that has more than one mechanism of resistance is said to have *multiple resistance*. For example, the resistant insect's cuticle (skin) may be thicker than normal, reducing the pesticide's ability to penetrate into the insect, and the same resistant insect may also have specialized enzymes inside its body to break the pesticide down once it gets through the cuticle.

What are the mechanisms of resistance?

There are three basic mechanisms of pesticide resistance in arthropods. Metabolic resistance is the most common mechanism of resistance. The insect uses various enzymes to detoxify (destroy) the pesticide before the poison can kill the insect. Many insects use esterase or mixed-function oxidase enzymes to break down pesticides. These enzymes are already in the insect, and resistant insects produce more of the enzymes or alter them slightly to prevent pesticides from binding to the target site. Target site resistance is another mechanism of resistance that occurs when the insect changes the structure of an enzyme or the function of part of its nervous system to reduce the effectiveness of a pesticide that acts on that site. Behavioral resistance, the third mechanism of pesticide resistance, consists of changes in the habits or actions of the insect to avoid exposure to a pesticide. For example, mosquitoes that hover and do not land on the pesticide-treated surface will not be killed.

How do low and high pesticide application rates influence the development of resistance?

The effect of low and high application rates depends on the insect or mite being studied. Generally speaking, you should use the lowest effective rate of a pesticide and avoid repeat applications of the same chemical class. If a low rate kills an economical number of pests and allows natural enemies to survive and they help kill the rest of the pests, it is a good rate. If it is too low to kill enough pests and the grower ends up making additional applications, resistance will be selected for more quickly. High application rates tend to select for resistance because they remove more of the susceptible individuals from the population so interbreeding cannot dilute the resistant strain.

How do tank mixes influence the development of resistance?

In general, tank mixes are likely to speed up the development of resistance because they select for pest individuals with multiple mechanisms of resistance. Tank mixes should be used only in situations where multiple pests are present or where the pesticides of choice kill only certain stages of the pest. For example, Savey mainly kills the eggs of spider mites, so it can be tank mixed with another miticide that kills adults. Another exception to the general rule is for control of silverleaf whitefly, which is improved with tank mixes of insecticides.

What is a pesticide resistance management program and when should it be initiated?

Pesticide resistance management is a strategy of using as few applications of any one pesticide class as possible in order to delay the development of resistance in insects. The strategy includes spraying only when economic thresholds are reached, using the most selective pesticides first so that natural enemies will survive and help control the pest population, and rotating between different pesticide classes. A resistance management program needs to be initiated before the resistance problem arises; once the insects have the genes for resistance, you can't get rid of them.

What is a bioassay?

A bioassay is a test of a living insect or mite's ability to survive a pesticide application. For example, with spider mites and aphids, a petri dish is treated with a pesticide at a concentration that is known to kill susceptible individuals. If more than a few individuals survive, we know that the sampled population has some resistance to the pesticide.

Why should we monitor resistance?

Resistance management anticipates the development of resistance and acts to slow its rate of development. If we use resistance monitoring and detect a resistance problem, we can avoid using that pesticide. We can reduce wasted pesticide applications by knowing ahead of time whether they will be ineffective. In addition, resistance is rarely an area-wide problem, so if we can detect it and stop using the problem pesticide the resistant pests can interbreed with nearby susceptible pests and the level of resistance may decrease.

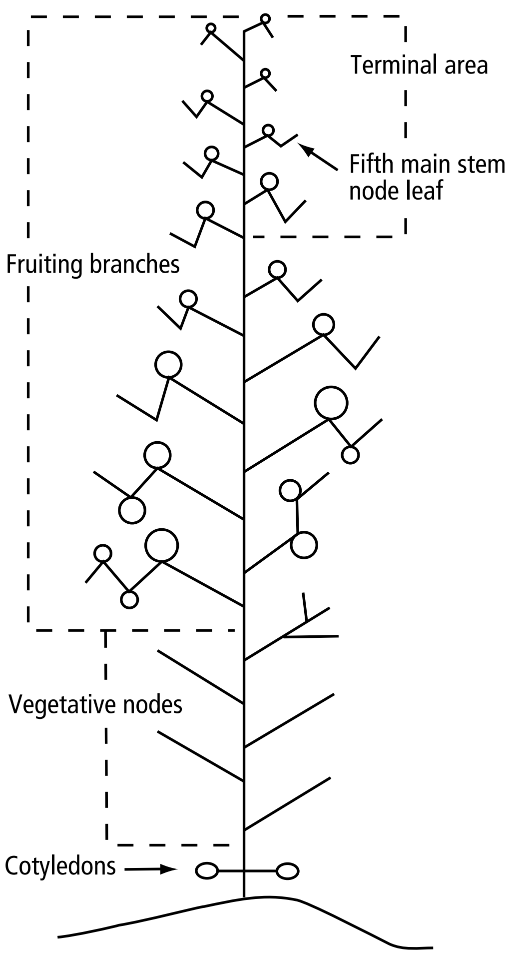


Figure 2. Schematic drawing of a cotton plant, showing the position of the fifth main stem node leaf (for spider mite, aphid, and silverleaf whitefly monitoring) and the terminal area (for beet armyworm egg cluster detection).

SPIDER MITES

Spider mites are key arthropod pests of San Joaquin Valley cotton fields. First reported as pests after the introduction of synthetic insecticides, they have become an annual problem accounting for estimated crop losses as high as 4 percent, not counting the cost of control. Spider mites cause damage by feeding on the cotton leaf surface, thereby reducing the plant's photosynthetic activity and yield. Three spider mite species are found in cotton: strawberry spider mite (*Tetranychus turkestani*), two-spotted spider mite (*T. urticae*), and Pacific spider mite (*T. pacificus*). One, two, or all three species may be found in a single cotton field. In most years, strawberry mite is more likely to cause defoliation and is the first to appear. The other two species gradually build in numbers as the season progresses. The combination of species present in a cotton field is influenced by the neighboring crops: strawberry mite prefers field crops, Pacific mite prefers trees and vines, and two-spotted spider mite has no preference.

A binomial sampling plan is used for spider mites, which involves inspecting leaves for the presence of immature and adult spider mites. The treatment threshold is 30 percent of the fifth main stem node leaves (Figure 2) infested with mites.

In general, spider mites are early to mid-season pests. Spider mite populations begin in cotton because overwintering adult mites emerge from the soil or are wind-borne from neighboring crops or weeds. These populations usually develop gradually, allowing growers ample time to monitor populations and make pest control decisions. In fields with low populations of natural enemies the spider mite population can increase more quickly. Late-season problems are often associated with the use of disruptive, broad-spectrum pesticides that eliminate the spider mites' natural enemies and allow damaging populations to build up.

Spider mite problems can also result from heavy infestations blown in from neighboring crops such as corn, alfalfa, sugar beets, or beans that are drying out.

Miticide resistance

Currently registered selective miticides include sulfur, Kelthane, Comite, Zephyr, Savoy, and Ovasyn. The broad-spectrum systemic insecticides Temik and Thimet can also effectively control mites. In laboratory bioassays from the 1980s to the this writing in 2001, strawberry mite has never been shown to be resistant to any of the currently registered miticides (Grafton-Cardwell, Granett, and Dennehy 1987). Laboratory bioassays have demonstrated that Kelthane and/or Comite resistance has been detected in 25 percent of two-spotted spider mite and 40 percent of pacific mite populations. During 1998, resistance to Zephyr was detected in cotton for the first time in three populations of two-spotted spider mite in Kern County. While Kelthane, Comite, and Zephyr resistances can be a problem in the San Joaquin Valley, these resistances are not dominant in inheritance. With sufficient mixing of susceptible and resistant spider mites, resistance frequently declines during winter. Careful rotation of miticides will help keep resistance low. Sometimes, growers think their mites have developed resistance because the pesticides are not providing control, but in such cases the spider mite densities may stay high because mites are blowing in from neighboring crops. In addition, some broad-spectrum insecticides used for the other pests (most pyrethroids) actually make mites reproduce faster. None of the miticides are very effective when spider mite densities are very high, even if there is no resistance, so avoid flaring mite populations with broad-spectrum pesticides.

Resistance management strategy

To manage miticide resistance in spider mites, we need to limit the total number of sprays of each pesticide. The best way to do this is to practice the basic principles of IPM:

- Monitor pests.
- Maximize the use of biological and cultural controls.
- Spray only when pests reach action thresholds.
- Use the most selective insecticides first so natural enemy populations can build and help out.
- Follow good application guidelines.
- Rotate among different pesticide chemical classes to reduce the likelihood of selection for any resistance in one class.
- Save the broad-spectrum insecticides for the end of the season.

In general it is important to rotate miticide classes to reduce resistance. Each of the miticides has its own special characteristics, however, that make it more or less useful at particular times of the year and under particular circumstances (Table 1).

Temik or Thimet applied at planting will remain effective for about six weeks, so both are only effective if mites arrive early. Use of these pesticides should be based on a history of early mite pressure and potential benefit that may be seen by controlling other early season pests (e.g., aphids and nematodes [Temik only]). If spider mites consistently infest young plants before complete coverage can be achieved with a foliar application, at-planting insecticides are suggested. If mite populations move in six or more weeks after planting a foliar miticide would be better.

If infestations occur when plants are small and/or v-shaped seed lines are prominent, complete coverage is hard to achieve. Under these early season circumstances, Zephyr is recommended on the basis of its good translaminar activity (movement through the leaf tissue).

Plants with more than 4 true leaves will allow adequate coverage for Kelthane, Ovasyn, and Savey. Ovasyn and Savey are ovicides and larvacides and are best used when populations are just starting to build and consist of adults laying eggs. Ovasyn is recommended for use in the mid and late season based on its activity against other pests commonly present at these times (e.g., aphids). Sulfer dust is useful against strawberry mites especially when temperatures exceed 95°F (35°C). Ground application is essential for achieving complete underleaf coverage and so ensuring maximum efficacy of these products.

Following the theory of resistance management, Temik sidedress should not follow at-planting Temik use, because we are trying to avoid repeat applications. However, this should be weighed against the added benefit of controlling other pests (e.g., aphids, lygus).

Comite is phytotoxic to cotton cotyledons and so must be applied later in the season. Sulfur kills only strawberry mite. Zephyr is effective against mites any time during the season but works best early to mid-season before the leaf ages and “hardens off.” In addition, Zephyr is a good fit in areas where Comite and Kelthane resistance is a problem.

Because of these unique characteristics, rotation is not as simple as randomly choosing a miticide from the list. The grower must make an informed decision that takes into account the mite species, the stages present (egg, immature, adult), the crop size, the time of year, the resistance levels of mites present, miticide characteristics, economics, and historical mite levels.

We recommend sampling for spider mites using the presence-absence method. When the field reaches a 30 percent spider mite-infestation of fifth main stem node leaves, the action threshold has been reached. In most situations, strawberry mite is the first species present and it is susceptible to all the early season miticides (sulfur, Savey, Ovasyn, Kelthane, and Zephyr). If possible, it is important to save the Ovasyn and Zephyr for later in the season when fewer effective miticides are available. Following the first miticide application, mite populations are likely to consist of either two-spotted or pacific mite. At this point, it is important to determine their level of resistance to Kelthane, Comite, and Zephyr by means of a bioassay (Grafton-Cardwell, Granett, and Dennehy 1987). It is also important to rotate pesticides as much as possible to avoid further resistance problems. In all situations, early season use of pyrethroids for aphids, lygus bugs, or whitefly can aggravate spider mite populations and so should be avoided. The miticides, for the most part, are specific to mites and so should not cause disruptions of insect pests.

If there is a repeat of the situation seen in Kern County in 1996, when the season began with Kelthane- and Comite-resistant two-spotted spider mites, applications of Savey and Ovasyn are needed to reduce grower dependence on Zephyr. Again, Savey is most appropriately used early in the season. It is highly specific for pest mites and will not disrupt natural enemies.

Table 1. Summary of miticide guidelines for 2001 (updated March 2001)

Early season (from planting to early squaring)	**Midseason (from early squaring to layby)**	**Late season (post layby)**
Kelthane*	Comite*	Comite†*
Zephyr*	Zephyr†*	Ovasyn
Sulfur‡	Ovasyn	
Temik/Thimet (at planting)	Temik (sidedress)	
Savey		

NOTE: These guidelines are based on best experience for consistent control results during the past few years. Local conditions may vary and may affect control. Check with qualified experts for control conditions in your area.

* Two-spotted and pacific mite may have resistance.

† If not used previously.

‡ Effective only on strawberry mite.

These guidelines should provide effective and economical control for spider mites while reducing the possible buildup of resistance to both old and new chemistries. These are only guidelines, however, and are subject to change based on further research and experience.

IPM for spider mites

(For further details, see to Cotton Pest Management Guidelines, available in UC IPM Pest Management Guidelines (ANR Publication 3339) or online at http://www.ipm.ucdavis.edu.

The timing of each miticide application is dependent upon crop stage, chemical selectivity, and pest resistance management practices.

Scouting and decision-making:

- Routinely check all parts of all fields for spider mites using presence-absence scouting methods. When populations reach the threshold, treat them.
- Identify the mite species, since mite species vary in their resistance to specific miticides. Check with an expert if there is any question about what mite species you are dealing with.
- Be especially alert for rapid increases in populations of spider mites when nearby host crops are in decline, including corn, sugar beets, alfalfa, or safflower.
- Time miticide treatments well to prevent outbreaks and reduce the chance for yield reduction. Always use action thresholds for a miticide application.

Influence of management for other insect pests. Other pests besides spider mites exist in cotton fields. Some insecticides used for pests such as lygus and aphids actually cause mites to reproduce faster and/or kill the mites' natural enemies. Whenever possible, use a pesticide that selectively kills the pest mites and not the natural enemies. Also, whenever possible, refrain from using pyrethroids until mid to late July.

Preserve natural enemies. Natural enemies play a key role in slowing the development of spider mite populations. Western flower thrips, for instance, are key egg predators early in the cotton crop's development, and later become prey for big-eyed bugs and minute pirate bugs. Six-spotted thrips and western predatory mites are key predators when they are present.

Resistance management:

- Rotate between miticides. Do not use the same product in back-to-back applications.
- Try to limit your use of any one miticide to once per season.
- Have the spider mites tested for susceptibility to miticides to ensure that the pesticides will be effective.
- If possible, have the species identified to ensure that you can make the best miticide selection.
- Practice good application technique: this is essential if you are to maximize control, including thorough leaf coverage, nozzle selection, nozzle placement, and proper adjuvants.

See Table 1 for summary of guidelines.

LYGUS BUG

Lygus hesperus (lygus bug or western tarnished plant bug) is a pest of numerous crops in the San Joaquin Valley. Lygus attacks dry beans, seed alfalfa, fruit trees, strawberries, lettuce, and cotton. It is also found in many other crops, including alfalfa hay, safflower, sugar beets, and understory plants in vineyards and orchards. This key cotton insect can make or break the profitability of a production season depending on the timing and severity of its migrations. There are no selective insecticides for control of lygus, so as lygus bugs go so goes all of insect pest management. Lygus can threaten every crop stage from earliest squaring through cutout and final boll set. The severity of lygus infestation in a field depends on many factors, including spring temperatures, rainfall patterns, surrounding crops, and the proximity to large areas of host plants, such as uncultivated foothills or weedy lands.

Lygus bugs feed in the upper portion of the plant, probing small squares and feeding on anther sacs. Migrations can occur quickly, but depending on environmental conditions they can either move off or establish residency through reproduction. Using a standard insect net, you have to check fields twice weekly to ensure an accurate assessment of lygus populations. Lygus treatment decisions are based on insect densities, expected square retention, and other plant-based measurements as described in *IPM for Cotton in the Western Region of the United States* (UC ANR Publication 3305). Square retention, number of fruiting branches, and boll retention are important components in making sound lygus management decisions.

Insecticide control factors

Any application of broad-spectrum insecticides can cause a reduction in natural enemies, destabilizing the natural biological control system. As a lygus infestation requires more chemical intervention, other pests such as spider mites, aphids, and worms can become more troublesome. A single broad-spectrum application during July usually will not cause secondary outbreaks, but repeated applications beginning in June can cause late-season mites to increase beyond the management capacity of their natural enemy.

There is a range in the impact an insecticide can have on natural enemies. For example, Provado is useful for managing low to moderate populations in situations where no residual control is required. While it does affect some natural enemies, it does so much less than other materials. Temik side-dressed at first square can contribute to lygus management and still help maintain the natural enemies complex.

Organophosphate insecticides are less effective than pyrethroids in terms of providing residual protection against lygus. Heavy pressure from sustained migrations requires the knockdown and residual control of pyrethroids. In most situations involving low populations, single migration episodes, or limited reproduction, however, chloronicotinyl, organophosphate, or carbamate insecticides can provide adequate control without sacrificing the natural enemies living in the cotton field.

Studies in Texas (Kidd, Rummel, and Thorvilson 1996) and California (Godfrey, Cisneros, and Keillor 2000) have implicated pyrethroids in causing increased cotton aphid populations. The evidence indicates that it is not just the reduction in natural enemies that causes the population to increase, but a direct effect of the chemical on the aphids or on the plant that causes a change in aphid reproduction. In the San Joaquin and Sacramento Valleys, many research and farming experiences indicate that the use of pyrethroids aggravates aphid problems.

Resistance in lygus

Historically, lygus is known to have developed resistance to a number of insecticide classes. Resistance in lygus bugs has been monitored in seed alfalfa for several years (Grafton-Cardwell 1997) and resistance to Metasystox-R and Capture has been documented. The pest's organophosphate resistance appears to be unstable, however, so it can be managed with rotation and limited use of any one class or product. This view is supported by research on Arizona cotton (Russell and Dennehy. 1997) where researchers noted an increase in susceptibility in lygus for several insecticides when their use against silverleaf whitefly was reduced in 1996. Bioassays of lygus from alfalfa found varying levels of resistance to Capture, Metasystox-R, Monitor, and Lannate. Pyrethroid resistance in lygus appears to be increasing despite its diminishing use in cotton. This may be due to increased pyrethroid use in many crops in the San Joaquin Valley.

Resistance management guidelines

For purposes of discussion, lygus infestations can be grouped into three general situations, which are summarized in Table 2.

Situation I. The first situation usually occurs during early fruiting. Lygus densities are low and square retention is only slightly (5 percent) off. In this case, the field should be re-inspected in 3 days before making a control decision.

Situation II. In the second situation lygus density in the field is low, but there is some migration pressure from the surrounding area. Square retention is slightly off normal for two inspections. Very little or no lygus reproduction is noted. Control measures that provide adequate but not complete control and little residual effect on natural enemies are useful to restore square retention without widespread disruption. Insecticides to consider include Provado; organophosphates including Monitor, Dimethoate, and Supracide; and carbamates such as Vydate C-LV and Temik side-dressed.

Situation III. The third situation can be described as high densities of lygus, the potential for repeated and sustained migrations, or the evidence of widespread reproduction. Square retention is far below the expected level, reduced greatly from previous field visits. Insecticides that provide quick knockdown, high levels of population mortality, and residual protection are required. Insecticides to consider include pyrethroids and Temik side-dressed and coupled, if required, with an organophosphate “over the top” to provide time for Temik to take effect.

Whenever broad-spectrum insecticides are applied repeatedly, there is a potential for secondary pest outbreaks as natural enemies such as thrips, big-eyed bugs, minute pirate bugs, and parasitic wasps are killed. You must pay attention to spider mites, armyworms, and aphids. Spider mite protection is advisable if small populations are present in the field at the time of application of a broad-spectrum insecticide.

Table 2. Summary of insecticide guidelines for 2001 for lygus bugs* (updated March 2001)

Chemical class	Single migration event, scattered nymphs†	Sustained or intense migration, nymphs widespread
Organophosphate	Monitor, Supracide, Dimethoate	
Carbamate	Temik sidedress Vydate C-LV	Temik sidedress‡ (plus a foliar insecticide if quick knockdown is required)
Chloronicotinyl	Provado	
Pyrethroids		Capture, Baythroid, Ammo, Mustang, Asana, Danitol, Scout X-tra

NOTE: These guidelines are based on best experience for consistent control results during the past few years. Local conditions may vary and may affect control. Check with qualified experts for control conditions in your area.

* For general consideration. Specific situations will influence decisions, including location, time of year, square retention, and other insect pests present. See publication text for details. Refer to IPM for Cotton in the Western Region of the United States (ANR Publication 3305) for additional information.

† Nymphs not found in every set of 50 sweeps.

‡ If not used previously.

Cultural management

Managing lygus in cotton:

- Plant cotton as soon as temperature allows. Square retention is in many cases reduced in crops planted after April 15.

- Avoid high plant populations. Studies indicate that square retention is significantly reduced when plant densities exceed 45,000 plants per acre.
- Avoid excessive irrigation. Use the pressure bomb method to schedule irrigations based on plant demand. Apply the first irrigation at 15 bars pressure and subsequent irrigations at 18 bars. In fields with low fruit retention, you may be able to help retain squares if you allow stress to increase to 20 bars before irrigation.
- Use mepiquat chloride in fields with low square retention and rank vegetative growth.

Managing lygus in surrounding crops:

To prevent large-scale movement of lygus bugs from alfalfa, alfalfa can be managed to conserve habitat. For example:

- Alternate the timing of harvest for blocks of alfalfa. That way you not remove all of the alfalfa in an area at one time and the alfalfa-dwelling lygus bugs can find an alternate host in the surrounding uncut alfalfa (Goodell, Wright, and Carter 2000).
- Provide habitat by retaining uncut strips throughout the field. For example, at the first alfalfa harvest leave the strip on every other irrigation berm uncut, and then alternate subsequent cuttings by harvesting just these strips and leaving previously harvested strips (Summers 1976).

Watch neighboring crops for lygus migrations:

- Safflower can produce large populations of lygus bugs. Area-wide management that is triggered based on 666 degree-days above 54°F (dd>54) after planting or April 1 can be useful to limit migrations into cotton.
- Lygus in orchard cover crops will move when the cover crop is mowed. Schedule mowing for times when cotton is less susceptible to lygus or mow frequently during late spring to reduce the available habitat.
- Processing tomatoes, sugar beets, and their associated weeds can develop lygus populations that will migrate to cotton as their fields of origin are dried down.

Fostering biological control. Predation by natural enemies is an important element in reducing the developing lygus population. Key predators include minute pirate bugs, big-eyed bugs, assassin bugs, and spiders. First and second instars of lygus are most vulnerable and cause the least damage to cotton. Preserve natural enemies for use against mites, worms, and aphids. Whenever possible, avoid using pyrethroids until late in the season. See Table 2 for summary of insecticide resistance guidelines.

COTTON APHID

The cotton aphid (*Aphis gossypii*) has become a significant pest of San Joaquin Valley cotton over the last several years. During the 1980s and early 1990s, high levels of cotton aphids were seen, primarily on seedling cotton (April and May) but also late in the season (September and October). Beginning in 1992, high numbers of cotton aphids have been developing in July and persisting into August on cotton during the squaring and boll-filling period. The severity of these populations has varied by location and area, but infestations were particularly severe and widespread in 1995 and 1997. Since 1998, cotton aphid outbreaks were localized and less significant.

The cotton aphid is an extremely adaptable insect and, under favorable conditions, reproduces and builds to high population densities extremely quickly. under favorable field conditions, mid-season aphid numbers have been observed to double about every 6 to 8 days. However, populations have also been known to crash quickly when high populations of beneficial insects are present early and late in the growing season.

The cotton aphid exists in several forms or morphs. These all belong to the same insect species, even though the color varies from pale yellow to almost black. The dark green to black individuals are generally found during periods of comparatively cooler weather and on cotton plants with higher levels of nitrogen. This morph has also been observed to produce more offspring and may be an important factor in aphid outbreaks. Conversely, the light morph cotton aphids (pale yellow in color) persist during periods of hot weather and do not reproduce as much. They are thought to be the "survival stage" that bridges periods of unfavorable environmental conditions. These trends generally occur in the field, but not in every case. When conditions become unfavorable for cotton aphids (i.e., very high population densities, poor food quality), winged aphids form and the aphids migrate to other areas. The wings are most evident on the adult aphids, but can also be seen as small buds on nymphs.

Several agronomic factors are related to high cotton aphid densities and may influence aphids' reproduction and their susceptibility to insecticides (Godfrey and Fuson 2001). Late-planted cotton, hairy-leaf varieties, high levels of nitrogen, and excessively irrigated cotton fields generally have higher aphid densities. Leaf hairiness does not vary greatly among SJV-Acala varieties, but DP6100 is generally the least hairy variety. Several of the California upland varieties have smooth leaf characteristics, but their susceptibility to cotton aphid in California has not been fully evaluated. Research in other states and in the San Joaquin Valley has shown that cotton aphid populations are stimulated by pyrethroid applications. These chemicals appear to have a direct effect of increasing cotton aphid reproduction in addition to an indirect effect of disrupting predators and parasites. Studies in Texas looked at the effects of Karate, whereas observations from California involved Capture and Baythroid. Aphid population flare-ups following pyrethroid applications should be monitored.

Natural enemies are an important factor in aphid management. Lady beetles, lacewings, big-eyed bugs, and damsel bugs are important predators of aphids. Parasites such as *Lysiphlebus testaceipes* mummify and kill cotton aphids. Populations of these natural enemies should be preserved to assist in management of cotton aphids. Small grain fields appear to be important sources of parasites and predators that eventually move to cotton.

The available insecticides differ in their effects on natural enemies. Soil-applied treatments and seed treatments have minimal effects on beneficials. Provado affects some natural enemies, but generally is not too detrimental to the overall system. Many natural enemies have built up some tolerance to organophosphates. Foliar-applied carbamates have a severe impact on beneficials, and pyrethroids are the most detrimental (see Table 7).

Action thresholds and sampling

Thresholds for cotton aphid control vary with the cotton plant's growth stage. Aphids feed by removing plant juices from the plant leaves. These juices contain the same energy reserves that the plant needs to develop squares and to fill and mature bolls. The source:sink relationship (production vs. use of energy) varies throughout the development of the cotton plant, and cotton aphid infestations compete with the plants for those energy reserves.

Seedling cotton. Research has shown that seedling cotton can generally withstand and fully compensate for a cotton aphid infestation when the plants reach the third true leaf stage before infestation, and the aphid infestation lasts about 10 to 14 days before natural enemies remove the aphids. In such a case, the plants are able to compensate enough to produce a "normal" yield. Plant growth is stunted for a few weeks, but this is quickly made up and by season-end the plant height, maturity, and yield appear to be unaffected. In some areas such as the eastern Tulare County citrus belt, cotton aphids occur earlier and infestations persist longer then in the rest of the San Joaquin Valley. In these cases, when the plants are infested at emergence and the infestations persist for several weeks, cotton plants are not able to compensate for the aphid feeding. In this situation, insecticidal control is warranted.

Squaring and boll-filling period. During squaring and boll-filling, aphid feeding competes directly with the squares or bolls for resources. Therefore, cotton aphids during this stage can substantially reduce yield and may need to be controlled. Threshold levels are not clearly defined because the damage depends not only on the aphid population, but also on the duration of the infestation. Researchers in Texas and New Mexico have recommended 50 aphids per leaf as an action threshold. Research results from California at this level have been somewhat variable. Some studies have demonstrated yield losses only after populations reached 100 aphids per leaf, but other studies have demonstrated significant yield losses when aphids have increased to levels between 50 and 75.

Based on these varied reports, delaying any insecticidal control for aphids until infestations exceed 50 aphids per leaf is probably a good guideline. This allows you time to schedule and apply insecticides before the threshold is reached and time for the insecticide to bring the infestation under control (usually 1 to 3 days) before it causes an economic yield loss. Aphid population trends, whether increasing or decreasing, should also be considered.

Sampling should be done on the fifth main stem node leaf. All aphids on the leaf, adults and nymphs, should be counted. In the field, aphid densities are often underestimated; it is important that you train your field scouts to ensure consistent counting. Dark morph aphids are thought to stress the plant more than the light morph aphids. The dark morphs are larger and probably remove more plant sap than the light morph aphids.

Boll crack to harvest. Cotton aphid feeding during the boll crack to harvest period has the potential to contaminate open bolls and lint. As the aphids feed, they excrete a sticky honeydew. This material, once deposited on the cotton lint, makes the cotton sticky which in turn makes it difficult to harvest and process. Action thresholds during this phase are low because lint contamination can be such a severe problem. Treatments should be initiated at 10 to 15 aphids per fifth main stem node leaf.

Cotton aphid resistance management

Worldwide, the cotton aphid has a long history of developing resistance to insecticides. Within California the level of resistance varies across regions and over the growing season (Grafton-Cardwell et al. 1992). Resistance to Capture was widespread by 1994. Resistance to Lorsban, Metasystox-R, and endosulfan (Thiodan, Phaser) has also been documented; however, these three products still provide excellent field control in many cases. Therefore, procedures should be undertaken to manage the aphids' resistance to these materials (and to all other insecticides), thereby extending their usefulness. This is of particular concern as the same materials are used to control cotton/melon aphid on multiple crops. Few new insecticides are under development to manage cotton aphid.

Minimize the likelihood of resistance. The factors that influence the level of resistance in cotton aphids are still under study. What is clear, however, is the importance of minimizing the number of applications and making sure that when an application is made it is effective and follows the best resistance management strategy. Since cotton aphids infest the undersides of leaves and may be present on lower portions of plants, insecticide coverage is critical. Inconsistencies in insecticide performance are more often due to application problems than to increased resistance levels, although resistance does magnify the effects of a coverage problem.

Ground applications should be made at speeds less than 6 miles per hour with at least three nozzles per row. A crop oil carrier may reduce the fuming action of Lorsban, and researchers in Texas have reported that crop oil carriers appear to impede the movement of the locally systemic insecticides into leaf tissue.

IMPORTANT: Practice the basic principles of IPM, including monitoring pest levels, maximizing the use of biological and cultural controls, treating only when aphids reach the action threshold, using the most selective insecticides first so that natural enemy populations can build and be maintained, and saving the most disruptive, broad-spectrum insecticides for the end of the season.

Special considerations. You should avoid the use of foliar insecticides on seedling cotton for cotton aphid control except in the case of chronic, long-lasting early cotton aphid infestations. If, based on the history of your cotton field, you have reason to expect this, then a planting-time systemic such as Thimet or Temik may be helpful. Orthene seed treatments may enhance aphid populations during the seedling stage. Gaucho seed treatments may increase spider mite levels. Rotate treatments among insecticide classes; each insecticide class should be used only once per growing season. Cultural and biological controls are also extremely important for managing cotton aphids. Following are a number of the important considerations:

- Manage for earliness, including timely planting and proper plant populations.
- Maintain beneficial insect populations by avoiding unnecessary insecticide applications.
- Minimize excessive nitrogen and irrigation by using soil/petiole testing and pressure bomb analyses, respectively, and by setting a realistic yield goal.
- Schedule timely crop termination and harvest, including an appropriate irrigation cutoff date and optimal timing of defoliation using the NACB (nodes above cracked boll) method.
- Limit regrowth.
- Limit the use of broad-spectrum insecticides until late in the growing season.

The best choice of late-season tank mix depends on what other pests are present and the costs of the various options. If you make the wrong choice, you may increase the threat from other pests. See Table 3 for a summary of insecticide resistance guidelines.

BEET ARMYWORM

Beet armyworm (*Spodoptera exigua*) occurs on cotton throughout California. Historically it has been typified as an occasional, late-season, foliage-feeding cotton pest. But in recent years the description of beet armyworm as a pest of cotton has changed dramatically. Beet armyworm larvae now begin showing up in San Joaquin Valley cotton in early and mid-season.

Damaging populations of beet armyworm occur early when large numbers attack and destroy small cotton plants. The larvae feed on leaves, squares, flowers, and small bolls. There are three to five beet armyworm generations a year. The pupa is the overwintering stage, but all stages may be present year-round in warm areas. In warm weather, a beet armyworm can grow from egg to adult in approximately 30 days. Mid-season damage occurs to leaves and can indirectly affect yield through a reduction of photosynthates. The pest can also affect yield directly through feeding on flowers and squares.

Natural enemies, such as the parasitic wasp *Hyposter exiguae* and a nuclear polyhedrosis virus generally keep beet armyworm in check. Several factors can contribute to beet armyworm problems: mild winters, delayed planting, delayed crop maturity, heavy early season insecticide use, and prolonged hot and dry weather conditions.

Management plan

There is no set treatment threshold for beet armyworm, but be alert for large infestations. To survey for larvae, use a beating sheet or sweep net. A beating sheet is a piece of cloth or canvas about 3 feet square. Place it between rows and shake the foliage of adjacent plant to dislodge larvae, which will fall onto the sheet where you can count them.

Watch for beet armyworms on crops adjacent to cotton and on weeds in and around the field. If many larvae are present on weeds while the cotton plants are small, it may be worth your while to use an insecticide to kill them before you destroy the weeds. Otherwise they could move to the seedlings and cause a loss of stand. Treatment of a limited area such as a strip at the edge of the field is usually successful.

Another approach to beet armyworm monitoring is to monitor for egg masses. Beet armyworm moths usually deposit eggs on plants at the borders of the field. When taking sweep net samples for lygus bugs, also look for beet armyworm egg masses. The egg masses are covered by grayish white, hairlike scales and are laid on upper leaf surfaces in the upper plant canopy, but below the terminal area (Figure 3). Also watch for clusters of small, greenish caterpillars that feed in groups in leaf folds that are webbed together. Early in the spring, the number of insects caught in pheromone traps baited with beet armyworm sex-lure will give you an indication of beet armyworm activity.

Resistance management

There have been reports throughout the western cotton growing areas of the United States and specifically in California that beet armyworm has demonstrated tolerance to many of the insecticides available to growers (Byrne, Bi, and

Table 3. Insecticide resistance management guidelines for 2001 for cotton aphids (updated March 2001)

Insecticide class	Seedling cotton	Squaring to boll crack*	Boll opening to harvest
Organophosphate	Least disruptive OPs: Dibrom, Metasystox-R†, Thimet at planting	Metasystox-R (if not used previously), or Lorsban†, or Dibrom	Lorsban (if not used previously) in combination with Curacron or other classes
Carbamate	Temik at planting	Temik‡ sidedress	Lannate, Furadan¶
Chloronicotinyl	Gaucho seed treatment, Provado	Provado (if not used previously)	
Organochlorine	Endosulfan†§	Endosulfan†§ (if not used previously)	Endosulfan†§ (if not used previously)
Amidene		Ovasyn†	

NOTE: These guidelines are based on best experience for consistent control results during the past few years. Local conditions may vary and may affect control. Check with qualified experts for control conditions in your area.

* Tank mixes of insecticides from two different classes may improve aphid control and may help control other arthropod pests that may be present during this period.

† Applicable for lower aphid densities and ground application; consider tank mixes with Provado for high densities or for aerial application.

‡ If a significant aphid population is present, a foliar insecticide may also be required during the period when Temik is being activated

§ There are several products available, and restrictions may vary between them. Check the label and contact your county Agricultural Commissioner if uncertain about any local restrictions.

¶ Section 18 applied. Check with Agricultural Commissioner for status of use.

Toscano 1999). The UC Pest Management guidelines list *Bacillus thuringiensis*, Lorsban, Lannate, and Asana for control of beet armyworm. Other registered insecticides include Success, Confirm, Steward, Curacron, and Dimilin. Under heavy population pressures over an extended period, all of these products allow escapes, so growers should take steps to manage the development of resistance to these insecticides and extend their usefulness.

To manage insecticide resistance in beet armyworm, limit the total number sprays of each insecticide. The best way to do this is to practice the basic principles of IPM:

Figure 3. Beet armyworm eggs are laid in clusters covered with white, hairlike scales from the female moth.

- Monitor pests and maximize the use of biological and cultural controls.
- Spray only when the pests are present.
  - Use the most selective insecticides first so that natural enemy populations can build and help with pest control.
  - Do not use the same class of insecticide on successive generations of beet armyworm.

See Table 4 for insecticide resistance management guidelines.

Table 4. Insecticide resistance management guidelines for 2001 for beet armyworm (updated March 2001)

Insecticide class	Early season (April to mid-June)	Midseason (mid-June through July)	Late season (August and September)
Bacillus thuringiensis	Various products	Various products	
Organophosphate		Lorsban or Curacron	Lorsban*
Carbamate		Lannate	Lannate*
Miscellaneous	Steward† Success Confirm†	Success*	Steward Confirm
Pyrethroid			Capture‡ Asana‡

NOTE: These guidelines are based on best experience for consistent control results during the past few years. Local conditions may vary and may affect control. Check with qualified experts for control conditions in your area.

Do not use the same product or class of insecticide in succession.

* If not used previously.

† Do not use more than twice per season or on successive generations.

SILVERLEAF WHITEFLY

Silverleaf whitefly first appeared in cotton and melons in the San Joaquin Valley during 1992. Occasional localized outbreaks of whitefly occurred in the southern and eastern parts of the San Joaquin Valley from 1993 through 1995. In 1996, we saw a major outbreak of silverleaf whitefly as a result of warm fall and winter temperatures. The increasing distribution and host range of silverleaf whitefly continued in 1997 with heavy migrations observed in August and September. Whitefly populations were significantly reduced in 1998 due to cool spring temperatures, which resulted in the development of two fewer generations. Besides the difficulty of managing high silverleaf whitefly populations, there is evidence that the whiteflies are developing resistance to insecticides. These factors, compounded by the diverse cropping patterns of the San Joaquin Valley, increase the complexity of silverleaf whitefly management. Field data from 1997 and 1998, however, indicate that a program that emphasizes cotton management, host plant sanitation, intensive monitoring, and close adherence to the suggested action thresholds can result in success at season's end.

Our guidelines are based on recommendations from Arizona (IPM Series No. 2, 3, and 6; Whiteflies in Arizona Series 8, 9, and 11) (Diehl, Ellsworth, and Meade 2001; Diehl, Ellsworth, and Naranjo 1997; Ellsworth, Dennehy, and Nichols 1996; Ellsworth and Diehl 1997; Ellsworth, Diehl, and Naranjo 1996; Ellsworth et al. 1996). However, the San Joaquin Valley environment is very different from that of the southern desert and central Arizona. Whitefly population dynamics in the San Joaquin Valley result in unique situations that often are related to local cropping patterns.

The first situation involves fields adjacent to overwintering whitefly populations that are sources of spring whitefly development. Insect growth regulators (IGRs) are best used at this stage when adults and nymphs are present. This condition is commonly observed after the initial period of invasion and internal buildup of low numbers of silverleaf whitefly. The size of the cotton plants and the potential for continued migration into the field should also be considered. The second situation (involving application of non-pyrethroids) occurs when there is a gradual invasion of silverleaf whitefly adults into fields before the bolls open, particularly when other pests may require treatment with the same insecticides. The last situation occurs at the end of the season, when silverleaf whitefly is migrating heavily, the bolls are opening, lint is at risk, and quick knockdown is required. Pyrethroids in combination with the organochlorine endosulfan or in combination with organophosphates are the most effective choices in this situation.

Insecticide resistance

During 1996 and 1997, researchers monitored the responses of adult silverleaf whitefly to various insecticides in six locations in the San Joaquin Valley using yellow sticky cards treated with insecticides (Toscano et al. 1998). These whitefly populations showed changing levels of resistance through the season, but during several weeks populations showed significant resistance to the organophosphate chlorpyrifos (Lorsban) and to the pyrethroids fenpropathrin (Danitol) and bifenthrin (Capture). In some cases combinations of organophosphates or the organochlorine with the pyrethroids increased whitefly susceptibility and allowed full control. Where mixtures have been used to control silverleaf whitefly populations in Arizona, however, significant resistance to these mixtures has developed. The mixture approach to reducing resistance and controlling silverleaf whitefly appears to be a delaying or short-term approach to insecticide resistance management. The result of this approach in Arizona is that mixtures only control silverleaf whitefly for a limited number of applications, after which they become ineffective.

Insecticide resistance management strategy

To manage insecticide resistance in silverleaf whitefly, we need to limit the total number of sprays of each pesticide. The best way to do this is to practice the basic principles of IPM: monitor pests, maximize the use of biological and cultural controls, spray only when pests reach economic thresholds, use the most selective insecticides first so that natural enemy populations can build and help out, and save the most toxic broad-spectrum insecticides for the end of the season when they are needed to protect the exposed lint.

We recommend sampling for both whitefly nymphs and adults. When the threshold for a particular situation is reached (see below for details), the first group of insecticides applied should be relatively soft on natural enemies, and could include non-pyrethroids (such as Provado or Thiodan/Phaser) or IGRs, depending on the situation. Beneficial insects are needed for silverleaf whitefly and for other cotton pests such as spider mites and aphids. Thiodan and Provado are effective on aphids as well, and if their presence coincides with significant whitefly populations both pests could be controlled with the same pesticide application.

There are three reasons why the use of pyrethroid mixtures should be delayed until the end of the season (September), when the bolls are open. First, there is evidence that pyrethroids can increase spider mite and aphid populations by causing them to reproduce faster (hormoligosis). Second, pyrethroids are toxic to natural enemies needed for aphid, spider mite, and silverleaf whitefly control. Third, pyrethroids are most effective against silverleaf whitefly adults whereas non-pyrethroids are most effective against nymphs. When the cotton bolls are open, both the adults and nymphs can produce honeydew that will rain down on the bolls. The pyrethroid mixed with an organophosphate or chlorinated hydrocarbon kills the silverleaf whitefly much more quickly than the IGRs, and so protects the cotton from stickiness.

Situation I: Initial (internal) buildup (use insect growth regulators). In the first situation, you use IGRs to reduce the whitefly population over time. These insecticides do their work over time and have very little initial knockdown effect. The decision threshold requires the presence of both adults (five or more individuals per leaf) and nymphs (one or more individual per leaf disk) on the fifth main stem node leaf down from the terminal. For details on sampling whiteflies, see Ellsworth and Diehl (1997) and Ellsworth et al. (1996).

In this situation, low numbers of adults have invaded a field and a buildup of nymphs on the leaves has followed. In contrast to the other situations described below, very low numbers of adults initially migrate into the field and both adults and nymphs are present.

Effective chemicals for this situation include Knack (pyriproxyfen) and Applaud (buprofezin); Section 18 emergency exemption required for use. Contact your local Agricultural Commissioner for status).

Benefits:

- good residual control
- good nymph control
- a different mode of action for each IGR
- selective, minimal disruption to natural enemies in cotton

Special concerns:

- To help prevent the development of resistance, no more than one application of each IGR can be allowed per season.
- IGRs are most effective when all stages of whitefly are present and beginning to increase. Observation of both the nymph and adult thresholds helps to ensure that the population is in this state of growth.
- IGRs often have a better fit on larger plants based upon their cost and activity (e.g., translaminar movement/vapor activity).
- IGRs do not provide quick knockdown of adult whiteflies.
- IGRs do not control lygus bugs or mites.

Situation II: Gradual invasion by adults (use non-pyrethroids). This situation occurs when whitefly populations established in cotton begin to migrate to other cotton fields or when whitefly populations migrate to young cotton from overwintering sites. Adults and eggs are commonly found but nymphs are rare. The economic threshold is 10 adults per leaf on the fifth main stem node leaf from the terminal.

This situation differs from *situation I* in that the adult population is greater and nymphs are not yet present. Under high pressure circumstances (e.g., cotton fields near the citrus belt), young plants may require non-pyrethroids followed later by IGRs after immigration from the overwintering sites has subsided. Edge treatments with non-pyrethroids may be helpful under these conditions.

Chemicals include Phaser/Thiodan (organochlorines), Ovasyn (formamadine), and Provado (chloronicotinyl).

Benefits:

- Most non-pyrethroids are less disruptive to natural enemies in cotton.
- Treatment delays whitefly exposure to pyrethroids until later in the season.
- Organochlorine provides whitefly knockdown during initial periods of adult migration.
- A single treatment can also provide control of lygus or aphids.

Special concern:

- Growers should limit the use of any one pesticide class in order to limit the potential for development of resistance.

Specific restrictions apply to the use of these products. See label for details.

Situation III: Heavy migration when lint is exposed (use pyrethroid combinations with non-pyrethroids). This situation involves the massive movement of silverleaf whitefly from one cotton field to another. A huge influx from other fields can cause populations of adults to exceed the threshold overnight. Populations can be so substantial that honeydew deposits on open lint can become an immediate problem. Pyrethroid combinations are used at this stage to provide quick knockdown.

This situation differs from *situation I* and *situation II* in that the migration is heavier, the bolls are open, eggs and adults make up most of the whiteflies present, and quick knockdown is required.

Suitable chemicals include combinations of pyrethroids with organochlorines or organophosphates.

Benefit:

- Quick knockdown of adult whiteflies (nymph mortality is dependent upon coverage)

Special concerns:

- Early use of pyrethroids may induce outbreaks of spider mites or aphids.
- Early use of pyrethroids may increase the resistance of silverleaf whiteflies and reduce the chemicals' effectiveness later in the season when the bolls are open and susceptible to honeydew damage.

Specific restrictions apply to the use of these products. See label for details.

Integrated pest management

Areawide management. The practices suggested here will be most effective when used across a large area. They can also be used effectively by individual growers, but their benefits may be diminished if whiteflies invade from nearby crops.

Host plant sanitation. *IMPORTANT: Promptly harvest all host crops and destroy crop residues immediately thereafter***.** Prevent regrowth after disking, especially postharvest in melon fields and after defoliation in cotton. Control weeds (e.g., ground cherry, field bindweed, and morning glory) in non-crop areas, including head rows and fallow fields.

Adjacent crop considerations. Monitor adjacent crops (e.g., citrus, dry beans, melons, peppers, potatoes, and tomatoes) and weeds for increasing whitefly populations. Allow the maximum time possible between host crops. Harvest spring vegetable crops as early as possible. Manage whiteflies in spring sources. Plant cotton away from spring whitefly sources and be attentive as spring sources are disked. In alfalfa, delay fall establishment as long as possible and allow only a minimum number of days between cuttings.

Cotton management and varieties. Cotton should be managed to promote early development in order to reduce susceptibility to late-season whitefly migrations. Plan to plant as early as legally allowed and when conditions are favorable based on degree-day forecasts and guidelines (for California guidelines, see page 22 of Cotton Production Manual (ANR Publication 3352). Encourage uniform planting and termination dates among other growers within your community. Defoliate the cotton crop as early as possible, using nodes above cracked boll (NACB) guidelines. Use plant mapping and a soil auger to ensure the accuracy of final irrigation dates, good cutout, and limited regrowth. Good defoliation with limited regrowth of leaves will offer the best late-season whitefly management.

In general, smooth-leaf varieties are less attractive to and less susceptible to whiteflies than hairy-leaf varieties. Avoid in-season moisture stress, as it is associated with increased honeydew production.

Table 5. Insecticide resistance management guidelines for 2001 for silverleaf whitefly (updated March 2001)

Chemical class	Initial buildup	Gradual invasion	Heavy migration*
Insect growth regulator Chitin synthesis inhibitor	Applaud†		
Insect growth regulator Metamorphosis inhibitor	Knack		
Chloronicotinyl		Provado	
Organochlorine		Endosulfan‡	Endosulfan‡
Amidene		Ovasyn§	
Pyrethroid			Capture
Pyrethroid + organochlorine			Pyrethroid + Endosulfan
Pyrethroid + organophosphate/ carbamate			Danitol + Orthene/ Curacron/ Lannate/ Vydate

NOTE: These guidelines are based on best experience for consistent control results during the past few years. Local conditions may vary and may affect control. Check with qualified experts for control conditions in your area.

* Options in the case of a heavy late-season migration depend upon the length of control desired and previous insecticides used. Tank mixes maybe required in many areas to provide adequate protection for lint. See publication text for details.

† Section 18 has been requested. Check with your Agricultural Commissioner for the status of this request. Read and follow the label when using any insecticide. See publication text for special concerns on any of these situations.

‡ Several products are available and restrictions may be different for each of them. Check the label and contact your Agricultural Commissioner if you are uncertain about any local restrictions.

§ For use in tank mix, depending on the pest complex that is present.

Scouting and decision-making. Routinely check all parts of all fields for whiteflies using adult and nymph scouting methods. When populations exceed the thresholds, treat the fields as needed.

Be sure on your species identification, checking with an expert if there is any question. Be especially alert for rapid buildup of whiteflies when nearby host crops are in decline. Sticky traps may be useful for detecting whitefly movement into cotton fields. Timely insecticide treatments can prevent outbreaks and reduce the chances of sticky cotton and yield loss. Always use action thresholds as a basis for timing insecticide applications. See Table 5 for insecticide resistance management guidelines.

Table 6. Summary of characteristics of key cotton insecticides and miticides for 2001 (updated March 2001)

Common name	Trade name	Restricted entry interval	Preharvest interval	Hazard to adult bees
Miscellaneous				
Abamectin	Zephyr	12 hours	20 days	moderate: 0.5 day
Amitraz	Ovasyn	24 hours	none	none
Azadirachtin	Neemix	4 hours	none	none
Bacillus thuringiensis	various	4 hours	none	none
Hexythizox	Savey	12 hours	120 days	none
Imidacloprid	Provado	12 hours	14 days	high: 3.5 days
(seed treatment)	Gaucho	—	—	none
Oils	various	4 hours	none	none
Propargite	Comite	7 days	50 days	none
Soaps	various	12 hours	none	none
Sulfur	various	24 hours	none	none
IGR				
Buprofezin*	Applaud	12 hours	14 days	none
Pyriproxyfen	Knack	12 hours	28 days	low
Carbamate				
Aldicarb	Temik	48 hours	90 days	none
Methomyl	Lannate	72 hours	15 days	high: 1.5 days
Oxamyl	Vydate L	48 hours	21 days	high: 4 days
Carbaryl	Sevin bait	12 hours	7 days	none
Organochlorine				
Dicofol	Kelthane	12 hours	30 days	none
Endosulfan	Thiodan, etc.	2 days	none	moderate: 2 days
Lindane (seed treatment)	Lindane 75 SC	—	—	none
Organophosphate				
Acephate (foliar)	Orthene	24 hours	21 days	high: 2.5 days
Chlorpyrifos	Lorsban	24 hours	14 days	high: 3.5 days
Dimethoate	Dimethoate	48 hours	14 days	high: 3.5 days
Malathion	Malathion	12 hours	none	high: 2 days
Methamidophos	Monitor	2-3 days†	50 days	high:>5 days‡
Methidathion	Supracide	48 hours	14 days	moderate: 2.5 days
Naled	Dibrom	48 hours	none	high: 1.5 days
Oxydemeton-methyl	Metasystox-R	2-3 days†	14 days	moderate: 0.5 day
Phorate	Thimet	2-3 days†	60 days	low: 1 day
Prophenofos	Curacron	2-3 days†	14 days	moderate: 0.5 day
Pyrethroid				
Bifenthrin	Capture	12 hours	14 days	high: 1 day
Cyfluthrin	Baythroid	12 hours	none	high
Cypermethrin	Ammo	12 hours	14 days	high: <1 day
Esfenvalerate	Asana	12 hours	21 days	high: <1 day
Fenpropathrin	Danitol	24 hours	21 days	high: 1 day
Tralomethrin	Scout X-tra	24 hours	28 days	low: <1 day
Zetacypermethrin	Mustang	12 hours	14 days	high: <1 day

NOTE: These guidelines are based on best experience for consistent control results during the past few years. Local conditions may vary and may affect control. Check with qualified experts for control conditions in your area.

* Check with your county Agricultural Commissioner about the availability of this material under a Section 18 registration; permit required.

† Determined by amount of yearly rainfall; see label.

‡ Brood poison at lower doses.

Table 7. Selectivity and persistence of key cotton insecticides and miticides (updated March 2001)

		Persistence against:		
Product	**Selectivity**	**Pest**	**Natural enemies**	**Major target pests**
Ammo	low	long	moderate	loopers, beet armyworm, other lepidopterous larvae
Applaud	high	long	long	whiteflies
Asana	low	long	moderate	loopers, beet armyworm, other lepidopterous larvae
Bacillus thuringiensis	high	short	short	loopers, beet armyworm
Baythroid	low	long	moderate	lygus, beet armyworm, loopers
Capture	low	long	long	lygus, whiteflies, beet armyworm, looper
Comite	high	moderate	short	mites
Curacron	moderate	short	short	aphids, beet armyworm, loopers
Dimethoate	moderate	short	short	lygus, aphids
Danitol	low	long	moderate	whiteflies, lygus
Dibrom	low	short	short	aphids
Gaucho (seed treatment)	moderate	long	moderate	aphids
Gossyplure	high	moderate	none	pink bollworm
Kelthane	high	moderate	short	mites
Knack	high	long	long	whiteflies
Lannate	low	short	short	loopers, beet armyworm, aphids
Lindane (seed treatment)	high	short	short	seed corn maggot, wireworm
Lorsban (foliar)	moderate	moderate	short	aphids, lygus
Lorsban (seed treatmentt)	high	moderate	short	seedcorn maggot
Malathion	low	short	short	grasshoppers
Metasystox-R	moderate	short	short	lygus, aphids
Monitor	moderate	short	moderate	lygus, aphids
Mustang	low	long	moderate	lygus, beet armyworm, looper
Neemix	moderate	short	short	aphids, whiteflies
Oils	low	short	short	aphids, whiteflies
Orthene (foliar)	low	moderate	moderate	thrips, lygus, loopers, whiteflies
Orthene (seed treatment)	high	moderate	short	thrips, aphids
Ovasyn	high	moderate	short	aphids, mites
Provado	high	moderate	short	aphids, lygus
Savey	high	moderate	short	spider mites
Scout Xtra	low	long	moderate	lygus
Sevin (bait)	moderate	moderate	moderate	cutworms
Sevin (foliar)	moderate	moderate	moderate	cutworms
Soaps	low	short	short	aphids, whiteflies
Steward	moderate	short	short	beet armyworm, loopers, other lepidopterous larvae
Success	high	short	short	lepidopterous larvae
Sulfur	high	short	short	mites
Supracide	moderate	short	short	lygus
Temik (at planting)	high	long	moderate	mites, aphids, thrips
Temik (side-dress)	high	long	short	lygus, aphids, mites
Thimet (at planting)	high	moderate	moderate	mites, aphids, thrips
Thiodan/Phaser	high	moderate	short	aphids, whiteflies
Vydate	low	moderate	moderate	whiteflies, lygus
Zephyr	high	long	moderate	mites

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