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UC IPM
Pest Management Guidelines:
COTTON

September 2015

Contents (Dates in parenthesis indicate when each topic was updated)

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An illustrated version of this guideline is available online at https://ipm.ucanr.edu/agriculture/cotton/.

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UC PEER REVIEWED

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The UC IPM Pest Management Guidelines are available from:

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Updates: These guidelines are updated regularly. Check with your University of California Cooperative Extension Office or the UC IPM website for information on updates.

Note to readers: These guidelines represent the best information currently available to the authors and are intended to help you make the best choices for an IPM program. Not all formulations or registered pesticides are mentioned. Always read the label and check with local authorities for the most up-to-date information regarding registration and restrictions on pesticide use. Check with your agricultural commissioner for latest restricted entry intervals.

To be used with *Integrated Pest Management for Cotton, 2nd edition*, UC ANR Publication 3305

For information on cotton production, see *Cotton Production Manual*, UC ANR Publication 3352

Both available from https://anrcatalog.ucanr.edu

www.ipm.ucanr.edu

Cotton Year-Round IPM Program

(Reviewed 5/13)

ANNUAL CHECKLIST

Supplement to UC IPM Pest Management Guidelines

Use these guidelines for a monitoring-based IPM program to effectively manage pests, while reducing the risks of pesticides on the environment and human health.

When a pesticide application is considered, review the **Pesticide Application Checklist** for information on how to minimize the risks of pesticide use to water and air quality. Water quality can be impaired when pesticides drift into waterways or when they move off-site. Air quality can be impaired when pesticide applications release volatile organic compounds (VOCs) into the atmosphere.

This year-round IPM program covers the major pests of cotton production in California. Details on carrying out each practice and information on additional pests can be found in the *UC IPM Pest Management Guidelines: Cotton*. Color photo identification pages and example monitoring forms can be found at the forms and photo identification pages.

Note: Growers using reduced tillage will have to modify some of these practices in this year-round IPM program.

✓ Done	**Preplant to Planting** **Mitigate pesticide effects on air and water quality.**
	Select your field, considering pest history and surrounding crops.
	Consider crop rotation if field had severe problems last year with root-knot nematode, Verticillium wilt, Fusarium wilt, or seedling diseases.
	Consider precision tillage and ripping for locations with a history of soil compaction, particularly if root-knot nematodes are also a problem.
	Consider a trap-crop interplant of alfalfa, cowpea, or lima bean for lygus bug management.
	Survey and manage weeds: • Keep records *(example form available online)*. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Select a variety, considering: • Local conditions and climate. • Field history of Verticillium wilt, Fusarium wilt, and root-knot nematode.
	Consider a seed treatment for pests based on field history and according to the *Cotton Pest Management Guidelines*: • Aphids • Seedcorn maggot • Seedling diseases • Thrips • Wireworms
	Start planning for when to plant around March 5 by checking 5-day degree-day forecast and taking soil temperature.

✓ Done	**Crop Emergence to Seedling Growth** **Mitigate pesticide effects on air and water quality.**
	Assess stand establishment and identify pests or diseases if stand is weak.
	Begin tracking degree-day accumulations for plant growth as soon as crop emerges.
	Monitor for spider mites, aphids, and thrips. • Keep records *(example form available online)*. • See photo ID page.
	Maintain a weed management program: • Survey weeds and keep records *(example form available online)*. • Cultivate or apply postemergence herbicides as suggested in *Cotton Pest Management Guidelines*. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Manage *Fusarium*: • Survey fields and record of locations suspected or confirmed to have race 4 *Fusarium.* • Consider the management options in the *Cotton Pest Management Guidelines*.
	Monitor nearby crops, fence rows, and weedy areas for false chinch bugs.

✓ Done	**Squaring to First Bloom** **Mitigate pesticide effects on air and water quality.**
	Begin weekly monitoring of plant growth. • Continue tracking degree-day accumulations for plant growth.
	Monitor for armyworms, cabbage loopers. Treat if needed according to *Cotton Pest Management Guidelines*.
	Monitor for spider mites, aphids, and whitefly: • Keep records *(example form available online)*. • See photo identification pages for these pests and their natural enemies. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Begin sweep net sampling and square retention monitoring for lygus bug activity: • Keep records *(example form available online)*. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Survey and manage weeds. • Keep records *(example form available online)*. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Sample for both races of *Fusarium* if there is evidence of *Fusarium* in the field, or if you planted a variety with unknown resistance.
	Manage alternate lygus bug hosts such as weeds, alfalfa, and safflower next to cotton.
	Adjust nitrogen application amount and first irrigation timing to limit rank growth.

✓ Done	**First Bloom to First Open Boll** **Mitigate pesticide effects on air and water quality.**
	Time a layby cultivation.
	Continue tracking degree-day accumulations for plant growth. Continue weekly monitoring of plant growth.
	Consider adjusting nitrogen, irrigation management, and application timing and rate of plant growth regulators.

✓ Done	**First Bloom to First Open Boll** **Mitigate pesticide effects on air and water quality.**
	Continue monitoring for armyworms: • Treat if needed according to *Cotton Pest Management Guidelines*.
	Start sampling plant terminals for bollworms.
	Continue monitoring for spider mites, aphids, and whitefly: • Keep records *(example form available online)*. • See photo identification pages for these pests and their natural enemies. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Continue sweep net sampling and square retention monitoring for lygus bug activity: • Keep records *(example form available online)*. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Other pests you may see: • Beet armyworm • Cabbage looper • Saltmarsh caterpillar • Stink bugs

✓ Done	**First Open Boll to Harvest** **Mitigate pesticide effects on air and water quality.**
	Continue tracking degree-day accumulations for plant growth. • Continue weekly monitoring of plant growth.
	Monitor aphids and whitefly, including regrowth after defoliation: • Keep records *(example form available online)*. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Survey weeds before harvest: • Keep records *(example form available online)*. • Treat if needed according to *Cotton Pest Management Guidelines*.
	Schedule defoliation to allow for timely harvest and minimum regrowth.
	If you have evidence of Verticillium wilt in your field, or if you want to plant a variety with unknown resistance, chose a time between crop maturity and harvest to sample stems for discoloration.
	Continue to monitor lygus bugs and treat if necessary according to the *Cotton Pest Management Guidelines*.
	Sample plant roots and rate nematode infestation while soil is still moist from final irrigation: • Keep records *(example form available online)*. • Treat if needed according to the *Cotton Pest Management Guidelines*

✓ Done	**Harvest to Postharvest** **Mitigate pesticide effects on air and water quality.**
	• Maintain maximum time between harvest and planting whitefly host crops. • Promptly destroy stalks to prevent regrowth and limit additional whitefly buildup.
	Observe local plowdown regulations and host-free periods to prevent establishment of pink bollworm.

✓ Done	**Pesticide Application Checklist**

✓ Done	**Pesticide Application Checklist** When planning for possible pesticide applications in an IPM program, consult the Pest Management Guidelines, and review and complete this checklist to consider practices that minimize environmental and efficacy problems.
	✓ Choose a pesticide from the Pest Management Guidelines for the target pest, considering:
	• Impact on natural enemies and honey bees. For more information see Protecting Natural Enemies and Pollinators at https://ipm.ucanr.edu/mitigation/protect_beneficials.html.
	• Potential for water quality problems using the UC IPM WaterTox database. See https://ipm.ucanr.edu/TOX/simplewatertox.html.
	• Impact on aquatic invertebrates. For more information, see *Pesticide Choice*, UC ANR Publication 8161, https://anrcatalog.ucanr.edu/pdf/8161.pdf.
	• Chemical mode of action (based on efficacy, spectrum of activity, and pesticide resistance). Select alternative chemical or nonchemical treatments, especially when resistance risk is high. For more information, see *Herbicide Resistance: Definition and Management Strategies*, UC ANR Publication 8012, https://anrcatalog.ucanr.edu/pdf/8012.pdf.
	• Endangered species that may be near your site. Find out using the Department of Pesticide Regulation's PRESCRIBE program. (https://www.cdpr.ca.gov/docs/endspec/prescint.htm)
	✓ Before an application
	Ensure that spray equipment is properly calibrated to deliver the desired pesticide amount for optimal coverage. (See https://ipm.ucanr.edu/training/incorporating-calibration.html)
	Use appropriate spray nozzles and pressure to minimize off-site movement of pesticides.
	Avoid spraying during these conditions to avoid off-site movement of pesticides. • Wind speed over 5 mph • Temperature inversions • Just prior to rain or irrigation (unless it is an appropriate amount, such as when incorporating a soil-applied pesticide) • At tractor speeds over 2 mph
	Identify and take special care to protect sensitive areas (for example, waterways or riparian areas) surrounding your application site.
	Review and follow labeling for pesticide handling, personal protection equipment (PPE) requirements, storage, and disposal guidelines.
	Check and follow restricted entry intervals (REI) and preharvest intervals (PHI).
	✓ After an application
	Record application date, product used, rate, and location of application.
	Follow up to confirm that treatment was effective.
	✓ Consider water management practices that reduce pesticide movement off-site.
	Consult relevant publications: • *Protecting Surface Water from Sediment-Associated Pesticides in Furrow-Irrigated Crops*, UC ANR Publication 8403 (PDF), https://anrcatalog.ucanr.edu/pdf/8403.pdf.
	Consult the Department of Pesticide Regulation Groundwater Protection Program (GWPA) Web site for pesticide information and mitigation measures. (https://www.cdpr.ca.gov/docs/emon/grndwtr/)
	Install an irrigation recirculation or storage and reuse system. Redesign inlets into tailwater ditches to reduce erosion.
	Use drip rather than sprinkler or flood irrigation.
	Limit irrigation to amount required using soil moisture monitoring and evapotranspiration (ET).
	Consider using cover crops.

✓ Done	Pesticide Application Checklist
	Consider vegetative filter strips or ditches. (For more information, see *Vegetative Filter Strips*, UC ANR Publication 8195, https://anrcatalog.ucanr.edu/pdf/8195.pdf.)
	Install sediment traps.
	Apply polyacrylamides in furrow and sprinkler irrigation systems to prevent off-site movement of sediments.
	Redesign inlets and outlets into tailwater ditches to reduce erosion. (For more information, see *Reducing Runoff from Irrigated Lands: Tailwater Return Systems*, https://anrcatalog.ucanr.edu/pdf/8225.pdf.)
	✓ Consider practices that reduce air quality problems.
	When possible, reduce volatile organic compound (VOC) emissions by decreasing the amount of pesticide applied, choosing low-emission management methods, and avoiding fumigants and emulsifiable concentrate (EC) formulations.

For more about mitigating the effects of pesticides, see the Mitigation page: https://ipm.ucanr.edu/mitigation/.

General Information

(Section reviewed 5/13)

SELECTING THE FIELD (5/13)

Choose fields for cotton planting carefully. A field's cropping history is important. Cotton planted in fields infested with cotton pests or in fields with poor nutrient balance will suffer yield loss. Also, keep in mind the crops surrounding your cotton fields. Do they harbor pests of cotton such as whitefly or lygus bugs? Carefully planned cultural practices in adjacent crops can help you reduce pest pressures in cotton. Use the checklists below when selecting fields for cotton planting.

CHECK SOIL RECORDS OR PERFORM SOIL ASSAYS FOR:

Nutrients	Assay for nitrogen content annually. Consider assaying for potassium, which changes slowly and is needed less often.
Soil type	Identify soil type. Clay loam to loam soils are generally the most productive soils in the San Joaquin Valley. Sandier soils usually have higher root-knot nematode populations.
Root-knot nematodes	Assay for nematodes before planting cotton directly after another crop. See details in *Integrated Pest Management for Cotton*, ANR Publication 3305.

CHECK RECORDS FOR:

Agronomic information	Determine past cotton varieties that have been planted and their planting and harvest dates and yields. See if the field has supported successful production.	
Weeds	Survey weeds in the spring before planting. This is crucial for the selecting an appropriate preplant herbicide or rotational crop.	
Cropping history	Identify previous crops that are known hosts of cotton pests.	
Surrounding crops	Check for cultivated crops such as alfalfa, safflower, sugarbeet, potato, and sunflower; all harbor lygus bugs.	
Presence of pests such as:	**Lygus bug**	Manage adjacent alfalfa for lygus bug control.
	Sweetpotato whitefly	Plant cotton at least 1/2 mile upwind from other key whitefly hosts such as melons and cole crops.
	Root-knot nematode	Check population levels with soil sampling. See the pest management guideline and the cotton IPM manual for more details.
	Verticillium wilt inoculum	Use results from soil or stem sampling (percent discoloration) taken preharvest or at harvest to determine the need for tolerant cotton or rotational crop.
	Fusarium wilt inoculum	Manage nematodes for race 1 Fusarium control. For race 1 and race 4 use Fusarium-free seed produced in disease-free fields. Avoid using gin trash in cotton fields.

SELECTING A VARIETY (5/13)

Consider planting pest-resistant varieties if *Verticillium*, *Fusarium*, or root-knot nematode have been a problem in your fields in the past. Other options in varietal selection include transgenic cotton with herbicide tolerance or *Bacillus thuringiensis* (Bt) cotton to control certain caterpillar pests.

The tables below describe variety choices related to pest management. New varieties become available regularly. If no data exists on a new variety that you would like to try, then try the following:

- Talk to your local farm advisor or seed company representative about suitable varieties.
- As a test, plant 2 acres of the new variety if you have a known history of *Verticillium* or other target pest in your field.

Table 1. *Verticillium* resistance in Acala, Non-Acala, and Pima varieties.

Pest	Cotton Variety		
	Acala Upland	**Non-Acala Upland**	**Pima**
***Verticillium* resistance**	A range of resistance exists within this group, but most have a high degree of resistance.	A range of resistance exists within this group, but many are highly susceptible.	Little is known about resistance. Variety trials in progress.

Table 2. Varieties tolerant or resistant to Fusarium wilt and caterpillars.

Pest	Variety	Comments on tolerance
***Fusarium* race 1**	Acala variety: • NemX-HY	This variety has tolerance to *Fusarium* race 1.
***Fusarium* race 4**	Pima varieties: • Phy-800 • Phy-802RF • Phy-805 • DP-360	These varieties have a relatively high level of resistance to Fusarium race 4. Other varieties range from highly susceptible to moderately susceptible, depending on soil inoculums levels.
Pink bollworm, Western yellowstriped armyworm, beet armyworm, and loopers	Bollguard II transgenic and other Bt varieties* *Bt* varieties of Non-Acala Upland (CA Uplands)	Effective suppression of pink bollworm (Southern deserts), plus additional suppression of armyworm and loopers.

* Resistance of pink bollworm to Bt cotton varieties may develop over time.

SELECTING A PLANTING DATE (5/13)

To determine the best planting date to establish a healthy stand, use a 5-day forecast of accumulated degree-days (heat units) and on-site soil temperature readings. Good stand establishment requires sufficiently warm air (measured in heat units) and suitable field soil temperatures. Use the following guidelines for 5-day degree-day forecast plus field soil temperatures until an optimal planting date is determined.

Cotton Planting 5-Day Degree-Day Forecast

March 10th is the first date available for planting in the San Joaquin Valley. It marks the end of the 90-day host-free period for the pink bollworm control program, but does not necessarily mark the ideal planting time. Optimal planting time depends on soil temperatures at planting and during the 5 days following planting. Cotton seed requires approximately 50 degree-days to accumulate in order to emerge when planted at an optimum planting depth. It is also important that temperatures be consistently warm and don't drop during the first 5 days after planting. To determine the ideal window for planting, start taking soil temperature readings in your fields on March 5 (see below) and follow forecasts from the Cotton Planting Forecast. Forecasts for the San Joaquin and Sacramento valleys are updated every day from early March through the end of April each year.

Use the following guidelines to interpret the 5-day forecast, also taking into account your field soil temperature readings:

- 10 degree-days or less are unfavorable for planting.
- 11 to 15 degree-days are marginally acceptable for planting.
- 16 to 20 degree-days are adequate for planting.
- Greater than 20 degree-days are ideal for planting.
- Be cautious about planting if cooling temperatures are forecast over the course of the 5-day period.

Field Soil Temperature Readings

Couple the 5-day forecast with soil temperature readings from a number of locations in your field. A soil temperature reading of 58° to 60° F, taken at 8 AM, is considered the minimum temperature required for good stand establishment, as long as the 5-day forecast predicts favorable conditions for the next 4 days.

To measure soil temperature:

- Use a soil thermometer. A fast-response thermometer (standard or digital) allows you to take readings quickly.
- Take soil temperatures at 8 AM.
- Make measurements by probing the seed planting depth.
- Take measurements in 6 different locations to get an average field temperature.

Many factors influence soil temperature. These include wet versus dry soil, bed orientation, bed type (flat versus furrow), and residue cover in reduced-till areas. Therefore, measure within a representative area in which you will plant.

Check the crop after planting. If cotton emerges in:

- Less than 10 days, it is an indication of good germination and emergence with seedlings experiencing ideal daily temperatures of 5 or more degree-days per day.
- More than 10 days, the plant has experienced less than ideal conditions and there is a likelihood that some chilling injury has occurred.

NOTE THAT IF YOU PLANTED YOUR COTTON "DEEP" FOR ADEQUATE MOISTURE, THE DEGREE-DAY ACCUMULATION WILL BE AFFECTED AND EMERGENCE WILL BE LATER.

ASSESSING STAND ESTABLISHMENT (5/13)

Assess stand establishment to see if your crop is growing satisfactorily. By comparing the plant population per foot with the seeding rate per foot, you can determine if the stand is optimal, weak, or excessive.

- If the stand is weak, monitor for and identify any pests such as seedling diseases or seedling insects associated with poor stands.
- If the stand is unacceptable or if there are multiple adjacent rows without plants, your main management option is to replant.
- If the stand is excessive, thinning may be required. Dense plant populations, combined with conditions of adequate moisture and nutrients, can lead to rank growth, making the crop more vulnerable to insects and diseases. Depending on the cotton variety, a plant stand in excess of 60,000 plants per acre may require thinning.

The following table gives a general range for plant stand populations—although ideal densities are variety and condition dependent. For cotton plants growing in low vigor situations, higher plant densities may be desirable.

General range for plant stand population

Stand establishment	Plants per acre
Optimal	40,000-60,000
Weak	below 30,000
Excessive	more than 60,000

To estimate plant population:

- Take at least 4 measurements from several representative areas of the field and average them.
- Use the table below to find the length of row that represents 1/1000 of an acre for various row widths.
- In your field, count the total number of plants in the 1/1000-acre area and multiply by 1000.

Length of row representing 1/1000 of an acre for various row widths

Row widths (inches)	1/1000 acre (row feet)
30	17.4
32	16.3
36	14.5
38	13.8
40	13.1

MONITORING PLANT GROWTH (5/13)

Plant monitoring (or mapping) provides a system to evaluate the growth and development of cotton plants throughout the season. You can use this information to fine tune management practices for the current crop stage. Many pest management decisions must be made at specific growth stages, and plant mapping helps you time them precisely. Plant measurements and calculations for making management decisions change as the plant develops.

EARLY SQUARING

Plant monitoring during early squaring focuses on plant vigor and square retention. Measure:

- Plant height.
- Total number of mainstem nodes.
- The first position squares on the terminal 5 fruiting branches.

For more information about making these measurements and for recording forms, ask your local farm advisor. You can also check the UCCE Cotton Production Information site https://cottoninfo.ucdavis.edu/ for details on how to apply monitoring information for plant growth regulator applications, lygus treatments, and irrigation decisions.

EARLY FLOWERING TO PREHARVEST

Mapping plant growth from early flowering to preharvest consists of tracking:

- Retention of squares in the bottom and top first position fruiting branches.
- The number of nodes above white flower.
- The number of nodes above the highest cracked boll.

MONITORING SQUARE RETENTION

Square retention is evaluated in the San Joaquin Valley to help determine the need for lygus bug management. Track the percent retention of the first-position squares on the top five and bottom five fruiting branches and keep records *(example form available online).*

Start at early squaring:

- Examine five top branches and five bottom branches on each of five plants in four areas of your field.
- On each branch check for the presence or absence of first-position squares.
- Use the diagram of the cotton plant *(available online)* to help you.
- After the plant has developed more than ten fruiting branches, stop counting fruit on the bottom five branches if the average boll retention remains constant for 2 weeks in a row. You can use this retention level for the rest of the season.

Treatment may be warranted if you find 3 to 6 lygus per 50 sweeps before bloom and the square retention is lower than expected.

After monitoring for fruit retention, use the square and fruit retention action threshold table *(available online)* to look up the critical square retention based on the total number of fruiting branches and the percent fruit retention on the bottom five fruiting branches.

MONITORING NODES ABOVE WHITE FLOWER

The primary use of measuring Nodes Above the White Flower (NAWF) is to determine when cutout occurs. Cutout is reached when 95 % of the cotton bolls are mature and have advanced beyond the presence of squares and blooms. There is also no new terminal growth. Cutout indicates that 95% of the crop has been set. Stop sampling for lygus bugs at cutout since bolls are generally not susceptible to lygus bug damage 10 days after flowering.

Measuring NAWF:

- Select a minimum of 5 plants with a first-position flower from each of four different areas in the field.
- Count the node with a first-position flower as zero and move toward the terminal.
- Record the total nodes above white flower for all of the samples.

- Record the number of plants sampled.
- Divide the total number of nodes by the total number of plants sampled.

If the terminal node has a leaf associated with it of at least 1 inch in diameter, consider it a new node.

MONITORING NODES ABOVE CRACKED BOLL

The average number of nodes above the cracked boll (NACB) provides a measure for defoliation timing, taking into account not only the potential yield loss but also the loss of fiber quality in immature bolls. Ideal timing for defoliation occurs when unopened harvestable bolls are an average of four or less nodes (including missing branches) above the highest first position cracked boll. If it becomes necessary to defoliate a field prematurely at an average of 5 nodes above cracked boll because of a honeydew-producing insect infestation, a yield loss of less than 1% will occur; at 6 nodes above cracked boll the loss will be less than 2%.

The number of nodes above the first cracked boll helps you determine the proper time to apply defoliants. Select 5 random plants from each of four representative areas of each field for a total of 20 plants. Choose plants that have a cracked boll on a first position fruiting branch. Use the cotton diagram *(available online)* to help locate the various parts. Find the uppermost cracked first position boll and count this as fruiting branch zero. Count the number of nodes above the fruiting branch zero until you reach the most apical harvestable boll on the plant. This is a boll that is large enough and mature enough in development that it will open before the scheduled harvest date. The number of nodes you counted above fruiting branch zero is the NACB. Average this number for the 20 plant samples.

How to calculate the NACB:

A. Total number of plants sampled ..... = _____

B. Total number of nodes above cracked boll ..... = _____

B ÷ A = _____

You can use NACB to schedule your defoliation as follows:

- 4 NACB is used as a target for the first harvest aid in Upland or Acala
- 3 NACB is used as a target for defoliant timing in Pima

MONITORING PESTS IN A COTTON FIELD (5/13)

Monitoring is a crucial component of all integrated pest management (IPM) programs. It helps to identify potential problems and to assess the overall field conditions. Check the field regularly for pests and natural enemies of pest species, as well as the maturity and health of the crop.

There are six major monitoring periods for a cotton crop. The presence and population development of key pests are tracked during these periods. The information in the table below outlines the monitoring periods, major pests monitored, and the methods used to monitor them. Detailed information on each pest and its monitoring method is available under the individual pest sections in this guideline.

Major Monitoring Periods, Pests Monitored, and Monitoring Methods Used in a Cotton Field.

Monitoring Period	Pests Monitored	Method Used
Preplant to planting	weeds	weed survey
Crop emergence to seedling growth	spider mites, aphids, cutworms, thrips	examine cotyledons or first true leaves
	false chinch bugs, stink bugs	monitor nearby crops, fence rows and weedy areas
	weeds	weed survey
Early squaring	spider mites, aphids, whitefly	examine 5th mainstem node leaf from top of plant
	lygus bugs	sweep sampling; square retention monitoring
	weeds	weed survey
Bloom to boll	spider mites, aphids, whitefly	examine 5th mainstem node leaf from top of plant
	lygus bugs	sweep sampling; square retention monitoring
First open boll to preharvest	aphids, whitefly	examine 5th mainstem node leaf from top of plant
	weeds	weed survey
	Verticillium wilt	stem sampling
Harvest to postharvest	nematodes	weighted nematode rating

MONITORING SPIDER MITES, APHIDS, AND THRIPS (SEEDLING COTTON) (5/13)

Start sampling for aphids, spider mites, and thrips as soon as plants emerge. Go to the specific pest sections for more information on when to treat and treatment options.

When and How to Sample

- Sample once or twice a week.
- Walk down rows in four quadrants of the field.
- Use a hand lens to examine the first true leaves or cotyledons of random plants looking for damage and insects and mites.

Treatment Thresholds

Thrips	No treatment is generally required. Treat for thrips only if plants show poor growth, there is terminal damage, and thrips are present in significant numbers.
Mites	Treat for mites before defoliation occurs and the mite populations are high.
Aphids	Treat for aphids if high populations persist for 7 or more days.

MONITORING SPIDER MITES, APHIDS, AND WHITEFLY (EARLY SQUARING TO BOLL DEVELOPMENT) (5/13)

How to Sample

Take a combined sample for spider mites, aphids, and whitefly at least once a week from early squaring through boll development. Beginning at least 50 paces into the field, choose a sample plant at random and select the 5th mainstem node leaf from the terminal. Using a hand lens, turn the leaf over and check for insects and mites on the underside (these are called leaf-turns). *(*Record monitoring results (*example form available online).*

Aphids	Count and record number and color (yellow or black).
Spider mites	Note the presence or absence—no need to count.
Whitefly adults	If 3 or more are found, count the leaf as infested
Whitefly nymphs	Place a quarter-sized ring between the central and left-side main veins and check for presence or absence of large nymphs (3rd or 4th instar).

Repeat these leaf-turn samples on 10 plants in this area of the field, walking at least 20 paces between sample plants. Then move to another area, repeating the procedure in a total of 4 areas of the field. Be sure to check the edges of the field for whiteflies migrating in. Also check for natural enemies of aphids, mites, and whiteflies including western flower thrips, western predatory mites, bigeyed bugs, minute pirate bugs, lacewing larvae, syrphid fly larvae, lady beetles, as well as parasitized aphids and whiteflies.

Treatment Thresholds

(See specific pest sections for more details on thresholds and treatment options.)

Aphids	Between first square and open boll when populations are persisting or building over a 5- to 7-day period, the treatment threshold is 50 aphids per fifth main stem node leaf.
Spider mites	30% of leaves show mite presence.
Whitefly adults	40% leaves with at least 3 adults. If using insect growth regulators (IGRs), nymphs must also be present to justify treatment. If high numbers of adults are at field edges, but no nymphs, an edge treatment with a non-IGR may be required.
Whitefly nymphs	40% leaves infested with large nymphs.

MONITORING APHIDS AND WHITEFLY
(1st OPEN BOLL TO PREHARVEST) (5/13)

How to Sample

After the first open boll, you can stop sampling for spider mites but continue to take a combined sample for aphids and whitefly at least once a week.

Beginning at least 50 paces into the field, choose a sample plant at random and select the 5th mainstem node leaf from the terminal. Using a hand lens, turn the leaf over and check for insects on the underside (these are called leaf-turns). Record monitoring results (*example form available online*).

Aphids	Count and record number and color (yellow or black).
Whitefly adults	If 3 or more are found, count the leaf as infested
Whitefly nymphs	Place a quarter-sized ring between the central and left-side main veins and check for presence or absence of large nymphs (3rd or 4th instar).

Repeat these leaf-turn samples on 10 plants in this area of the field, walking at least 20 paces between sample plants. Then move on to another area, repeating the procedure in a total of 4 areas of the field. Be sure to check the edges of the field for whiteflies migrating in. Also check for natural enemies of aphids and whiteflies including bigeyed bugs, minute pirate bugs, lacewing larvae, syrphid fly larvae, lady beetles as well as parasitized aphids and whiteflies.

Treatment Thresholds

(See aphid and whitefly sections for more details on thresholds and treatment options.)

Aphids	Between open boll to preharvest, treatment threshold is as low as 5 to 10 aphids per 5th mainstem node leaf because of honeydew deposition on lint.
Whitefly adults	40% leaves with at least 3 adults. If using insect growth regulators (IGRs), nymphs must also be present to justify treatment. If high numbers of adults are at field edges, but no nymphs, an edge treatment with a non-IGR may be required.
Whitefly nymphs	40% leaves infested with large nymphs.

SCHEDULING DEFOLIATION (5/13)

Harvest cotton as early as possible to avoid yield and quality losses due to insects, weathering of cotton fiber, moisture, and poor drying conditions. Harvest operations should start only after an acceptable percentage of bolls are mature and open, and after effective defoliation is achieved.

Defoliation is the last operation where management decisions can have a large impact on profit. Defoliants are applied to cotton to increase the rate of leaf loss and desiccation, allowing for timely and efficient harvesting. An earlier crop termination is often suggested when populations of whiteflies or aphids are threatening. Be sure to control threshold and greater-than-threshold populations. An additional consideration of timing defoliation and harvest is the regulation of root dislodging, residue shredding, and residue incorporation for the pink bollworm control program in the San Joaquin Valley.

Make defoliation decisions on a field-by-field basis. You will see a wide range of crop maturity and impacts of weather and crop conditions among fields. Note that fields with even vegetative cutout and good boll load will be far easier to defoliate than fields with a non-uniform fruit set. Remember that there is substantial late vegetative growth due to factors like late plantings, late irrigations, or high late-season soil nitrogen. Plan for early crop termination where whitefly or aphid infestations are severe.

To time application of defoliants, count the nodes above cracked bolls (NACB) and follow these guidelines:

- Generally, if the percent open boll is 60% or higher, it is safe to defoliate.
- For Upland or Acala, 4 to 5 NACB is the target for the first harvest aid.
- For Pima, 3 to 4 NACB is the target for defoliant timing.

BEST CONDITIONS FOR EFFECTIVE DEFOLIATION

- Moderate to high air temperatures (daytime greater than or equal to 80 F, nighttime greater than 60°F)
- Relatively low plant and soil nitrogen levels
- Moderate soil water levels (plants not water stressed)
- Relatively uniform crop development; plants at vegetative cutout with limited or no regrowth
- Weeds, insects, and diseases under control
- Ability to get good chemical coverage and penetration of the chemicals into the plant canopy

Pay attention to the calendar, the weather, and consider how much risk you want to take when choosing a final harvest date. Use these steps:

1. Keep an eye on predicted trends in the weather.
2. Consider your own experience when determining the number of days needed for harvest.
3. Determine the last harvest date you consider to be an acceptable risk.
4. If using nodes above cracked boll (NACB) to determine readiness for harvest, recommended values are 3 NACB for Pima and 4 NACB for Acala and Upland varieties.

If the crop is late and it is not possible to wait to reach the recommended NACB values, count back 21 to 28 days from the desired harvest date to determine when to start with the defoliation program. In this case, the start of defoliation is independent of the maturity stage of the crop.

CROP ROTATION (5/13)

Rotate your cotton crop as needed with other field or vegetable crops to maintain soil productivity and reduce the incidence of various cotton pests such as nematodes, *Verticillium* wilt, seedling diseases, pink bollworm and other diseases. Different rotational crops impart different benefits to the soil and therefore to subsequent seasons of cotton production:

- **Pest resistant crops:** suppression of various cotton pests
- **Cereals:** have fibrous root systems that loosen compacted soil
- **Legumes** (such as alfalfa, beans)**:** add nitrogen to soil
- **Grain corn:** adds organic matter to soil
- **Vegetable crops:** contribute high fertilizer carryover

Rotation Crops for Reducing the Incidence of Various Cotton Pathogens.

	Nematodes	Seedling Diseases			
Rotational Crops	**Root-knot nematode**	**Verticillium wilt**	***Rhizoctonia* and *Pythium***	***Thielaviopsis basicola***	**Fusarium wilt**
Small grains and summer fallow	satisfactory	satisfactory	satisfactory	some	some
Winter small grains grown as silage	some	some	some	some	some
Resistant cowpea cultivars: California blackeye CB 46, CB 27, CB 50, and CB 5	satisfactory	satisfactory	minimal	some	some
Corn	satisfactory	satisfactory	satisfactory	satisfactory	some
Sorghum and sudangrass	satisfactory	satisfactory	satisfactory	satisfactory	some
Alfalfa	satisfactory	some	satisfactory	some	some
Onions and garlic	minimal	satisfactory	minimal	satisfactory	some
Clean fallow (weed-free)	some	some	some	some	minimal
Root-knot-resistant cultivars of processing tomatoes	some	minimal	minimal	minimal	race 1: satisfactory race 4: some

Key to ratings:
satisfactory = significant suppressive activity but does not control
some = has an inhibitory effect but less than satisfactory
minimal = has very little effect

SELECTIVITY OF INSECTICIDES AND MITICIDES (5/13)

Integrated pest management (IPM) makes use of all available control strategies, including cultural, host plant resistance, biological, and chemical controls to manage pests. Natural enemies are an extremely important component of integrated pest management of cotton insects and mites. Common natural enemies include lacewings, big-eyed bugs, damsel bugs, minute pirate bugs, lady beetles, thrips, and several parasitic wasps. Lacewings, lady beetles, and parasitic wasps help control cotton aphids. Spider mite populations can be controlled by predatory mites and thrips. Lepidopterous larvae can be controlled or suppressed by several species of natural enemies. Research has shown that 99% of beet armyworm, cabbage looper, and cotton bollworm eggs and early-instar larvae are consumed by predators in fields that have a natural population of predators and parasites. Some insects, such as thrips, can be predators (feeding on spider mite eggs) as well as plant feeders. Generally, the beneficial aspects of thrips outweigh the damage to seedling cotton.

Insecticides and miticides are also a useful component of IPM programs and are effective for reducing crop damage during periods of pest outbreaks. Using selective insecticides and miticides to kill the target pest without killing natural enemies helps maximize as well as integrate chemical and biological controls. Selectivity usually arises from the specific chemical aspects of the insecticide. Nonselective insecticides and miticides, however, can be made more selective by careful application rates, timings, gallonages, and coverage to minimize killing natural enemies.

For most major cotton insect and mite pests, a number of pesticides are available that differ in their toxicity to natural enemies. Botanical, microbial, oil, or soap insecticides are relatively nondisruptive to most natural enemies. In some cases, selective insecticides and miticides may not control pest populations as well as nonselective materials. However, use of selective materials for treatments, especially early in the season, allows natural enemies to survive, which in turn helps minimize outbreaks of pests such as mites and aphids later in the growing season.

Nonselective insecticides and miticides leave residues on the plant that may be toxic to predators and parasites for days to weeks following application, depending on the persistence of the product. Products that have a short residual effect on natural enemies are favored for IPM programs. Consider both the short-term and long-term effects of an application when selecting an insecticide treatment.

The table on SELECTIVITY AND PERSISTENCE OF KEY COTTON INSECTICIDES AND MITICIDES details information on the selectivity of a chemical, an important factor to consider when selecting a treatment. This includes the effect the material has on nontarget species, its persistence in the environment, and its toxicity to both the pest and to natural enemies.

SELECTIVITY AND PERSISTENCE OF KEY COTTON INSECTICIDES & MITICIDES (5/13)

Product (Common name)	Selectivity	Persistence to Pest	Persistence to Natural enemies	Major Target Pests
Acramite (bifenazate)	high	short	short	mites
Admire Pro (imidacloprid)	high	moderate	short	aphids, lygus bug
Asana (esfenvalerate)	low	long	moderate	loopers, beet armyworm, other caterpillars
Assail (acetamiprid)	high	moderate to long	short	whiteflies, aphids
Agri-Mek 0.15 EC (abamectin)	high	long	moderate	mites**
Bacillus thuringiensis	high	short	short	loopers, beet armyworm
Baythroid (beta–cyfluthrin)	low	long	moderate	lygus bug, beet armyworm, looper
Belay (clothianidin)	low	moderate	long	lygus bug, aphids
Brigade (bifenthrin)	low	long	long	lygus bug***, whiteflies, beet armyworm, looper
Carbine (flonicamid)	high	moderate	short	lygus bug, aphids
Comite (proparite)	high	moderate	short	mites**
Centric (thiamethoxam)	high	moderate	short	whiteflies, aphids
Coragen (chlorantraniliprole)	high	unknown	short	primarily caterpillars
Courier (buprofezin)	high	long	long	whiteflies
Cruiser[1] (thiamethoxam)	high	moderate to long	short	thrips, mites, lygus bug
Danitol (fenpropathrin)	low	long	moderate	whiteflies, lygus bug***
Diamond (novaluron)	moderate	moderate	moderate	lygus bug, beet armyworm, loopers
Dimethoate (dimethoate)	moderate	short	short	lygus bug***, aphids, thrips
Dimilin (diflubenzuron)	high	moderate	short	beet armyworm, other caterpillars
Fujimite (fenpyroximate)	high	moderate	short	mites
Fulfill (pymetrozine)	high	short	short	aphids
Gaucho[1] (imidacloprid)	moderate	long	moderate	aphids, thrips
Gossyplure	high	moderate	none	pink bollworm
Intrepid (methoxyfenozide)	high	moderate	moderate	beet armyworm, other caterpillars
Dicofol (dicofol)	high	moderate	short	mites**
Knack (pyriproxyfen)	high	long	short	whiteflies
Lannate (methomyl)	low	short	short	loopers, beet armyworm, aphids
Leverage (imidacloprid+beta-cyfluthrin)	low	long	moderate	lygus bug, aphids
Malathion (malathion)	low	short	short	grasshoppers
Mustang (zeta-cypermethrin)	low	long	moderate	lygus bug, beet armyworm, loopers
Neemix (azadirachtin)	moderate	short	short	aphids, whiteflies
Oberon (spiromesifen)	high	moderate	moderate	mites, whiteflies
Oils	low	short	short	aphids, whiteflies
Onager (hexythiazox)	high	moderate	short	mites
Orthene[2] (acephate)	low	moderate	moderate	thrips, lygus bug, loopers, whiteflies
Orthene[1] (acephate)	high	moderate	short	thrips, aphids
Radiant (spinetoram)	high	moderate	short	thrips
Sivanto	high	moderate	short	aphids, whiteflies
Soaps	low	short	short	aphids, whiteflies
Steward (indoxacarb)	moderate	moderate	moderate	beet armyworm, loopers, lygus bug****
Success, Entrust (spinosad)	high	moderate	short	beet armyworm, other caterpillars
Sulfur (sulfur)	high	short	short	mites

(continued next page)

aldicarb: at plant	high	long	moderate	mites, aphids, thrips
aldicarb: sidedress	high	long	short	lygus bug, aphids, mites
Thimet: at plant (phorate)	high	moderate	moderate	mites, aphids, thrips
Venom (dinotefuran)	moderate to high	moderate	short	whiteflies, aphids, plant bugs
Vydate (oxamyl)	low	moderate	moderate	whiteflies, lygus bug
Warrior, etc. (lambda-cyhalothrin)	low	long	moderate	lygus bug, beet armyworm, looper
Zeal (etoxazole)	high	moderate	—	mites

[1] seed treatment

** resistance in some twospotted and Pacific spider mite populations

Product (Common name)	Selectivity	Persistence to Pest	Persistence to Natural enemies	Major Target Pests
[2] foliar treatment			***	resistance in some lygus bug populations
*	resistance in some cotton aphid populations		****	suppression

Acknowledgments: This table was compiled based on research data and experience of University of California scientists who work on a variety of crops and contribute to the Pest Management Guideline database, and from Flint, M. L. And S. H. Dreistadt. 1998. *Natural Enemies Handbook: An Illustrated Guide to Biological Pest Control*, ANR Publication 3386.

SUMMARY OF CHARACTERISTICS FOR KEY COTTON INSECTICIDES & MITICIDES (5/13)

Trade Name	Common name	Restricted Entry Interval	Preharvest Interval	Chemical Class	Mode of Action[1]	Hazards to Adult Bees[2]	Residual Toxicity to Adult Bees
Acramite	bifenazate	12 hours	60 days	bifenazate	un	II	—
Admire Pro	imidacloprid	12 hours	14 days	neonicotinoid	4A	I	3.5 days
Asana	esfenvalerate	12 hours	21 days	pyrethroid	3A	I	<1 day
Assail	acetamiprid	12 hours	28 days	neonicotinoid	4A	II	—
Agri-Mek 0.15 EC	abamectin	12 hours	20 days	avermectin	6	I	0.5 day
Various	Bacillus thuringiensis ssp. Aizawai	4 hours	0	biological	11A	II	—
Various	Bacillus thuringiensis ssp. kurstaki	4 hours	0	biological	11A	III	—
Baythroid	beta–cyfluthrin	12 hours	0	pyrethroid	3A	I	>1 day
Brigade	bifenthrin	12 hours[3]	14 days	pyrethroid	3A	I	1 day
Carbine	flonicamid	12 hours	30 days	selective feeding blockers	9C	III	—
Centric	thiamethoxam	12 hours	21 days	neonicotinoid	4A	I	—
Comite	propargite	6–7 days	50 days	sulfite	12C	III	—
Courier	buprofezin	12 hours	21 days	insect growth regulator	16	II	—
Cruiser	thiamethoxam (seed trt.)	12 hours	—	neonicotinoid	4A	—	—
Danitol	fenpropathrin	24 hours	21 days	pyrethroid	3A	I	1 day
Diamond	novaluron	12 hours	30 days	chitin inhibitor	15	I	—
Dibrom	naled	48 hours	—[5]	organophosphate	1B	I	1.5 days
Dimethoate	dimethoate	48 hours	14 days	organophosphate	1B	I	3.5 days
Dimilin	diflubenzuron	12 hours	14 days	benzoylphenyl urea	15	II	—
Fujimite	fenpyroximate	12 hours	14 days	METI acaricide	21A	III	—
Fulfill	pymetrozine	12 hours	21 days	—	9B	II	<2 hours
Gaucho	imidacloprid (seed trt.)	—	—	neonicotinoid	4A	III	—
Intrepid	methoxyfenozide	4 hours	14 days	insect growth regulator	18	II	—
Dicofol	dicofol	12 hours	30 days	dicofol	un	III	—
Knack	pyriproxyfen	12 hours	28 days	insect growth regulator	7C	II	—
Lannate	methomyl	72 hours	15 days	carbamate	1A	I	1.5 days
Leverage	imidacloprid+beta-cyfluthrin	12 hours	14 days	neonicotinoid+pyrethroid	4A+3A	I	—
malathion	malathion	12 hours	0	organophosphate	1B	I	2 days
Monitor	methamidophos	2-3 days[4]	50 days	organophosphate	1B	I	>5 days[6]
M-Pede	soaps	12 hours	0	miscellaneous	un	III	—
Mustang	zeta-cypermethrin	12 hours	14 days	pyrethroid	3A	I	<1 day
Neemix	azadirachtin	4 hours	0	botanical	un	II	—
Oberon	spiromesifen	12 hours	30 days	tetronic acid derivatives	23	II	—
Oil	oils	4 hours	0	miscellaneous	—	—	—
Onager	hexythiazox	12 hours	35 days	thiazolidinone	10A	II	—

(continued next page)

Trade Name	Common name	Restricted Entry Interval	Preharvest Interval	Chemical Class	Mode of Action[1]	Hazards to Adult Bees[2]	Residual Toxicity to Adult Bees
Orthene	acephate (foliar)	24 hours	21 days	organophosphate	1B	I	2.5 days
Sivanto	flupyradifurone	12 hours	14 days	butenolide	4D	II	—
Steward	indoxacarb	12 hours	14 days	oxadiazine	22A	I	—
Success	spinosad	4 hours	28 days	naturalyte	5	II	<2 hours
sulfur	sulfur	24 hours	0	miscellaneous	un	III	—
various	aldicarb	48 hours	90 days	carbamate	1A	I	—
Thimet	phorate	2-3 days[4]	60 days	organophosphate	1B	III	1 day
Venom	dinotefuran	12 hours	14 days	neonicotinoid	4A	I	—
Vydate C-LV	oxamyl	48 hours	14 days	carbamate	1A	I	4 days
Warrior, etc.	lambda-cyhalothrin	24 hours	21 days	pyrethroid	3A	I	—
Zeal	etoxazole	12 hours	28 days	—	10B	II	—

> = greater than < = less than — = information not available

[1] Rotate insecticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. Mode-of-action group numbers for insecticides and miticides (un=unknown or uncertain mode of action) are assigned by IRAC (Insecticide Resistance Action Committee). For more information, see https://irac-online.org.

[2] Ratings are as follows: I–Do not apply or allow to drift to plants that are flowering, including weeds. Do not allow pesticide to contaminate water accessible to bees, including puddles. II–Do not apply or allow to drift to plants that are flowering, including weeds, except when the application is made between sunset and midnight if allowed by the label and regulations. Do not allow pesticide to contaminate water accessible to bees, including puddles. III–No bee precaution, except when required by the label or regulations. For more information about pesticide synergistic effects, see *Bee Precaution Pesticide Ratings*. (Available online at https://ipm.ucanr.edu/bee-precaution-pesticide-ratings/.)

[3] Restricted entry interval is 7 days for cotton scouts.

[4] Determined by amount of yearly rainfall; see label.

[5] Do not apply after bolls open.

[6] Brood poison at lower doses.

TRANSGENIC COTTON (5/13)

Transgenic, Herbicide-Tolerant Cotton

Herbicide-tolerant cotton varieties provide growers a weed management option that can both reduce weed control costs and provide effective control of hard-to-control weeds such as nutsedge, nightshades and annual morningglory. The two types of herbicide-tolerant cotton available are Roundup Ready and Liberty Link varieties. Roundup Ready varieties comprise about 50% of the Acala and Upland cotton acreage, whereas Liberty Link cotton is planted on limited acres. Approximately 80 percent of Pima acreage is glyphosate herbicide-tolerant.

There are several glyphosate-tolerant varieties available, all genetically engineered to tolerate over-the-top applications (from the time the cotyledons appear to the emergence of the first true leaves) of glyphosate. Glyphosate provides excellent control of the many winter and summer annual weeds associated with cotton as well as suppressing or controlling many perennials. With Roundup Ready Flex systems, glyphosate can be applied postemergence until seven days before harvest, which provides increased crop safety and enhances flexibility. Either over-the-top or postdirected (post-crop emergence, directed at weeds) applications can be made, depending on the type of coverage needed for best weed control. There are no restrictions on timing of sequential applications, and insecticides and mepiquat can be tank mixed, if needed, with over-the-top applications.

The Liberty Link system uses glufosinate (Rely), which has a different mode of action than glyphosate—an important consideration in preventing the development of herbicide resistance. Rely provides broad-spectrum weed control and has no growth restrictions for over-the-top applications or rotational restrictions. Glufosinate can also be applied postdirected with hooded sprayers to non-Liberty Link cotton. At this time there are few varieties available for California with this trait.

Weed Resistance Concerns

Potential for weeds to develop resistance to specific herbicides is always a concern with herbicide programs, but with transgenic herbicide-tolerant cotton, weed resistance is of greater concern.

Glyphosate is an herbicide that controls many weeds, including hard-to-control species. Because the potential to reduce weed control costs by using glyphosate exclusively is so great, a real potential exists for the rapid development of weed resistance. Researchers in California have identified glyphosate-resistant ryegrass species (*Lolium rigidum*) as well as horseweed and hairy fleabane (*Conyza* spp.). Also, while not confirmed as having resistance to glyphosate, lambsquarters (*Chenopodium album*) and pigweeds (*Amaranthus* spp.) are becoming more difficult to control with glyphosate.

No matter which type of production system is used, conventional versus no-till or standard versus herbicide-tolerant varieties, a well-balanced, long-term weed management approach will incorporate resistance management strategies. Management strategies should include crop rotation, rotation of herbicides that have different modes of action, herbicide combinations, and control of escaped weeds by tillage or hand removal in order to delay or prevent development of resistant weeds.

Insects and Mites

(Section reviewed 5/13)

ALFALFA AND CABBAGE LOOPERS (5/13)

Scientific Names: Alfalfa looper: *Autographa californica*
Cabbage looper: *Trichoplusia ni*

DESCRIPTION OF THE PESTS

Alfalfa and cabbage loopers are quite similar in appearance. The greenish larvae crawl by arching their bodies and are 1 to 1.5 inches long when mature. Looper eggs are similar to those of the bollworm in that they are spherical with vertical ridges from top to bottom. However, looper eggs are more flattened and have finer ridges. Alfalfa looper is usually found in May and early June while cabbage looper appears in late June through September.

DAMAGE

Loopers feed on leaves, but the resulting ragged appearance of leaves is not important unless it is very extensive (more than 50%) and occurs during squaring. June defoliation is seldom sufficiently extensive to cause economic damage to cotton.

MANAGEMENT

Loopers are seldom numerous enough to cause significant damage and are usually kept under control by natural enemies. Moderate populations of loopers may be more beneficial than harmful, as they support populations of natural enemies that also attack the more destructive bollworms, budworms, and beet armyworms. In most cases, control is needed only where insecticides applied for other pests have reduced natural enemy populations; in the San Joaquin Valley, cabbage loopers often increase in numbers following treatment for lygus bugs. Occasionally, however, widespread outbreaks occur, apparently as a result of unusually favorable weather.

Biological Control

Many predators and parasites combine to substantially maintain looper populations at low levels. The eggs and small larvae are attacked by bigeyed bugs, minute pirate bugs, and other predators. *Trichogramma* parasites kill the eggs, and several other parasites, especially *Hyposoter exiguae* and *Copidosoma truncatellum*, attack the larvae. Loopers are also subject to a nuclear polyhedrosis virus that can reduce populations rapidly.

Cultural Control

The use of *Bt* cotton will help to reduce damage by loopers. A recently developed transgenic cotton, Bollguard II, offers suppression of a broader range of caterpillars than earlier *Bt* varieties and will also control caterpillars such as beet armyworms, cotton bollworm, pink bollworm, and tobacco budworm, which were not controlled by the earlier *Bt* varieties.

Organically Acceptable Methods

Biological control and sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad are acceptable for use on organically grown cotton.

Monitoring and Treatment Decisions

Damage by loopers is not important unless it is very extensive and occurs when it will affect the supply of energy to fruit. During the most vulnerable period, from first square to first open boll, plants can lose 20 to 25% of their leaf area without a reduction in yield. Before and after this period, plants can tolerate a loss of about half of the leaf area.

When loopers are numerous, ragging of leaves is usually obvious, and you will probably find the larvae while sweeping for lygus bugs or monitoring for other pests. Smaller loopers feed on older leaves where they are easily sampled using a beating sheet. Spread a 40-inch square piece of cloth between two rows of cotton and vigorously shake an arm's length of plants from one row onto the sheet. Lay the plants back and look for worms that are looping on the cloth. There are no specific treatment thresholds for loopers. If you find large numbers, check for signs of virus disease before applying an insecticide. Insecticides used for control, including *Bacillus thuringiensis*, are effective mainly against young larvae. Spot treatments are usually adequate for infestations on seedlings.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. BACILLUS THURINGIENSIS ssp. KURSTAKI#
(various products) — Label rates — 4 — 0
SELECTIVITY: High
PERSISTENCE (PEST): Short; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 11
COMMENTS: Ground or air application. Not harmful to natural enemies.

B. METHOXYFENOZIDE
(Intrepid 2F) — 4–10 fl oz — 4 — 14
SELECTIVITY: High
PERSISTENCE (PEST):Moderate
PERSISTENCE (NE[2]): Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 18
COMMENTS: An insect growth regulator.

C. INDOXACARB
(Steward) — Label rates — 12 — 14
SELECTIVITY: Moderate
PERSISTENCE (PEST): Moderate; PERSISTENCE (NE[2]): Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 22A

D. SPINOSAD
(Entrust)# — 1.25–2 oz — 4 — 28
(Success) — 4–6 fl oz — 4 — 28
SELECTIVITY: High
PERSISTENCE (PEST): Moderate; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Use of Success allowed under a supplemental 24(c) label.

E. NOVALURON
(Diamond 0.83EC) — 6–12 fl oz — 12 — 30
SELECTIVITY: Moderate to High
PERSISTENCE (PEST): Moderate; PERSISTENCE (NE[2]): Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 15
COMMENTS: A chitin inhibitor.

F. CHLORANTRANILIPROLE
(Coragen) — 5.0–7.5 fl oz — 4 — 21
SELECTIVITY: High
PERSISTENCE (PEST): unknown; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 28

G. ACEPHATE
(Orthene 97) — Label rates — 24 — 21
SELECTIVITY: Low
PERSISTENCE (PEST): Moderate; PERSISTENCE (NE[2]): Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: Severe spider mite infestations may follow use as foliar spray.

H. METHOMYL*
(Lannate SP) — 0.12–0.25 lb — 72 — 15
SELECTIVITY: Low
PERSISTENCE (PEST): Short; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Kills eggs and larvae. Use may redden cotton. According to the label, do not make more than 8 applications per crop. Do not graze or feed cotton trash to livestock.

* Permit required from county agricultural commissioner for purchase or use.
** Mix with sufficient water to provide complete coverage.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown cotton.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

BEET ARMYWORM (9/15)

Scientific Name: *Spodoptera exigua*

DESCRIPTION OF THE PEST

Beet armyworm larvae are 1 inch long when fully grown. They are usually dull green but color can vary from pale to dark green with wavy, light-colored stripes running down the back and a broader pale stripe along each side. They usually have a dark spot on each side of the body above the second pair of true legs. Eggs are laid in clusters. These clusters are covered with dirty white, hairlike scales, forming a cottony covering. Adult beet armyworms are mottled gray and brown moths with a wingspan of a little over 1 inch. There are three to five generations a year. The pupa is the overwintering stage, but all stages may be present throughout the year in the low desert agricultural production valleys of southeastern California.

DAMAGE

Beet armyworm destroys seedlings, terminals of young plants, and squares and small bolls during early July. Early season infestations may develop on weeds and move to cotton when weeds are controlled, destroying seedling cotton or the terminals of older plants. As cotton plants grow, young larvae skeletonize leaves and bracts, often spinning loose webbing over the feeding site. Older larvae chew irregular holes in leaves and also feed on squares, flowers, and bolls. Square damage by the beet armyworm differs from bollworm damage in that the surrounding bracts and foliage are often damaged by the beet armyworm but not by bollworm. The loss of a majority of squares and bolls during July or August may reduce yield or delay maturity by delaying fruit set. Severe defoliation may cause crop loss as well.

MANAGEMENT

In addition to cotton, beet armyworms feed on alfalfa, vegetables, sugarbeets, beans, and weeds such as pigweeds (*Amaranthus* spp.) and nettleleaf goosefoot (*Chenopodium murale*). In occasional years, there may be widespread outbreaks when favorable weather allows exceptionally large populations to build up early in the season on alternate hosts. Damaging populations may also occur where insecticides applied for other pests reduce natural enemy populations. Watch for beet armyworm on adjacent crops and on weeds in and around the field. If many larvae are present on weeds while cotton plants are small, it may be worthwhile to use an insecticide to kill them before destroying the weeds. Otherwise, they could move to the seedlings and cause stand loss. Treatment of a limited area, such as a strip at the edge of the field, is usually successful. When selecting an insecticide from a group of effective products, always select the insecticide that is least harmful to natural enemies.

Biological Control

Many predators and parasites combine to substantially maintain armyworm populations at low levels. Predators include assassin bugs, bigeyed bugs, spiders, minute pirate bugs, damsel bugs, and lacewings. The parasitic wasp, *Hyposoter exiguae*, is believed to be the most important of at least 10 parasites attacking this pest; other parasitic wasps include *Trichogramma* spp. And *Cotesia marginiventris.* Virus and bacterial diseases can also be important. Insecticide sprays for other pests may disrupt natural control.

Cultural Control

A recently developed transgenic cotton, Bollguard II, offers suppression of a broader range of caterpillars, such as beet armyworms, cotton bollworm, pink bollworm, and tobacco budworm, than earlier Bt varieties (Bollguard I).

Organically Acceptable Methods

Biological control and applications of *Bacillus thuringiensis* and the Entrust formulation of spinosad are acceptable for use on organically grown cotton.

Resistance

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

- Monitor pests and maximize the use of biological and cultural controls.
- Spray only when pest numbers warrant an application.
- Use the most selective insecticides first to conserve natural enemy populations so they help with the control of pests.
- Do not use insecticides with the same mode of action number on successive beet armyworm generations.

The following table provides insecticide resistance management guidelines.

Insecticide Resistance Management Guidelines for Beet Armyworm.

Insecticide Class	Mode of Action[1]	Early Season April to Mid-June	Mid-season Mid-June through July	Late Season August through Sept.
Bacillus thuringiensis ssp. *Aizawai*	11	various products	various products	NA
insect growth regulators	18 15	Intrepid[2] Diamond	NA	Intrepid[2]
carbamate	1A	NA	Lannate	Lannate
miscellaneous	22A 5	Steward Success	Steward Success[3]	NA
pyrethroid[4]	3	NA	NA	Brigade, Asana

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

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action Group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at https://irac-online.org.

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

3 If not used previously.

4 Pyrethroids are suggested only late in season to avoid aphid and spider mite disruptions.

NA Not applicable.

Monitoring and Treatment Decisions

Early in the season, plants can sustain up to 50% loss of leaf surface without affecting yield. During the fruiting period, only 20 to 25% of the leaf surface can be lost without yield loss. After this period, up to 50% loss of leaf surface can again be tolerated. If beet armyworms build up on weeds in areas adjacent to the crop, consider treating a strip at the edge of the field to prevent entry into cotton.

When taking sweep net samples for lygus bug, also look for beet armyworm egg masses. The egg masses are covered with grayish white, hairlike scales and are laid on upper leaf surfaces in the upper plant canopy, but below the terminal area. Also watch for clusters of small, greenish caterpillars that feed in groups in leaf folds that are webbed together. To determine the actual number of caterpillars present, lay a 40-inch square piece of canvas between the rows and vigorously shake an arm's length of plants from one row onto the canvas. Count the number of armyworms on the canvas. There is no set treatment threshold for beet armyworm; it is up to the grower, based on past history and overall crop conditions, to determine if beet armyworm is causing significant economic losses to justify a treatment.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A.	BACILLUS THURINGIENSIS ssp. AIZAWAI# (various products) SELECTIVITY: High PERSISTENCE: PEST: Short NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 11A COMMENTS: Does not disrupt natural enemies.	Label rates	4	0
B.	METHOXYFENOZIDE (Intrepid 2F) SELECTIVITY: High PERSISTENCE: PEST: Short NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 18 COMMENTS: An insect growth regulator.	4–10 fl oz	4	14

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
C. CHLORANTRANILIPROLE			
(Coragen)	3.5–7.0 fl oz	4	21
SELECTIVITY: High			
PERSISTENCE: PEST: unknown NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 28			
D. SPINOSAD			
(Entrust)#	1.25–2 oz	4	28
(Success)	4–6 fl oz	4	28
SELECTIVITY: High			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 5			
COMMENTS: Use of Success allowed under a supplemental 24(c) registration			
E. INDOXACARB			
(Steward)	Label rates	12	14
SELECTIVITY: Moderate			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 22A			
COMMENTS: An oxadiazine.			
F. DIFLUBENZURON*			
(Dimilin 25W)	Label rates	12	14
SELECTIVITY: High			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 15			
COMMENTS: An insect growth regulator. Do not exceed 6 applications or 24 oz per season.			
G. NOVALURON			
(Diamond 0.83EC)	6–12 fl oz	12	30
SELECTIVITY: Moderate to High			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 15			
COMMENTS: A chitin inhibitor.			
H. BIFENTHRIN*			
(Brigade 2EC)	3.8–6.4 fl oz	12	14
SELECTIVITY: Low			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 3A			
COMMENTS: A pyrethroid. Apply in a minimum of 5 gal water/acre with ground equipment or 1 gal/acre by air. When applying by air, 1 qt of emulsified oil may be substituted for 1 qt water in the finished spray. May also be applied in refined vegetable oil. Do not apply more than 0.3 lb a.i./acre per season or make more than 3 applications per season. Do not graze livestock in treated areas or cut treated crops for feed. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
I. ESFENVALERATE*			
(Asana XL)	5.8–9.6 fl oz	12	21
SELECTIVITY: Low			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 3A			
COMMENTS: A pyrethroid. Do not graze or feed trash to livestock. Very destructive to natural enemies; can result in buildup of spider mites, and is not recommended in San Joaquin Valley. Do not exceed 0.5 lb a.i./acre per season. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
J. METHOMYL*			
(Lannate SP)	0.12–0.25 lb	72	15
SELECTIVITY: Low			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 1A			

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

COMMENTS: A carbamate. Kills eggs and larvae. Use may redden cotton. According to the label, do not make more than 8 applications per season. Do not graze or feed cotton trash to livestock. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

\# Acceptable for use on organically grown cotton.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

COTTON APHID (9/15)

Scientific Name: *Aphis gossypii*

DESCRIPTION OF THE PEST

Cotton aphid is the most common aphid on cotton in California and it can be present at any time during the growing season. Cotton aphid is highly variable in body size and color, and adults may be winged or wingless. Nymphs and adults of wingless cotton aphids vary in color from yellow to green to nearly black. The darker forms tend to be substantially larger. Nymphs that are developing into winged adults look very different from the nymphs developing into wingless adults: they bear small welts or protuberances on their bodies and may be covered with a coat of dusty-appearing whitish wax. Their body color is often greenish blue, or amber and blue.

DAMAGE

The different forms of the cotton aphid differ in their ability to cause population outbreaks and plant damage, therefore it is important to be aware not only of the number of aphids present, but also of their color form. The small yellow aphids develop slowly from newborn nymph to adult and do not produce many offspring; thus, their populations rarely increase rapidly. The larger, darker aphids (green and black) are quite different; they develop more rapidly, produce many more offspring in a rapid burst, and can generate rapid population growth rates.

Additionally, damage caused by cotton aphid varies seasonally with the growth stage of the plant.

Presquaring (Early Season)

Heavy populations on seedling cotton can cause crinkling and cupping of leaves leaves, failing to expand, defoliation, and a severe stunting of seedling growth. In addition, honeydew contamination on leaves may make the leaves appear wet and shiny. Cotton appears to be able to compensate fully for early season damage as long as the aphid feeding ceases.

Squaring and Boll Production (Mid-season)

Low aphid numbers (<25 per leaf) on mid-season cotton often do not generate any obvious damage symptoms. High aphid numbers (>50 per leaf) create the same symptoms as observed on seedling cotton (cupped, crinkled leaves, honeydew accumulations, sooty mold, and in extreme cases, limited defoliation). High aphid numbers at this time can decrease the size of bolls, stunt plant growth, and may increase square and boll shedding.

From the Opening of the First Boll until Harvest (Late Season)

The cotton crop is most sensitive to cotton aphid damage at this time because honeydew can contaminate the exposed cotton lint, creating "sticky cotton". Aphid populations as low as 5 per leaf can result in honeydew deposition on lint.

MANAGEMENT

Generally, cotton aphid populations on seedling cotton plants (presquare) in most regions of the western United States are not considered a pest problem. However, some areas have consistently severe and prolonged problems with early season aphids. Growers in these areas may need to adopt a more aggressive approach to monitoring and controlling these pests, especially when their fields have a history of early season aphids persisting into the period when squares are produced and yield losses can occur.

Biological Control

During the pre-squaring period of the crop, natural control of aphids is generally strong. The parasitic wasp *Lysiphlebus testaceipes* and a group of aphid predators (including the lady beetles *Hippodamia convergens* and *Coccinella novemnotata franciscana* and the predatory larvae of syrphid flies) are important natural enemies.

During the period of square and boll production and continuing until harvest, parasitic wasps and coccinelid beetles may still be present, especially if aphids reach extremely high densities, but in most fields they are rare. The most common aphid natural enemies at this time are minute pirate bugs (*Orius tristicolor*), bigeyed bugs (*Geocoris* spp.), damsel bugs (*Nabis* spp.), a complex of green lacewings (*Chrysoperla* and *Chrysopa* spp.), and a fungus (*Entomophthora* sp.). Although these natural enemies do provide some control, they generally are not able to strongly suppress aphid populations, or cause strong suppression only after severe damage has occurred to the plant.

Augmentative releases of predatory green lacewings generally are not effective. Natural densities of lacewing eggs are often quite high, making it prohibitively expensive to achieve meaningful increases in egg densities through releases. Furthermore, lacewing larvae are generalist predators and will feed on (cannibalize) other green lacewings, reducing the effectiveness of augmentive releases to suppress aphids.

Cultural Control

Higher cotton aphid numbers consistently develop on late-planted cotton (late April to early May) when compared to early-planted cotton (early April). Additionally, aphids prefer cotton plants that are well watered and highly fertilized. Thus avoid excessive or poorly scheduled nitrogen applications that stimulate growth later in the cropping season.

Cultivar selection also appears to influence aphid population growth. Pima cultivars appear to be more susceptible to aphid infestations and associated damage. Within the Acala cotton cultivars, hairy-leaf varieties, which comprise the majority of the market, are more susceptible to aphids than are smooth-leaf varieties.

Organically Acceptable Methods

Cultural and biological controls and sprays of insecticidal soap, oils, and azadirachtin are acceptable for use on organically grown cotton.

Resistance

Chemical management of cotton aphid can be extremely erratic and unpredictable. Part of the problem is that cotton aphid has developed resistance to many chemical classes, including organochlorine, organophosphate, carbamate, and pyrethroid insecticides. In addition, these broad-spectrum pesticides kill the natural enemies of the cotton aphid. Another resistance concern is with the neo-nicotinoid insecticides. Repeated applications of any neonicotinoids can result in resistance to *all* neo-nicotinoids.

To manage resistance, follow the basic principles of IPM: (1) spray only when pests reach economic thresholds; (2) start with the most selective pesticides and avoid pyrethroids early in the season in order to preserve natural enemies; (3) save the broad-spectrum pesticides for mid- to late-season aphid outbreaks; and (4) rotate insecticides that have a different MODE-OF-ACTION GROUP NUMBER1 if you have to spray more than once. The following table summarizes these insecticide resistance guidelines.

Insecticide Resistance Management Guidelines for Cotton Aphids.

Insecticide Class	Mode of Action[1]	Seedling Cotton	Squaring to Boll Crack[2]	Boll Opening to Harvest[2]
Organophosphate (OP)	1B	Least disruptive OPs: Dibrom, Thimet (at planting)	Dibrom	—
Carbamate	1A	at planting	sidedress	Lannate
Neonicotinoid	4A	Gaucho (seed treatment) Cruiser (seed treatment)	Admire Pro (if not used previously), Centric, Assail	Assail
Unknown	9C		Carbine	

1 Rotate chemicals with a different mode-of-action Group number, and do not use products with the same mode-of-action Group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a Group number of 1B; chemicals with a 1B Group number should be alternated with chemicals that have a Group number other than 1B. Mode-of-action Group numbers are assigned by IRAC (Insecticide Resistance Action Committee). For additional information, see their Web site at https://irac-online.org.

2 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.

3 If significant aphid population is present, may need to apply an insecticide over-the-top during the period when aldicarb is being activated.

4 There are several products available and restrictions may be different between them. Check the label and contact Agricultural Commissioner if uncertain about any local restrictions.

Monitoring and Treatment Decisions

in some areas along the eastern edge of the southern San Joaquin Valley (especially eastern Tulare County) early season aphids can be a persistent problem. If early season populations have a history of being severe, a seed treatment may be warranted; otherwise, seed treatments are not usually applied for cotton aphid control.

Because research has shown that cotton aphids can be stimulated by pyrethroids and increase in numbers, be sure to carefully monitor for aphids following application of pyrethroid insecticides.

The critical time for monitoring aphids is from crop emergence through preharvest. To improve the efficiency of your monitoring program, combine sampling of aphids with monitoring for other pests. From crop emergence to seedling growth, sample aphids, mites, and thrips together as described in MONITORING SPIDER MITES, APHIDS, AND THRIPS. From early squaring through boll development, combine sampling for aphids with monitoring for mites and whitefly as described in MONITORING SPIDER MITES, APHIDS, AND WHITEFLY. From first open boll to preharvest, combine sampling for aphids with whitefly monitoring as described in MONITORING APHIDS AND WHITEFLY. Monitoring forms are available on the online version of this guideline.

Make insecticide applications only when the cotton aphid population exceeds the economic threshold. Terminate the crop as early as feasible, using the nodes above cracked boll (NACB) method described in MONITORING PLANT GROWTH.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. ACETAMIPRID (Assail 70WP) — 0.6–1.1 oz — REI‡: 12 hours — PHI‡: 28 days
SELECTIVITY: High
PERSISTENCE: PEST: Moderate–Long NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Apply mid- to late season. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

B. FLONICAMID (Carbine 50WG) — 1.4–2.8 oz — REI‡: 12 hours — PHI‡: 30 days
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 9C

C. FLUPYRADIFURONE (Sivanto 200SL) — 7–10.5 fl oz — REI‡: 12 hours — PHI‡: 14 days
SELECTIVITY:
PERSISTENCE: PEST: NE:[2]
MODE-OF-ACTION GROUP NUMBER[1]: 4D

D. IMIDACLOPRID (Admire Pro) — 0.9–1.7 fl oz — REI‡: 12 hours — PHI‡: 14 days
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Foliar application. Do not exceed 0.31 lb a.i./acre per season. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. THIAMETHOXAM (Centric 40WG) — 1.25–2.5 oz — REI‡: 12 hours — PHI‡: 21 days
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Apply mid- to late season. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

F. PYMETROZINE (Fulfill) — 2.75 oz — REI‡: 12 hours — PHI‡: 21 days
SELECTIVITY: High
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 9B
COMMENTS: Offers some suppression of whiteflies. Low toxicity to beneficial insects.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
G. NALED* (Dibrom 8E)	11.5pt	48	4

SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: An organophosphate. Tank mixing may affect the selectivity and persistence of this material. Do not apply more than 5 pt/acre per season. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

THE FOLLOWING THREE MATERIALS ARE ORGANICALLY ACCEPTABLE FOLIAR SPRAYS.

H. INSECTICIDAL SOAP# (M-Pede)	2.5 oz/gal	12	0

SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE OF ACTION: A contact insecticide with smothering and barrier effects.
COMMENTS: Spray to wet all infested plant surfaces and repeat treatments at weekly to biweekly intervals. Rotate sprays to avoid more than three consecutive sprays of this material.

I. NARROW RANGE OIL# (TriTek)	1–2 gal/ 100 gal water	4	0

SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE OF ACTION: Contact including smothering and barrier effects.
COMMENTS: Works by suffocating eggs, nymphs, and adults. Requires total spray coverage.

J. AZADIRACHTIN# (Neemix 4.5)	5–7 fl oz	4	0

SELECTIVITY: Moderate
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: un
COMMENTS: in an organically certified crop, restrictions apply regarding the use of this material.

SEED TREATMENTS (not usually required for cotton aphid)

A. IMIDACLOPRID (Gaucho 600F)	6.4 oz per 50 lb bag of seed	12	NA

SELECTIVITY: Moderate
PERSISTENCE: PEST: Long NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Seed treatment. May stimulate buildup of spider mites.

B. THIAMETHOXAM (Cruiser 5FS)	Label rates	12	NA

SELECTIVITY: High
PERSISTENCE: PEST: Moderate–Long NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Do not apply another neonicotinoid within 45 days of planting seed treated with Cruiser 5FS. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

Acceptable for use on organically grown cotton.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

NA Not applicable

COTTON BOLLWORM (5/13)

Scientific Name: *Helicoverpa zea*

DESCRIPTION OF THE PEST

Cotton bollworm moths are about 0.75 inch long, with a wing span of 1 to 1.5 inches. Eggs are spherical, flattened, with 10 to 15 perpendicular rows of toothed ribs. Newly hatched, first-instar larvae have several rows of dark tubercles along the back, each bearing one or two bristles. Larvae range from olive green to dark reddish brown in color and can be best distinguished from most other caterpillars (except the budworm) by the tiny spines, visible under a hand lens, that cover most of the body surface. Bollworm larvae must be at least in the third instar in order to be distinguishable from the budworm. The budworm has a toothlike structure on the inner surface of the mandibles that is lacking in the bollworm, and it has the tiny spines of the skin extending onto the tubercles on top of the eighth abdominal segment; in the bollworm, these tubercles lack spines.

DAMAGE

Cotton bollworm larvae damage bolls and squares. Larvae chew holes into the base of bolls and may hollow out locks. Moist frass usually accumulates around the base of the boll. Larvae may also chew shallow gouges in the boll surface, which can become infected with rot organisms. Squares injured by cotton bollworm usually have a round hole near the base. Fifth-instar larvae are the most destructive; they not only damage more fruit than do earlier instars, but they damage larger fruit that are harder for the plant to replace.

MANAGEMENT

The impact of a bollworm infestation depends on the number of larvae present, the age of the larvae, and the timing of damage relative to the crop's fruiting cycle. Although large larvae do most of the damage, it is not possible to kill a significant proportion of them once they are older than the third instar. Monitoring and control must therefore be aimed at the eggs and small larvae.

Natural enemies are very important in managing populations of bollworms, especially in the San Joaquin Valley. Damaging populations usually do not appear until late in the season, after treatments for other pests have disrupted natural enemies. Insecticides are needed only if the population exceeds the treatment threshold while the crop has a significant number of squares or green bolls that will have time to develop into mature bolls by season's end. There is no need to treat once bolls begin cracking, because most bolls are too mature by that time to be susceptible and squares still present will not have time to mature. The same principle applies to long-season desert valley crops, except that there are two periods when injury can occur – one in each fruiting cycle.

Biological Control

Many predators and parasites combine to substantially maintain cotton bollworm populations at low levels. Insecticide sprays for other pests will disrupt this natural control and may result in severe outbreaks of this pest.

Cultural Control

The use of transgenic cotton, Bollguard II, offers suppression of cotton bollworm, along with beet armyworms, pink bollworm, and tobacco budworms. Other forms of transgenic cotton (with 'Cry' proteins) are being developed and introduced into the commercial market.

Cotton bollworms are attracted to succulent, rank-growing cotton plants; keep water, fertilizer, and plant density at recommended levels to avoid rank growth. Because populations seldom reach damaging levels before late summer, manage the crop for early maturing and plan to defoliate by late September.

Organically Acceptable Methods

Biological and cultural controls and *Bacillus thuringiensis* applications are acceptable for use on organically grown cotton.

Monitoring and Treatment Decisions

In the San Joaquin Valley, start sampling plant terminals for bollworms as soon as bolls are present and continue until most bolls mature. Check five adjacent plants at each stop as you pass through the field. Choose the first plant at random; then check its mainstem terminal and those of the four plants next to it. For standard sampling select at least 100 plants.

There are two treatment thresholds for bollworms in the San Joaquin Valley. In fields that have not been treated with broad-spectrum insecticides, treat when you find 20 small bollworms per 100 plants. In fields that have been treated previously, treat when you find 8 small bollworms per 100 plants. Later instar larvae are the most destructive but are very resistant to insecticides; therefore, aim treatments at first or second instars.

In desert valleys, start sampling in mid-July, about 1 to 2 weeks after peak squaring. Continue sampling until most bolls have matured. In crops with a second fruiting cycle, continue until top crop bolls have matured. For standard sampling, check for larvae on the terminal growth of at least 100 plants chosen at random. Divide fields of up to 80 acres into quarters and check 25 plants in each quarter. Divide larger fields into more areas and check 25 plants in each area. The treatment threshold is 10 to 12 small budworm or bollworm larvae per 100 plants.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

SAN JOAQUIN VALLEY

A. BACILLUS THURINGIENSIS ssp. KURSTAKI#
(various products) — Label rates — 4 — 0
SELECTIVITY: High
PERSISTENCE: PEST: Short NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 11
COMMENTS: Not harmful to beneficials.

B. CHLORANTRANILIPROLE
(Coragen) — 3.5–7.0 fl oz — 4 — 21
SELECTIVITY: High
PERSISTENCE (PEST): unknown; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 28

C. METHOMYL*
(Lannate LV) — 0.4–0.75 pt — 72 — 15
(Lannate SP) — 0.12–0.25 lb — 72 — 15
SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Kills eggs and larvae. Use may redden cotton. According to the label, do not make more than 8 applications per season. Do not graze or feed cotton trash to livestock.

DESERT VALLEYS

A. BACILLUS THURINGIENSIS ssp. KURSTAKI#
(various products) — Label rates — 4 — 0
SELECTIVITY: High
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 11
COMMENTS: Not harmful to beneficials.

B. CHLORANTRANILIPROLE
(Coragen) — 3.5–7.0 fl oz — 4 — 21
SELECTIVITY: High
PERSISTENCE (PEST): unknown; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Do not apply more than 9 oz/acre/year or make more than 4 applications a year. Do not apply with less than 100 or more than 200 gallons water/acre.

C. ESFENVALERATE*

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
(Asana XL)	5.8–9.6 fl oz	12	21
SELECTIVITY: Low PERSISTENCE: PEST: Long NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 3 COMMENTS: Do not graze or feed trash to livestock. Very destructive to natural enemies; can result in buildup of spider mites and is not recommended in San Joaquin Valley.			

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown cotton.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

COTTON LEAF PERFORATOR (5/13)

Scientific Name: *Bucculatrix thurberiella*

DESCRIPTION OF THE PEST

Cotton leaf perforator is a pest only in the southern desert areas of California. Early larval instars of the cotton leaf perforator are flattened, yellow to orange caterpillars that bore into leaves and tunnel between leaf surfaces until the fourth instar. They can be distinguished from maggots of leafmining flies by looking with a hand lens for the presence of a head capsule and mandibles. The fourth instar emerges from the leaf and begins skeletonizing leaves. During the molt between the fourth and fifth instar, the larva forms a thin silk shelter and curls into a horseshoe shape inside the shelter. The fourth and fifth instars are green to gray, with two black spots and several smaller white spots on each segment.

DAMAGE

Leaves damaged by cotton leaf perforators have numerous windows, i.e., holes with a transparent membrane remaining on one side. Heavily infested leaves may be reduced to a network of veins. Most damage occurs in the top third of plants. Severe defoliation may cause bolls to open prematurely, and also cause shedding of squares and small bolls.

MANAGEMENT

Any practice that reduces the use of insecticides lessens the chance of a perforator outbreak. Follow the management guidelines for other pests to avoid unnecessary destruction of natural enemies.

Cultural Control

Early harvest and plowdown will help reduce overwintering populations. The use of Bt cotton can also help reduce damage by this pest.

Organically Acceptable Methods

Cultural controls and sprays of the Entrust formulation of spinosad are acceptable for use on organically grown cotton.

Monitoring and Treatment Decisions

Cotton leaf perforator moths can be monitored with pheromone traps to detect adult populations several weeks before damage occurs. A 1-milligram dispenser placed in a delta trap and hung 1 to 2 feet above ground is effective for 4 weeks. Infestations of cotton leaf perforators usually begin at the edges of a field or in sandy streaks where plants are stressed. Check these areas first for damage to upper leaves. A treatment guideline suggested in Arizona is to treat when 25 to 50 % of the leaves in the top half of the plants have one or more exposed larvae. Count only those larvae on the leaf surface, including horseshoe stage larvae; don't count leafmining instars. The guideline applies only during the part of the season when plants have yet to set a significant part of their boll load. Look for live larvae, not just damage.

Treatment timing is critical because sprays cannot reach leafmining instars or horseshoe-stage larvae. If infestations are severe, wait until most larvae are in the horseshoe stage, then spray within 2 days to kill the fifth instars when they emerge from their shelters. Spot treat infestations that are limited to certain parts of the field.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. ALDICARB*	14 lb	48	90
SELECTIVITY: High			
PERSISTENCE: PEST: Long NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 1A			

COMMENTS: Apply at layby by cultivation. Side-dress granules 8–16 inches to one side of the plant row, 2–6 inches deep. Do not graze or feed trash to livestock. Do not make more than 1 application at planting and 1 application after the crop has emerged. Six to 10-month plantback restrictions for crops not on label. Apply between March 1 and Sept. 1 only.

B.	ESFENVALERATE*			
	(Asana XL)	5.8 fl oz	12	21
	SELECTIVITY: Low			
	PERSISTENCE: PEST: Long NE:[2] Moderate			
	MODE-OF-ACTION GROUP NUMBER[1]: 3			
	COMMENTS: Do not graze or feed cotton forage. See label for plantback restrictions. Do not apply more than 0.5 lb a.i./acre during the growing season.			
C.	INDOXACARB			
	(Steward)	Label rates	12	14
	SELECTIVITY: Moderate			
	PERSISTENCE: PEST: Moderate NE:[2] Moderate			
	MODE-OF-ACTION GROUP NUMBER[1]: 22A			
D.	SPINOSAD			
	(Entrust)#	1.25–2 oz	4	28
	(Success)	4–6 fl oz	4	28
	SELECTIVITY: High			
	PERSISTENCE: PEST: Moderate NE:[2] Short			
	MODE-OF-ACTION GROUP NUMBER[1]: 5			
	COMMENTS: Use of Success allowed under a supplemental 24(c) label.			

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown produce.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

CUTWORMS (9/15)

Scientific names: Black cutworm: *Agrotis ipsilon*
Granulate cutworm: *Agrotis subterranea*
Variegated cutworm: *Peridroma saucia*

DESCRIPTION OF THE PESTS

Cutworm larvae vary in color, but they are usually dull gray, blend in with the soil, and always appear smooth skinned. The black cutworm larva is gray to dark brown above and has a greasy appearance. Faint light stripes run lengthwise down the body. It lives in soil and is usually not seen until damage is found. The granulate cutworm is about an inch long when mature, dark gray in color, and the surface of its body is covered with black granules. It lives in the soil and cuts plants off below ground. The variegated cutworm is a dark gray caterpillar with a light stripe on the side and small yellow to orange spots on top of the abdominal segments.

DAMAGE

Cutworm larvae chew young plants off at the base at or near ground level. Damage is usually limited to certain parts of a field and may reoccur each season in the same place. Usually several plants in the same row are damaged.

MANAGEMENT

Cutworms may become a problem if good field sanitation practices are not used and residue from a previous crop is allowed to remain in the field over the winter.

Cultural Control

Allow time for previous crop residues to decompose and destroy vegetation from weeds and cover crops for at least 3-4 weeks before planting to minimize the cutworm problem.

Monitoring and Treatment Decisions

Watch for cutworm injury by walking the field during the seedling stage. Pay special attention to field edges and any low or weedy areas. Use spot treatments, preferably with a ground rig, where treatment is necessary.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. INDOXACARB (Steward) SELECTIVITY: Moderate PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 22A COMMENTS: An oxadiazine. Use if granulate cutworm (Feltia subterranea) is present. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.	Label rates	12	14

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

DARKLING BEETLES (5/13)

Scientific Name: *Blapstinus* spp.

DESCRIPTION OF THE PESTS

Darkling beetle adults range from 0.12 to 0.25 inch (3–6 mm) long and are about half as wide. They are dirty black to rusty brown in color, but this may be obscured by dust or a thin layer of soil. Larvae are very similar to wireworms in appearance.

DAMAGE

Beetle adults girdle or cut off seedlings at or below the soil surface, and are mostly active at night. After plants reach a height of 4 to 6 inches, darkling beetles are usually not a problem. Darkling beetles sometimes invade cotton from grain fields, weedy areas, or from adjacent alfalfa.

MANAGEMENT

Watch for darkling beetle injury by walking the field during the seedling stage. Pay special attention to field edges and any low or weedy areas. Currently there are no bait products registered for control of darkling beetles in cotton.

FALSE CHINCH BUG (5/13)

Scientific name: *Nysius raphanus*

DESCRIPTION OF THE PEST

False chinch bugs are about 0.12 inch (3 mm) long, narrow bodied, and gray-brown. Immature bugs have inconspicuous red markings on the body. False chinch bugs often hide under plants or clods during the heat of the day. Do not confuse them with bigeyed bugs, which are wider with flatter heads. False chinch bugs migrate to cotton when cruciferous weed hosts dry up or are destroyed by cultivation; migration can be a concern for cotton fields near pastures or rangelands that are drying down for the summer.

DAMAGE

These bugs feed on seedlings. Individual bugs do little damage, but large migrations can severely injure or kill young plants in a few hours. Damage is usually confined to border rows.

MANAGEMENT

In cotton fields isolated from pastures, rangelands, or weedy fallow fields, early season control of cruciferous weed hosts within the field well before planting will eliminate the probability of this pest occurring in cotton. For fields adjacent to weedy areas, pastures, or rangelands, monitor for this pest during crop emergence and seedling growth. Monitoring nearby crops, fences, and weedy areas surrounding the field can serve as an early detection method for migrating bugs.

If damage from false chinch bugs reaches unacceptable levels, treatments to field edges are usually sufficient to control this pest.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. ESFENVALERATE* (Asana XL) SELECTIVITY: Low PERSISTENCE: PEST: Long NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 3 COMMENTS: Do not graze or feed cotton forage. See label for plantback restrictions. Do not apply more than 0.5 lb a.i./acre during the growing season.	5.8 fl oz	12	21
B. BETA–CYFLUTHRIN* (Baythroid XL) SELECTIVITY: Low MODE-OF-ACTION GROUP NUMBER[1]: 3	2.6 fl oz	12	0
C. ZETA-CYPERMETHRIN* (Mustang Max) SELECTIVITY: Low PERSISTENCE: PEST: Long NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 3	2.64–3.6 oz	12	14

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

FIELD CRICKETS (5/13)

Scientific name: *Gryllus* spp.

DESCRIPTION OF THE PESTS

Field crickets are about 1 inch long and are dark brown to black with stiff forewings, large folded fan-shaped hind wings, and enlarged hind legs for jumping. Field crickets are usually hidden, although males may be detected by their loud chirping.

DAMAGE

Crickets gouge and girdle stems of young plants, and may also feed on leaves. Feeding occurs at night; crickets hide during the day. Injury is significant only in occasional seasons, and most common in low deserts.

MANAGEMENT

Currently there are no bait products registered for control of field crickets in cotton.

GRASSHOPPERS (5/13)

DESCRIPTION OF THE PESTS

Grasshoppers can be occasional early season pests. In late summer and fall, grasshopper eggs are laid in grassy foothills, on ditchbanks, along roadsides and fence rows, in pasture areas, and in alfalfa fields. The eggs hatch in spring and the young nymphs feed on nearby plants. When wild grasses and other plants become dry, the grasshoppers migrate to irrigated croplands.

DAMAGE

Grasshoppers feed on foliage, most often on the edges of fields near pasture areas or roadsides. They seldom cause economically significant injury.

MANAGEMENT

Topical treatments are most effective; treating field borders may be adequate. Insecticidal baits are not effective in cotton itself but may be when applied to rangelands or other breeding grounds before grasshoppers migrate to crops.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. MALATHION (Malathion 8-E) SELECTIVITY: Low PERSISTENCE: PEST: Short NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: Limited residual effectiveness.	1.5–2 pt	12	0
B. NALED (Dibrom 8EC) SELECTIVITY: Low PERSISTENCE: PEST: Short NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: Apply before bolls open. Do not graze livestock in treated fields. Destructive of natural biological control. Tank mixing may affect selectivity and persistence of this material. Do not apply more than 5 pt/acre/season.	0.5–0.75 pt	48	See comments

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

LEAFHOPPERS (5/13)

Scientific Names: Potato leafhopper: *Empoasca fabae*
Southern garden leafhopper: *Empoasca solana*

DESCRIPTION OF THE PESTS

Several species of leafhoppers may occur on cotton. The southern garden leafhopper is most common in desert valleys, and the potato leafhopper is most common in the San Joaquin Valley. Only these two species cause economic damage. The potato leafhopper generally appears in cotton fields near potato fields in the Arvin-Edison area of Kern County and near the Sierra Nevada foothills in northern Kern, Tulare, and Fresno counties. Outbreaks of the southern garden leafhopper are most common near sugarbeet fields in the Imperial Valley.

Both species are identical in appearance; they can only be distinguished by examining their reproductive organs. Adults are pale green, wedge shaped, 0.12 inch (3 mm) long, with inconspicuous white spots on the head and pronotum. Adults fly or jump when disturbed. Nymphs (immatures) also have green wedge-shaped bodies and run rapidly forward, backward, or from side to side when disturbed. Their unique movement plus their bright color and shape distinguishes them from lygus bug nymphs and other slower moving insects like aphids.

DAMAGE

Adults and nymphs suck sap from veins on the undersides of mature leaves, mostly on the lower half of the plant. The midrib veins become roughened. Affected leaves may become distorted, leathery, and develop yellow or red blotches. Though rare, severe infestation may cause plants to shed squares and small bolls. Larger bolls may turn soft and spongy, and fail to mature. Other species cause leaf stippling.

MANAGEMENT

Natural enemies usually keep leafhoppers from building up large populations in cotton. However, if large numbers migrate to cotton from other hosts, treatment may be needed if extensive symptoms appear.

Monitoring and Treatment Decisions

There is no treatment threshold for leafhoppers. Before applying an insecticide, check for swollen, lumpy main veins on a sample of injured leaves to make sure the field symptoms are actually caused by leafhoppers.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. ALDICARB* — 10–14 lb — 48 — 90
SELECTIVITY: High
PERSISTENCE: PEST: Long NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: at layby by cultivation. Sidedress granules 8–16 inches to one side of the plant row, 2–6 inches deep. Do not graze or feed trash to livestock. Do not make more than 1 application at planting and 1 application after the crop emerges. Apply between March 1 and Sept. 1 only.

B. MALATHION 8E — Label rates — 12 — 0
SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: Ground or air application

C. IMIDACLOPRID (Provado 1.6F) — 3.75 fl oz — 12 — 14
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Foliar application. Do not exceed 0.31 lb a.i./acre/season.

D. ACEPHATE

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
(Orthene 97)	4 oz	24	21
SELECTIVITY: Low PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: An organophosphate. Do not graze or feed trash to livestock. Apply in water at 5–10 gal spray/acre by air or 10–25 gal spray/acre by ground. May induce outbreaks of spider mites.			
E. DINOTEFURAN (Venom)	1–3 oz	12	14
SELECTIVITY: Moderate to High PERSISTENCE: PEST: Moderate NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: A neonicotinoid. Kills lady beetles.			

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

LYGUS BUG (WESTERN TARNISHED PLANT BUG) (9/15)

Scientific name: *Lygus hesperus*

DESCRIPTION OF THE PEST

Lygus bug adults are about 0.25 inch long and 0.1 inch (2.5 mm) wide, and flattened on the back. They vary in color from pale green to yellowish brown with reddish brown to black markings, and have a conspicuous triangle in the center of the back. Nymphs resemble adults, but are uniformly pale green with red-tipped antennae; larger nymphs have five black spots on the upper body surface. Nymphs do not have wings. Other insects may be confused with lygus bugs, including beneficials such as the bigeyed bug.

DAMAGE

Lygus bugs can threaten a cotton crop from earliest squaring through cutout and final boll set. Lygus bugs pierce squares and damage anthers and other tissues. When squares are less than 0.2 inch (5 mm) long, they shrivel, turn brown, and drop from the plant. Damage to larger squares may be to anthers, styles, and stigma, and may interfere with fertilization. If many squares drop, the plant may put its energy resources into vegetative growth, resulting in tall, spindly plants and reduced yields. Lygus bugs also feed on and destroy terminal meristems, causing bushy plants. If these bugs pierce the wall of young bolls (typically less than 10 days old) and feed on young seeds, these seeds may fail to develop. Lint around the injured seeds is stained yellow, and may not mature normally.

MANAGEMENT

Lygus bugs migrate to cotton from other hosts, so management of this pest begins with assessing its populations outside the field. Check for them on weeds, in nearby alfalfa, and in other crops, and keep in touch with your pest control adviser, Extension agent or Farm Advisor for area-wide information on lygus bug populations. Proper management of alfalfa harvest can reduce damaging migrations to cotton. The need for insecticides in cotton must be evaluated carefully on a field-by-field basis, as treatments may result in secondary outbreaks of spider mites, aphids, or other pests.

Cultural Control

Other crops are more attractive to lygus bugs than cotton. These include alfalfa (seed and hay), safflower, sugarbeet, tomato, beans, potato, and occasionally oats. As these crops are prepared for harvest, winged adults migrate out of the field in search of new hosts. Careful management of these crops can reduce the migration of lygus bugs into cotton fields during cotton's most vulnerable period: mid-May through late July. Watch closely cotton fields that are downwind from these crops by sampling the cotton and surrounding fields often.

As a preferred host, alfalfa hay can be managed to minimize movement of lygus bugs into cotton by staggering cuttings to preserve habitat.

- Maintain nearby alfalfa fields in a succulent condition.
- Avoid cutting all alfalfa fields in an area within a short time period. Leave an uncut strip or check at each cutting along the border between alfalfa and cotton to slow lygus bug migration.
- If lygus bug numbers get very high, uncut strips of alfalfa may be treated with an insecticide if needed, but sprays should be avoided where possible to protect beneficials.

Mitigating Lygus Bug Movement through Alfalfa Forage Management

As a preferred host, alfalfa hay can be managed to minimize movement of lygus bugs into cotton by staggering cuttings to preserve alfalfa habitat. Leaving small, uncut strips at each harvest is very valuable in limiting the movement of lygus into neighboring cotton. Alfalfa strips also serve as reservoirs for predators and parasites that will eventually move into cotton and help suppress spider mites, lygus bugs, and worm pests. It is important to maintain nearby alfalfa fields in a succulent and vigorous condition to prevent large-scale release of lygus bugs. Avoid cutting all alfalfa fields in an area within a short time period. Staggering cutting will provide a mosaic of alfalfa growth stages. Within a field, leave uncut strips at each cutting in several locations in a field and along the border between alfalfa and cotton to slow lygus bug migration. The border strip may be used as a trap crop if lygus bug numbers are very high and threaten to move into cotton. If needed treat with an insecticide. Broad-spectrum insecticides should be avoided where possible to protect natural enemies.

Interplanting alfalfa and cotton has been successfully practiced in the past, drawing migrating lygus bugs away from cotton and concentrating it in alfalfa. This practice requires additional planning and management to avoid spilling lygus bugs from interplanted strips to cotton.

Black-eyed beans, easier to integrate into cotton production, have also been used successfully as a border crop to intercept and trap lygus bugs.

Weed Management

Lygus bugs have a wide host range of over 200 plants including many weeds. Russian thistle, black mustard, London rocket, wild radish, and goosefoot are good lygus bug hosts. When weedy fields and orchards are located near cotton, the lygus bug population in these fields may migrate when the weeds begin to dry. Avoid such migrations by removing the weeds before the population of lygus bugs reaches the winged adult stage. Before discing or mowing weeds, inspect them for the presence of lygus bugs and the stage of population development. If the population is already in the adult stage, migration will occur. Where possible, apply an insecticide before discing or drying the field.

Organically Acceptable Methods

Most of the cultural controls detailed above can be used to manage lygus bugs in organically certified cotton with the exception of treating weeds with an insecticide.

Resistance

Populations of lygus bugs from cotton, alfalfa hay, and alfalfa seed fields have developed resistance to certain organophosphate, carbamate, and pyrethroid insecticides. Pyrethroid resistance increased significantly in the late 1990s, shortening the residual period for lygus bug control following an application. To manage resistance in lygus bugs that are infesting cotton fields, spray as few times as possible and rotate between insecticides with a different mode-of-action group number. Remember that sprays applied for other pests such as aphids can select for resistance in lygus bugs if they are present, so these need to be considered in a rotation scheme when selecting an insecticide for lygus bugs.

Monitoring and Treatment Decisions

Consider fruit retention (in the San Joaquin Valley) as well as the results of sweep net samples when making treatment decisions.

Measuring Fruit Retention

In the San Joaquin Valley, begin monitoring fruit retention when five fruiting branches are present. Take weekly plant measurements from four different areas of the field to assess plant retention of squares. Randomly select 5 plants in each area (for a total of 20 plants). Count the following (diagram of a cotton plant *available online*):

- **The number of first-position squares present on the *top* five nodes**: Starting at the top of the plant, count the first mainstem leaf that is at least the size of a quarter dollar as the first node.
- **The number of retained fruit in the first position on the *bottom* five fruiting branches**: Until 10 fruiting branches are available, there will be overlap between the top five and the bottom five nodes.
- **The number of fruiting branches**: that is, those branches above the vegetative branches. (After the plant has developed more than 10 fruiting branches, counting fruit on the bottom fruit branches can be discontinued after 2 weeks if the average boll retention remains constant, assuming that no boll damage or loss due to bollworm and stink bug occurs.)

Determine the percent retention of first-position fruit for both the bottom and the top five fruiting branches by dividing the number of retained first-position fruit by the number of fruiting branches examined (20 plants X 5 fruiting branches = 100 branches) and multiply by 100.

> For example: If 60 first-position fruits were found on the bottom five fruiting branches of 20 plants, then 60 first-position fruits ÷ 100 fruiting branches = 0.60. Multiply this number by 100 to get percent retention (0.60 X 100 = 60%). Therefore, the percent retention for the bottom five branches is 60%. Do the same calculation to determine the percent retention of the top five fruiting branches.

Use the table in the online version of this guideline to determine the critical square retention based on the total number of fruiting branches and the percent fruit retention on the bottom five fruiting branches. Continue sampling for lygus bugs until monitoring nodes above white flower< indicates the plants are no longer susceptible to their damage.

Taking Sweep Net Samples
Begin sweep net samples for lygus bugs at first square, sampling twice a week in each field. Note that lygus bug populations may rise rapidly when they migrate in from drying weeds or safflower, harvested alfalfa, or other crops.

- Always use a standard net with a diameter of 15 inches. Take one sample in each quarter of the field in fields that are up to 8 acres. Take more samples in fields that are larger.
- Each sample consists of 50 sweeps across a single row of cotton. Walk briskly down the row and swing the net in front of you so that the lower edge of the rim strikes the plants at about 10 inches below the top. Keep the lower edge slightly ahead of the upper edge.
- Keep the sweeps far enough apart that you do not sweep plants that have already been jostled by the net. Sweeps that are too closely spaced may cause lygus bugs to fly or drop from the plants and thus be missed. Keep the net in motion to prevent adults from flying out.
- After each set of 50 sweeps, count all the lygus bugs in the net including nymphs, and record the number on a monitoring form. Do not confuse aphids or big-eyed bug nymphs with small lygus bug nymphs.
- Stop monitoring lygus bugs when Acala has 5 nodes about white flower (NAWF) and Pima has 3.5

Thresholds
Suggested thresholds are sliding thresholds, because lygus bug densities increase at a steady pace between late May and the end of June:

- Early Squaring (before 1st flower, until early June): >1 lygus bug per 50 sweeps
- Until June 15: <2 lygus bugs per 50 sweeps
- June 15-June 30: >2 lygus bugs per 50 sweeps
- Mid-Squaring (1st flower - 1st mature boll, beginning of July): 7-10 lygus bugs (at least 1 nymph) per 50 sweeps and expected or better fruit retention. If retention is higher than expected you may be able to wait and monitor again that week before making a treatment decision. If retention is lower than expected and lygus bugs are present, consider treating.
- Late Squaring (after 1st mature boll): 10 lygus bugs per 50 sweeps, including the presence of nymphs

The above thresholds are guidelines to be used with square monitoring, depending on the particular weather patterns. For example, during warm springs they are very reasonable, because cotton is setting fruit early and has high retention potential. Higher thresholds may also be applicable, if fewer samples than outlined above are taken.

In contrast, late plantings, vigorous cotton, and high plant populations promote lower fruit retention and therefore thresholds will be lower. Additionally, duration of fruit retention may vary according to the cotton cultivar present in the field. The longer the fruit is retained, the longer it will be attractive to lygus bug populations. Finally, success in retaining early squares will greatly determine the final yield; therefore protecting cotton during the early square formation period (June) is critical. Protection during the early season is very complex. Factors such as low lygus bug numbers, high susceptibility of cotton, and variability in sampling require the grower to be extremely vigilant and ready to act at an instant.

Insecticide Selection
There are two basic approaches to selecting an insecticide for lygus bug control.

First Approach
During early fruiting when monitoring indicates lygus densities are low and square retention is only slightly off (5%).

Under these circumstances, reinspect the field again in 3 days before making a control decision. Upon reinspection, if square retention continues to be slightly off normal and there is some migration in from surrounding areas, consider an insecticide that provides adequate control but has little residual effect on natural enemies. Examples of such insecticides include flonicamid (Carbine), novaluron (Diamond), indoxacarb (Steward), or oxamyl (Vydate).

Second Approach
Population densities of lygus bugs are high and there is the potential for repeated and sustained invasion or there is evidence of widespread reproduction. In addition, square retention is below the expected level and greatly reduced from previous inspections.

Insecticides that provide quick and residual protection are required; these include the pyrethroids (bifenthrin [Brigade], beta-cyfluthrin [Baythroid], imidacloprid plus cyfluthrin [Leverage], lambda-cyhalothrin [Warrior], zeta-cypermethrin [Mustang]) or a side dress of aldicarb combined with a quick-acting treatment such as an organophosphate (dimethoate, acephate [Orthene]), if required. Research has demonstrated the link between pyrethroid use and aphid population buildup, and this must be considered when planning to use one of these products.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. FLONICAMID
(Carbine 50WG) — 1.7–2.8 oz — 12 — 30
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 9C
COMMENTS: Very selective and has a low impact on beneficials.

B. INDOXACARB
(Steward) — Label rates — 12 — 14
SELECTIVITY: Moderate
PERSISTENCE: PEST: Moderate NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 22A

C. OXAMYL*
(Vydate C-LV) — 26–34 fl oz. — 48 — 14
SELECTIVITY: Low
PERSISTENCE: PEST: Moderate NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: A carbamate. Apply in sufficient refined vegetable oil (minimum 3 pt/acre) or in sufficient water to obtain thorough coverage. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

D. IMIDACLOPRID+BETA-CYFLUTHRIN*
(Leverage 360) — Label rates — 12 — 14
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 4A + 3A
COMMENTS: A neonicotinoid and pyrethroid. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. BIFENTHRIN*
(Brigade 2EC) — 3.8–6.4 fl oz — 12 — 14
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Long
RESISTANCE: in many lygus populations.
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: A pyrethroid. Heavy insect pressure and arid climates generally require the high rate. Do not make more than 3 applications a season or apply more than 0.3 lb a.i./acre per season. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

F. BETA–CYFLUTHRIN*
(Baythroid XL) — 1.6–2.6 fl oz — 12 — 0
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: A pyrethroid. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

G. ZETA-CYPERMETHRIN*
(Mustang) — 3.0–4.3 fl oz — 12 — 14

Common name (Example trade name)			Amount per acre**	REI‡ (hours)	PHI‡ (days)
	SELECTIVITY: Low PERSISTENCE: PEST: Long NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.				
H.	LAMBDA-CYHALOTHRIN* (Warrior II with Zeon) SELECTIVITY: Low PERSISTENCE: PEST: Long NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: A pyrethroid. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.		Label rates	24	21
I.	NOVALURON (Diamond 0.83EC) SELECTIVITY: Moderate to High PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 15		9–12 fl oz	12	30
J.	DIMETHOATE (Dimethoate 2.67) SELECTIVITY: Moderate PERSISTENCE: PEST: Short NE:[2] Short RESISTANCE: in some lygus bug populations. MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: An organophosphate. Ground or air application. Do not repeat application within 14 days. Make only 2 applications per season. May induce mite outbreaks. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.		0.75–1.5 pt	48	14
K.	ACEPHATE (Orthene 97) SELECTIVITY: Low PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: An organophosphate. Do not graze or feed trash to livestock. Apply in water at 5–10 gal spray/acre by air or 10–25 gal spray/acre by ground. May induce outbreaks of spider mites. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.		0.75– 1 lb	24	21
L.	CLOTHIANIDIN (Belay) SELECTIVITY: Low PERSISTENCE: PEST: Moderate NE:[2] Long MODE-OF-ACTION GROUP NUMBER[1]: 4A COMMENTS: Toxic to bees 0–5 days after treatment. May induce outbreaks of spider mites. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.		3–6 fl oz	12	21

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

OMNIVOROUS LEAFROLLER AND FALSE CELERY LEAFTIER (5/13)

Scientific Names: Omnivorous leafroller: *Platynota stultana*
False celery leaftier: *Udea profundalis*

DESCRIPTION OF THE PESTS

These small caterpillars web leaves or bracts together with silk and form a shelter in which they feed. They wiggle violently when disturbed.

DAMAGE

Injury caused by these insects is sporadic, localized, and seldom of economic importance. Larvae feed on leaves, small squares, and on the surface of green bolls; injured bolls may open prematurely.

MANAGEMENT

Infestations are usually reduced by natural enemies. In Arizona, the suggested treatment threshold is when 25% of the plants have an active larva; California has not established a threshold.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. METHOMYL*			
(Lannate SP)	0.5 lb	72	15
(Lannate LV)	Label rates	72	15
SELECTIVITY: Low			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 1A			
COMMENTS: Do not graze or feed livestock.			

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

PINK BOLLWORM (9/15)

Scientific name: *Pectinophora gossypiella*

DESCRIPTION OF THE PEST

Pink bollworm is a major pest of cotton in southern California deserts. While apparently established in the San Joaquin Valley, economic infestations have not occurred in this area. Adults are small, grayish brown, inconspicuous moths. When their wings are folded, they have an elongated slender appearance. The wing tips are conspicuously fringed. Young larvae are tiny, white caterpillars with dark brown heads. When mature, they are about 0.5 inch long and have wide transverse pink bands on the back. To be able to see pink bollworm larvae, bolls have to be cracked open. The first and second instars are difficult to see against the white lint of the bolls. Eggs are very small, slightly elongated, and laid under the calyx of green bolls.

DAMAGE

Pink bollworms damage squares and bolls, the damage to bolls being the most serious. Larvae burrow into bolls, through the lint, to feed on seeds. As the larva burrows within a boll, lint is cut and stained, resulting in severe quality loss. Under dry conditions, yield and quality losses are directly related to the percentage of bolls infested and the numbers of larvae per boll. With high humidity, it only takes one or two larvae to destroy an entire boll because damaged bolls are vulnerable to infection by boll rot fungi.

MANAGEMENT

When high population levels of pink bollworm occur, the objectives of management are to keep infestations below damaging levels in the current season—without creating secondary outbreaks of other pests—and to reduce the overwintering population that will threaten the following season's crop. The main control tools are observance of host-free period (San Joaquin Valley), the judicious use of insecticides, timely crop termination and harvest, rapid crop destruction, properly timed winter and spring irrigations, and compliance with plowdown requirements. When pink bollworms are found in the San Joaquin Valley, a regional monitoring and sterile moth release program is implemented.

Because of the danger of secondary outbreaks, especially in the low desert valleys, it is wise to limit insecticide treatments to those periods when susceptible bolls are present and when sampling shows the percentage of infested bolls is above the treatment threshold. It is rarely necessary to apply insecticides against moths from the overwintered population of pink bollworm and, often, treatments are not needed against the first generation of moths that develop from larvae within squares. Be alert, however, for high populations of pink bollworm moths when squares are developing, especially if other pests such as lygus bugs and armyworms are also threatening. Mating disruptants and sterile moth releases, on the other hand, are most effective when aimed at the overwintering generation, usually about the time cotton plants have 6 to 8 leaves.

Cultural Control

The use of *Bt* cotton will help prevent damage by pink bollworm. A recently developed transgenic cotton, Bollguard II, offers suppression of cotton bollworm, along with beet armyworms, pink bollworm, and tobacco budworm.

Eliminate the food supply for pink bollworm by cutting off irrigation early enough to stop production of green bolls by early September. Regardless of when the crop is terminated, immediately shred the cotton plants following harvest. Shredding destroys some larvae directly and promotes rapid drying of unharvested bolls. If fall temperatures are high during September and much of October, leave crop debris on the soil surface for two or more weeks after the shredding operation to further destroy larvae. Be sure to comply with plowdown requirements and cross disc or plow to a depth of at least 6 inches. In the San Joaquin Valley, there is a 90-day host-free period that extends from plowdown to March 10.

Winter irrigations can reduce populations of overwintering pink bollworms by as much as 50 to 70%; flooding in December is more effective than flooding in November or January. Take advantage of pink bollworm mortality afforded by winter irrigations and rotate to small grains or newly seeded alfalfa.

In spring, irrigations can also be used to promote early spring emergence of pink bollworm. If cotton is being followed with cotton, preirrigate in February and plant as early as possible, following guidelines to ensure adequate soil temperature for germination and emergence. Plan irrigations of the crop to prevent even slight moisture stress and to promote maximum emergence of moths in advance of susceptible squares.

Organically Acceptable Methods

Cultural controls, with the exception of the use of *Bt* cotton and the use of mating disruption and sprays of the Entrust formulation of spinosad are acceptable to use on organically grown cotton.

Monitoring and Treatment Decisions

In the San Joaquin Valley, pink bollworm is primarily managed with a host-free period. In Southern California, sampling bolls is the most reliable way to monitor pink bollworm populations. See UC ANR Publication 3305, *Integrated Pest Management for Cotton*, 2nd edition, for detailed sampling methods and thresholds. The use of gossyplure, a sex attractant that disrupts mating when distributed throughout the field, may be effective against pink bollworm when it is supplemented with cultural control practices that minimize the number of overwintering bollworms.

Do not apply insecticides to control larvae; larvae are either inside the boll or in the ground and therefore insecticide contact is difficult.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. ESFENVALERATE* (Asana XL)	5.8–9.6 fl oz	12	21
SELECTIVITY: Low PERSISTENCE: PEST: Long NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 3A COMMENTS: Do not graze or feed trash to livestock. Very destructive to natural enemies; can result in buildup of spider mites and is not recommended in San Joaquin Valley. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
B. INDOXACARB (Steward)	Label rates	12	14
SELECTIVITY: Moderate PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 22A COMMENTS: Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			
C. SPINOSAD (Entrust)#	1.25–2 oz	4	28
(Success)	4–6 fl oz	4	28
SELECTIVITY: High PERSISTENCE: PEST: Moderate NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 5 COMMENTS: Use of Success allowed under a supplemental 24(c) label. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.			

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

\# Acceptable for use on organically grown produce.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

SALTMARSH CATERPILLAR (5/13)

Scientific name: *Estigmene acrea*

DESCRIPTION OF THE PEST

Saltmarsh caterpillar larvae are hairy and gray when first hatched, then darken to yellow, brownish, or almost black with yellow lines. They are covered with reddish or black hairs, and can be up to 2 inches long when fully grown. Eggs are spherical, whitish, somewhat flattened, about 0.03 inch (0.75 mm) in diameter, and found in naked clusters on the undersurface of leaves.

DAMAGE

Saltmarsh caterpillars are occasional pests that cause the same foliar injury as loopers. Early instars skeletonize leaves, and older instars rag leaves. Extensive defoliation can reduce yield if it occurs before bolls mature.

MANAGEMENT

Heavy infestations seldom occur until late in the season after bolls have already matured. Defoliation in late season usually does not cause economic loss, and may actually benefit the crop by opening the canopy and reducing the chance of boll rot.

Cultural Control

The use of *Bt* cotton will help prevent damage by saltmarsh caterpillar.

Organically Acceptable Methods

Sprays of *Bacillus thuringiensis* and the Entrust formulation of spinosad are acceptable for use on organically grown cotton.

Monitoring and Treatment Decisions

Consider treatment only if extensive defoliation threatens to occur before bolls mature.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. BACILLUS THURINGIENSIS# ssp. KURSTAKI			
(various products)	Label rates	4	0
SELECTIVITY: High			
PERSISTENCE: PEST: Short NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 11			
COMMENTS: Does not disrupt natural enemies.			
B. SPINOSAD			
(Entrust)#	1.25–2 oz	4	28
(Success)	4–6 fl oz	4	28
SELECTIVITY: High			
PERSISTENCE: PEST: Moderate NE:[2] Short			
MODE-OF-ACTION GROUP NUMBER[1]: 5			
COMMENTS: Use of Success allowed under a supplemental 24(c) registration.			
C. METHOXYFENOZIDE			
(Intrepid) 2F	4–10 fl oz	4	14
SELECTIVITY: High			
PERSISTENCE: PEST: Moderate NE:[2] Moderate			
MODE-OF-ACTION GROUP NUMBER[1]: 18			
COMMENTS: An insect growth regulator.			
D. CHLORANTRANILIPROLE			
(Coragen)	3.5–7.0 fl oz	4	21

SELECTIVITY: High
PERSISTENCE (PEST): unknown; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Do not apply more than 9 oz/acre/year or make more than 4 applications a year. Do not apply with less than 100 or more than 200 gallons water/acre.

E. METHOMYL*
(Lannate) SP 0.5 lb 72 15
SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: Kills eggs and larvae. Use may redden cotton. According to the label, do not make more than 8 applications per season. Do not graze or feed cotton trash to livestock.

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* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown produce.

1 Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

2 NE = natural enemies

SEEDCORN MAGGOT (9/15)

Scientific name: *Delia platura*

DESCRIPTION OF THE PEST

The adult is a light gray fly about 0.2 inch (5 mm) long. Larvae are white, cylindrical, tapered anteriorly, and are also about 0.2 inch (5 mm) long. Larvae can be found inside damaged seeds or in the soil nearby.

DAMAGE

Damage generally occurs in localized areas of the field and appears as areas where seedlings have not emerged. Seedcorn maggots hollow out seeds or eat portions of seedlings. Damage is most common in early plantings when the soil is cool, especially in fields with lots of organic matter. Damage tends to be worse on sandier soils.

MANAGEMENT

If cotton follows corn in a crop rotation, seedcorn maggot may become a problem, especially if crop residue is present in soil for the maggot to overwinter on. Once damage occurs it is too late to treat. Planting later in spring when the soil isn't excessively moist and soil temperatures are warmer will help to reduce damage by this pest. Also, destroying vegetation from the previous crop at least 1 month before planting should help minimize damage.

STINK BUGS (9/15)

Scientific Names: Consperse stink bug: *Euschistus conspersus*
Say stink bug: *Chlorochroa sayi*
Western brown stink bug: *Euschistus impictiventris*
Brown stink bug: *Euschistus servus*

DESCRIPTION OF THE PESTS

The stink bug adult is shield-shaped with the posterior angles of the pronotum extended to prominent points. They are about 0.5 inch long, and more than half as wide. Color varies from green to dark brown. Nymphs may be nearly round and black or various colors in early instars. Eggs are barrel-shaped and laid in groups, usually in multiples of seven.

DAMAGE

Stink bugs puncture squares and bolls and cause young cotton bolls to drop; however, principal damage is to older bolls. On older bolls lint may be stained and matted, and seeds shrunken by stink bug feeding. Injured locks or bolls may fail to open. Stink bugs may also introduce bacteria and fungi that cause boll rots.

MANAGEMENT

While it is seldom worthwhile to monitor for stink bugs, you should be alert for them during crop emergence and seedling growth, especially along the edge of the field closest to crop or weed hosts such as alfalfa grown for seed, grain sorghum, or Russian thistle. Also, look for stink bugs when sampling for lygus bugs with a sweep net. The sweep net is not an efficient way to sample stink bugs, however, because they feed on bolls on the bottom portion of the plant.

In early September, search plants by looking for the brown stains of fecal spots beneath the bracts of bolls to detect the presence of the bugs (they are under the bracts of green bolls). Treat if you can find more than 20 to 25 adult bugs by searching six or seven randomly chosen plants. This threshold applies only until early September because after that time, the bugs will not be feeding on bolls.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. ACEPHATE (Orthene 97) — 0.75 lb — 24 — 21
SELECTIVITY: Low
PERSISTENCE: PEST: Moderate NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: An organophosphate. Do not graze or feed trash to livestock. Apply in water at 5–10 gal spray/acre by air or 10–25 gal spray/acre by ground. May induce outbreaks of spider mites. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

B. ZETA-CYPERMETHRIN* (Mustang) — 2.8–3.8 fl oz — 12 — 14
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

C. BIFENTHRIN* (Capture 2EC-CAL) — 2.6–6.4 fl oz — 12 — 14
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] LONG
MODE-OF-ACTION GROUP NUMBER[1]: 3A

D. BIFENTHRIN + ZETA-CYPERMETHRIN* (Hero EW) — 5.2–10.3 oz — 12 — 14

SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] LONG
MODE-OF-ACTION GROUP NUMBER[1]: 3A + 3A

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* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

SWEETPOTATO WHITEFLY (SILVERLEAF WHITEFLY) (9/15)

Scientific name: *Bemisia tabaci* Biotype B, (formerly *B. Argentifolii)*

DESCRIPTION OF THE PEST

Sweetpotato whitefly is a major problem in California's southern desert and in the San Joaquin Valley.

Several species of whiteflies may infest cotton. Proper identification of sweetpotato whitefly is important because other whitefly species do not usually cause economic damage in cotton. Use a hand lens to examine both immatures and adults. Sweetpotato whitefly adults are tiny (0.06 inch or 1.5 mm long), yellowish insects with white wings. Their wings are held somewhat vertically tilted, or rooflike, over the body and generally do not meet over the back but have a small space separating them. Greenhouse whitefly (*Trialeurodes vaporariorum*) adults, the species that is most similar in appearance, hold their wings flatter over the back and there is no space separating the two wings where they join. Bandedwinged whiteflies (*Trialeurodes abutiloneus*) have brownish bands across their wings.

Whiteflies are found mostly on the undersides of leaves. They fly readily when plants are disturbed. The tiny, oval eggs hatch into a first nymphal stage that has legs and antennae and is mobile. The legs and antennae are lost after the first molt and subsequent stages remain fixed to the leaf surface. The last nymphal stage, often called the pupa or the red-eye nymph, is the stage that is easiest to identify. Sweetpotato whitefly pupae are oval and yellowish with red eye spots. The edge of the pupae tapers down to the leaf surface and has few to no long waxy filaments around the edge. In contrast, greenhouse whitefly and banded-winged whitefly pupae have many long waxy filaments around the edge and the edge is somewhat vertical where it contacts the leaf surface.

Sweetpotato whitefly is a multihost pest. Problems in cotton develop from sweetpotato whiteflies that overwinter in cole crops, ornamentals, and weeds. Numbers often increase in spring melons. Once these alternative host crops are harvested or destroyed, whiteflies migrate into adjacent cotton fields. As temperatures warm up, numbers rapidly increase, with the highest numbers occurring in mid- to late summer.

DAMAGE

Whiteflies are sucking insects and their feeding removes nutrients from the plant. Feeding by high populations may result in stunting, poor growth, defoliation, boll shed and reduced yields. As they feed, whiteflies produce large quantities of honeydew which, if deposited on fibers, will reduce cotton quality and may interfere with picking, ginning, and spinning. Honeydew also supports the growth of black sooty molds that stain lint, lowering its quality. The sweetpotato whitefly vectors the *Cotton leaf crumple virus* in southern California desert valleys.

MANAGEMENT

Whiteflies are difficult to manage once their populations have reached high levels. Repeated exposure to insecticide treatments is very likely to lead to development of resistant strains. In general, the best approach is an integrated pest management strategy that relies first on cultural and biological control methods and uses chemical controls only when needed.

Biological Control

Several wasps, including species in the genera *Encarsia* and *Eretmocerus*, parasitize whiteflies. Whitefly nymphs are also preyed upon by bigeyed bugs, lacewing larvae, and lady beetles. Sweetpotato whitefly is an introduced pest that has escaped its natural enemies. Some indigenous native parasites and predators, such as the sevenspotted lady beetle, *Coccinella septempunctata*, do attack it but do not keep it below damaging numbers.

Cultural Control

When possible, plant cotton at least one-half mile upwind from other key whitefly hosts such as melons, cole crops, and tomatoes. Maintain good sanitation in areas of winter and spring host crops and weeds by destroying and removing all crop residues as soon as possible. Control weeds in noncrop areas including head rows and fallow fields, and harvest alfalfa on as short a schedule as possible. Before destroying weeds, however, check them for whitefly predators and parasites because they can be an important source of these natural enemies. In addition, allow the maximum time between whitefly host crops and produce vegetables and melons in the shortest season possible.

Where whitefly infestations are severe, plan for early crop termination and defoliation. After harvesting, promptly destroy stalks to prevent regrowth and limit additional whitefly buildup. Use glyphosate with the defoliation treatment to reduce regrowth.

Acala varieties, which require less time to mature than Pima varieties, may have fewer whitefly infestations. In general, all Pima varieties are more attractive to sweetpotato whitefly than upland cotton varieties. of the upland varieties, hairy-leaf cottons are more susceptible than smooth-leaf varieties.

Organically Acceptable Methods

Cultural and biological controls and sprays of insecticidal soap, some oils, and azadirachtin are acceptable for use on organically grown cotton.

Resistance

Some pyrethroid and organophosphate insecticides have lost their effectiveness for controlling whiteflies. Repeated applications of a product may build high resistance levels in whiteflies. To delay and manage resistance, do not treat successive generations of whiteflies with same product or with insecticides that have the same mode of action number; rotate insecticides with a different mode of action number during the season.

Unsprayed alternative host crops, from which sweetpotato whiteflies migrate into sprayed cotton fields, may be an important source of susceptible whitefly genes and therefore may act as resistance management agents.

Monitoring and Treatment Decisions

Routinely check field margins for whiteflies; these areas are usually infested first. Be especially alert for rapid population buildup when nearby host crops are in decline. During these critical periods, check cotton fields twice weekly. Whitefly adults and nymphs need to be monitored on undersides of leaves from early squaring to harvest. Check for whitefly adults on undersides of leaves—if 3 or more are found, rate the leaf as infested. For whitefly nymphs, place a quarter-sized ring between the central and left-side main veins and check for presence or absence of large nymphs. Score the leaf as infested if any large nymphs are present (3rd and 4th instars) within the quarter-sized ring.

To improve efficiency of your monitoring program, combine sampling of spider mites with other pests. From early squaring to boll development, combine sampling for spider mites, aphids, and whitefly as described in MONITORING SPIDER MITES, APHIDS, AND WHITEFLY. From open boll to harvest follow guidelines described under MONITORING FOR APHIDS AND WHITEFLY. Monitoring forms are available on the online version of this guideline.

The treatment threshold is 40% of leaves infested with large nymphs or 40% of leaves infested with whitefly adults—but remember, a leaf is not called "infested" unless at least 3 whitefly adults are present. If using insect growth regulators (IGRs), nymphs must also be present to justify treatment. If high numbers of adults are at field edges, but no nymphs, an edge treatment with a non-IGR may be required.

Early-season treatments for sweetpotato whitefly nymphs should be limited to IGRs (buprofezin [Courier], pyriproxyfen [Knack], or spiromesifin [Oberon]), or nonpyrethroid insecticides. Pyrethroids should not be used until later in the season when the bolls are open, because they increase populations of spider mites and aphids by causing them to reproduce faster; they are more toxic to natural enemies of aphids, spider mites, and sweetpotato whiteflies than the other materials; and they are most effective against adult whiteflies, whereas nonpyrethroids are most effective against nymphs.

The IGRs (buprofezin and pyriproxyfen) may be applied only once per season; an application of either one may provide up to 6 weeks of whitefly control. Spiromesifen may be applied twice during the season. Sample carefully to be sure that an application is needed before applying IGRs, and use only full-field treatments. Use of insect growth regulators for whitefly control can reduce outbreaks of mites and aphids because of their selectivity.

In fields where whitefly populations are migrating in from overwintering sites or from other cotton fields and adults and eggs are present but nymphs are rare, a nonpyrethroid (acetamiprid [Assail], oxamyl [Vydate]) treatment can be used. In fields with young plants, an IGR may also be required after immigration from overwintering sites has subsided. Edge treatments of nonpyrethroids may also be useful under these conditions. Treat when leaf-turn samples average 10 or more adult whiteflies per leaf. If higher populations are present at the field margins than in the field centers, treat only field margins; this will help reduce cost as well as preserve beneficials. Treatment usually can be delayed until mid-July in the San Joaquin Valley. Holding off treatment until mid-July also reduces selection for pesticide resistance, which can develop rapidly in this pest.

Later in the season when bolls are open and lint is exposed, if there is a massive influx of sweetpotato whitefly from other cotton fields, use a pyrethroid such as bifenthrin (Brigade) or fenpropathrin (Danitol) in combination with DEF or an organophosphate to provide quick knockdown of adults.

Rotate classes of insecticides to manage resistance. This includes all insecticides used in the field, including those used for other insect pests during the current season. Whitefly control with insecticides is maximized by thorough spray coverage. Ground application may give more complete coverage than air.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

EARLY TO MID-SEASON (Light population mid-season)

Insect Growth Regulators

A. BUPROFEZIN
(Courier SC) — Label rates — 12 — 21
SELECTIVITY: High
PERSISTENCE: PEST: Long NE:[2] Long
MODE-OF-ACTION GROUP NUMBER[1]: 16
COMMENTS: Chitin synthesis inhibitor; effective against nymphs. Apply no more than twice per season. Apply no sooner than 21 days after pyriproxyfen.

B. PYRIPROXYFEN
(Knack) — 8–10 fl oz — 12 — 28
SELECTIVITY: High
PERSISTENCE: PEST: Long NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 7C
COMMENTS: Juvenile hormone mimic; sterilizes adults and eggs; prevents adult emergence. Use only once per season. Apply no sooner than 14 days after buprofezin.

EARLY TO MID-SEASON (Light population mid-season)

A. SPIROMESIFEN
(Oberon 2SC) — See comments — 12 — 30
SELECTIVITY: High
PERSISTENCE: PEST: Unknown NE:[2] Unknown
MODE-OF-ACTION GROUP NUMBER[1]: 23
COMMENTS: Early in the season, use 6 fl oz/acre; from mid- to late season 8-16 fl oz/acre. Do not apply more than 3 applications per crop season or at intervals less than 7 days or exceed 32 fl oz/acre/season.

MID- TO LATE-SEASON

A. ACETAMIPRID
(Assail 70WP) — 1.7–2.3 oz — 12 — 28
SELECTIVITY: High
PERSISTENCE: PEST: Moderate–Long NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Treat when adult whiteflies first appear, do not wait until nymphs are present. Do not exceed 0.4 lb a.i./acre per crop or make more than 4 applications per season. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

B. SPIROMESIFEN
(Oberon 2SC) — See comments — 12 — 30
SELECTIVITY: High
PERSISTENCE: PEST: Unknown NE:[2] Unknown
MODE-OF-ACTION GROUP NUMBER[1]: 23
COMMENTS: Early in the season, use 6 fl oz/acre; from mid- to late season 8-16 fl oz/acre. Do not apply more than 3 applications per crop season or at intervals less than 7 days or exceed 32 fl oz/acre per season.

C. FLUPYRADIFURONE
(Sivanto 200SL) 10.5–14 fl oz 12 14
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4D

D. DINOTEFURAN
(Venom) 1–3 oz 12 14
SELECTIVITY: Moderate to High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: A neonicotinoid. Kills lady beetles. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

E. CLOTHIANIDIN
(Belay) 3–6 fl oz 12 21
SELECTIVITY: Low
PERSISTENCE: PEST: Moderate NE:[2] Long
MODE-OF-ACTION GROUP NUMBER[1]: 4A
COMMENTS: Toxic to bees 0–5 days after treatment. May induce outbreaks of spider mites. Toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

LATE-SEASON USE

Bifenthrin may be used alone for control of light-to-moderate populations. For moderate-to-heavy populations use the pyrethroid bifenthrin (Brigade) in combination with fenpropathrin (Danitol) in combination with oxamyl (Vydate) or an organophosphate. For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.
Whitefly susceptibility to insecticides may change during the season depending upon use patterns.

A. BIFENTHRIN*
(Brigade 2 EC) 2.6–6.4 fl oz 12 14
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Long
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: A pyrethroid. Apply in a minimum of 5 gal water/acre with ground equipment or 1 gal/acre by air. When applying by air, 1 qt of emulsified oil may be substituted for 1 qt water in the finished spray. May also be applied in refined vegetable oil. Do not apply more than 0.3 lb a.i./acre per season or make more than 3 applications per season. Do not graze livestock in treated areas or cut treated crops for feed. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

B. FENPROPATHRIN*
(Danitol 2.4EC) 8–16 fl oz 24 21
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 3A
COMMENTS: Acephate is an organophosphate and fenpropathrin is a pyrethroid. Do not feed gin trash or treated forage to livestock or allow animals to graze on treated fields. Do not exceed 2.66 pt/acre per season. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.
. . . PLUS . . .
OXAMYL*
(Vydate C-LV) 17–34 fl oz 48 14
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Short
PERSISTENCE: (Pest) Moderate, (Natural Enemies) Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 1A
COMMENTS: A carbamate. Apply in sufficient refined vegetable oil (minimum 3 pt/acre) or in sufficient water to obtain thorough coverage. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.
. . . or . . .
ACEPHATE
(Orthene 97) 0.5 – 1 lb 24 21
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Short
PERSISTENCE: (Pest) Long, (Natural Enemies) Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 1B

COMMENTS: An organophosphate. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

ORGANICALLY ACCEPTABLE ALTERNATIVES

A. INSECTICIDAL SOAP#
(M-Pede) 2.5 oz/gal 12 0
SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE OF ACTION: A contact insecticide with smothering and barrier effects.
COMMENTS: Spray to wet all infested plant surfaces and repeat treatments at weekly to biweekly intervals. Rotate sprays to avoid more than three consecutive sprays of this material.

B. NARROW RANGE OIL#
(TriTek) 1–2 gal/ 100 gal water 4 0
SELECTIVITY: Low
PERSISTENCE: PEST: Short NE:[2] Short
MODE OF ACTION: Contact including smothering and barrier effects.
COMMENTS: Works by suffocating eggs, nymphs, and adults. Requires total spray coverage.

C. AZADIRACHTIN#
(Neemix 4.5) 0.25–1 pt 4 0
SELECTIVITY: Moderate
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: un
COMMENTS: Kills nymphal stages only; use low rate when pest pressure is low or in conjunction with a material that kills adult whiteflies. In an organically certified crop, the use of this material is restricted.

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown produce.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

THRIPS (5/13)

Scientific Names: Western flower thrips: *Frankliniella occidentalis*
Bean thrips: *Caliothrips fasciatus*

DESCRIPTION OF THE PESTS

Thrips are tiny, slender insects less than 0.06 inch (1.55 mm) long. Western flower thrips are by far the most common thrips on cotton and may be found all season. They are light colored; adults have clear, slender wings. The bean thrips occasionally appears on cotton in summer, usually at field edges. Immature bean thrips have orange or red spots at either side on the end of their abdomen; adults are usually dark with white bands on their wings.

DAMAGE

Although western flower thrips feed on leaves and buds and may sometimes cause seedling leaves to become distorted, their benefits as predators of mites generally outweigh any damage they may cause. While infested seedlings may appear severely deformed, they will grow out of the damage rapidly with the onset of hot weather. In unusual seasons when cool spring weather persists into June, damage to terminals and squares may be severe, particularly in the northern cotton growing areas of the San Joaquin Valley (Merced County). In the low desert growing areas where *Bt* cottons are used, Delta *Bt* cotton appears to be more susceptible to damage by western flower thrips.

Bean thrips feed on the cotton plant and may cause mature leaves to turn coppery brown or red and lower leaves to drop. Bean thrips injury may resemble spider mite injury, but affected leaves are covered with tiny black specks, which are the feces of the thrips. Usually injury is confined to field borders.

MANAGEMENT

No treatment is generally recommended for western flower thrips. Young plants will rapidly recover from injury. Insecticides applied to control flower thrips are usually counterproductive, as they tend to promote outbreaks of mites. Only in situations where a prolonged thrips infestation is destroying seedling terminals is treatment justified.

Bean thrips outbreaks most commonly occur where there are abandoned fields or pasture areas with an abundant growth of prickly lettuce and morningglory, or field bindweed. Control of these weeds will reduce the probability of an outbreak. Spot or strip treatments may occasionally be needed; the bean thrips is controlled by most insecticides used against lygus bug.

Some Californian upland cotton varieties appear to be more susceptible to thrips than Acala varieties. These susceptible varieties should be monitored more closely for thrips populations and damage.

Monitoring and Treatment Decisions

The critical time for monitoring thrips is from crop emergence through seedling stages. To improve the efficiency of your monitoring program, combine sampling of thrips with other pests. From crop emergence to seedling growth sample aphids, mites, and thrips together as described in MONITORING SPIDER MITES, APHIDS, AND THRIPS.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. ACEPHATE
(Orthene 97) — 3 oz — 24 — 21
SELECTIVITY: Low
PERSISTENCE: PEST: Moderate NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 1B
COMMENTS: Do not graze or feed trash to livestock. Apply in water at 5–10 gal spray/acre by air or 10–25 gal spray/acre by ground. May induce outbreaks of spider mites.

B. SPINETORAM

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
(Radiant SC) SELECTIVITY: high PERSISTENCE: PEST: Moderate NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 5 COMMENTS:	4.25–8.00 fl oz	4	28

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

TOBACCO BUDWORM (5/13)

Scientific name: *Heliothis virescens*

DESCRIPTION OF THE PEST

The budworm is an important pest of cotton only in the desert valleys. Budworm moths are about 0.75 inch long, with a wing span of 1 to 1.5 inches. Eggs are spherical, flattened, with 10 to 15 perpendicular rows of toothed ribs. Newly hatched larvae have several rows of dark tubercles along the back, each bearing one or two bristles. Larvae range from olive green to dark reddish brown in color and can be best distinguished from most other caterpillars by the tiny spines, visible under a hand lens, that cover most of the body surface. To distinguish the budworm from bollworm larvae, they must be at least in the third instar. The budworm has a toothlike structure on the inner surface of the mandibles that is lacking in the bollworm, and it has the tiny spines of the skin extending onto the tubercles on top of the eighth abdominal segment; in the bollworm, these tubercles lack spines.

DAMAGE

Heliothis larvae damage bolls and squares. Larvae chew holes into the base of bolls and may hollow out locks. Moist frass usually accumulates around the base of the boll. Larvae may also chew shallow gouges in the boll surface, which can become infected with rot organisms. Bracts of young squares flare outward and the squares become yellow and abort from the plant. Older squares may remain but usually have a round hole and frass near the base. Fifth-instar larvae are the most destructive; they not only damage more fruit than do earlier instars, but they damage larger fruit that are harder for the plant to replace.

MANAGEMENT

The impact of a budworm infestation depends on the number of larvae present, the age of the larvae, and the timing of damage relative to the crop's fruiting cycle. Although large larvae do most of the damage, it is not possible to kill a significant proportion of them once they are older than the third instar. Monitoring and control must therefore be aimed at the eggs and small larvae.

Natural enemies are very important in managing populations of budworms. Damaging populations usually do not appear until late in the season, after treatments for other pests have disrupted natural controls. Insecticides are needed only if the population exceeds the treatment threshold while the crop has a significant number of squares or green bolls that will have time to develop into mature bolls by season's end. There is no need to treat once bolls begin cracking, because most bolls are too mature by that time to be susceptible and squares still present will not have time to mature. In the low desert valleys, there are two periods when injury can occur—one in each fruiting cycle.

Biological Control

Many predators and parasites combine to substantially maintain *Heliothis* populations at low levels. Insecticide sprays for other pests will disrupt this natural control.

Cultural Control

Heliothis are attracted to succulent, rank-growing cotton plants; keep water, fertilizer, and plant density at recommended levels to avoid rank growth. Because populations seldom reach damaging levels before late summer, manage the crop for early maturing and plan to defoliate by late September.

The use of Bt cotton will help prevent damage by this pest. The use of transgenic cotton, Bollguard II, offers suppression of cotton bollworm, along with beet armyworms, pink bollworm, and tobacco budworm.

Organically Acceptable Methods

Biological controls, cultural practices that promote early harvest, and sprays of *Bacillus thuringiensis* are acceptable for use on organically grown cotton.

Monitoring and Treatment Decisions

In desert valleys, start sampling in mid-July, about 1 to 2 weeks after peak squaring. Continue sampling until most bolls have matured. In crops with a second fruiting cycle, continue until top crop bolls have matured. For standard sampling, check for larvae on the terminal growth of at least 100 plants chosen at random. Divide fields of up to 80 acres into quarters and check 25 plants in each quarter. Divide larger fields into more areas and check 25 plants in each area. The treatment threshold is 10 to 12 small budworm or bollworm larvae per 100 plants. In

fields that have been treated previously, treat when you find 8 small bollworms per 100 plants. Later instar larvae are the most destructive but are very resistant to insecticides; therefore, aim treatments at first or second instars.

See UC ANR Publication 3305, *Integrated Pest Management for Cotton*, 2nd edition, for detailed sampling information, including a sequential sampling program.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

A. BACILLUS THURINGIENSIS ssp. KURSTAKI#
(various products) — Label rates — 4 — 0
SELECTIVITY: High
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 11
COMMENTS: Not harmful to beneficials.

B. CHLORANTRANILIPROLE
(Coragen) — 3.5–7.0 fl oz — 4 — 21
SELECTIVITY: High
PERSISTENCE (PEST): unknown; PERSISTENCE (NE[2]): Short
MODE-OF-ACTION GROUP NUMBER[1]: 28
COMMENTS: Do not apply more than 9 oz/acre/year or make more than 4 applications a year. Do not apply with less than 100 or more than 200 gallons water/acre.

C. ESFENVALERATE*
(Asana XL) — 5.8–9.6 fl oz — 12 — 21
SELECTIVITY: Low
PERSISTENCE: PEST: Long NE:[2] Moderate
MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Do not graze or feed trash to livestock. Very destructive to natural enemies; can result in buildup of spider mites and is not recommended in San Joaquin Valley. Do not exceed 0.5 lb a.i./acre/season.

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

\# Acceptable for use on organically grown produce.

1 Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

2 NE = natural enemies

WEBSPINNING SPIDER MITES (5/13)

Scientific Names: Strawberry spider mite: *Tetranychus turkestani*
Pacific spider mite: *Tetranychus pacificus*
Twospotted spider mite: *Tetranychus urticae*
Carmine spider mite: *Tetranychus cinnabarinus*

DESCRIPTION OF THE PESTS

To the naked eye, spider mites appear as tiny moving dots. Adult females are about 0.01 inch (0.3 mm) long. Spider mites live in colonies, mostly on the lower surfaces of leaves, and produce a webbing that can cover much of the undersurface of the leaf. Adults have eight legs and an oval body, usually with two red eyespots near the head. Eggs are spherical and translucent. Immatures resemble adults and feed on leaves in the same way.

These four species of spider mites are similar in appearance; it is important, though, to be able to distinguish early season infestations of strawberry mites because this species is more damaging to cotton and because it is more susceptible to miticides. Strawberry mites form compact colonies on the undersurface of cotyledons and early true leaves. The infested part of the leaf puckers upward and later turns red, then brown; this mite produces only light webbing. Infested plants may lose most of their lower leaves by first bloom. Pacific and twospotted mites produce dense webbing and can cause reddening and abscission of leaves, but only do so at higher densities.

Pacific mites spread out from the base of the leaf along the main veins, and will colonize the upper leaf surface to a greater degree than is commonly observed with the other species. Carmine and twospotted mites start in a leaf fold or at the base of leaf blades near the petiole. They gradually spread to the edges of the leaf. All three species produce considerable webbing and are usually much less abundant than strawberry mites early in the season. Adult female carmine mites are red, while adult females of the other three species are green or straw yellow with dark blotches on the side.

DAMAGE

Spider mites can cause leaves or parts of leaves to turn yellow or red and to drop. Loss of leaf surface reduces energy available to maturing fruit, so squares and bolls may fail to develop and may eventually drop. Entire plants in heavily infested areas of the field may be defoliated.

MANAGEMENT

Managing spider mites requires preserving natural enemies as long as possible each season and anticipating outbreaks following insecticide applications. When treating for mites, follow resistance management guidelines.

Biological Control

Preserve natural enemies of mites by avoiding early season, broad-spectrum insecticide applications. The most important predator early in the season is the western flower thrips. Later, bigeyed bugs, minute pirate bugs, predaceous mites, and other predators are also important. Releases of the western predatory mite, *Galendromus occidentalis*, may help control populations of pest mites, but more research is needed in this area.

Cultural Control

Water-stressed plants stimulate spider mite outbreaks; be sure to keep the crop properly irrigated. In addition, sprinkler irrigation has been observed to suppress spider mites. Pima cotton is less susceptible to spider mites than upland cotton varieties.

Organically Acceptable Methods

Biological control as releases of predatory mites and sprays of insecticidal soap, some oils, and sulfur are acceptable to use on organically grown cotton.

Resistance

Research has confirmed that populations of the twospotted and Pacific mites in some areas have developed resistance to dicofol (Dicofol 4E), propargite (Comite), abamectin (Agri-Mek), or any combination of these. However, resistance can change, even during the field season, so it is important that you monitor for resistance immediately before making a decision about which miticide to use.

Rotation of abamectin (Agri-Mek), etoxazole (Zeal), spiromesifen (Oberon), hexythiazox (Onager), or other recently registered miticides with the older miticides may help to reduce resistance to any one of them and slow the

development of resistance in areas where it is not yet a problem. Growers are urged to use a miticide only once per season, and, if a second application is needed, switch to another miticide. Growers should also rotate to a different miticide the following season.

While it is important to rotate miticides with a different mode of action, each miticide has characteristics that make it more or less useful at different times of the year and under different circumstances. Aldicarb or phorate (Thimet) applied at planting remain effective for about 6 weeks and are useful for early season infestations. Base a decision to use these miticides on a history of early season mite infestations and potential benefits derived from controlling other early season pests. Mite populations that typically move in 6 weeks or more after planting are best controlled with a foliar miticide applied when the populations appear.

If infestations occur when plants are small and/or V-shaped seed lines are prominent, complete coverage is hard to achieve. In this instance use a miticide such as abamectin, which has the ability to move through the leaf tissue.

Plants with more than four true leaves will allow adequate coverage for the use of foliar miticides such as etoxazole (Zeal), spiromesifin (Oberon), and hexythiazox (Onager). Because all three of these miticides work by regulating mite growth, their best use is when mite populations are low and just starting to build.

Propargite (Comite) is phytotoxic to cotton cotyledons and must be applied later in the season. Sulfur only kills strawberry mite. Abamectin (Agri-Mek) is effective against mites anytime during the season but works best early to mid-season before the leaf ages and "hardens off." Fenproximate (Fujimite) is a contact miticide that can only be applied by ground and is, therefore, best if used early in the season. Zeal and Oberon have proven to be the best options for mites after layby where applications must go on by air. Oberon also has the added benefit of providing control of whitefly. Any of these products can be used in areas where propargite and dicofol resistance is a problem.

In most field situations, strawberry mite is the first species present during the growing season and it is susceptible to all of the early season miticides (sulfur, hexythiazox, dicofol, abamectin, and fenproximate). If possible, it is important to save abamectin for just before layby. Following the first miticide application, mite populations are likely to consist of either twospotted or Pacific spider mites. At this point it is important to determine their level of resistance to dicofol, propargite, and abamectin when determining the best miticide to use.

In all situations, early season use of pyrethroids for aphids, lygus bugs, or whiteflies can aggravate spider mite populations because they destroy natural enemies so avoid them when possible. On the other hand, most miticides are specific for mites and should not cause disruptions of insect pests.

Monitoring and Treatment Decisions

The critical time for monitoring spider mites is between crop emergence and first open boll. To improve efficiency of your monitoring program, combine sampling of spider mites with other pests. From crop emergence to seedling growth, sample mites, aphids, and thrips together as described in MONITORING SPIDER MITES, APHIDS, AND THRIPS. From early squaring to boll development, combine sampling for spider mites, aphids, and whitefly as described in MONITORING SPIDER MITES, APHIDS, AND WHITEFLY. Record your results *(example forms available online)*.

Generally treatment of seedling cotton is required if defoliation is occurring and the mite populations are high. From early squaring to first open boll, treatment can be considered if 30 to 50% of leaves have spider mites following the monitoring procedures outlined above.

Spot Treatments

Sometimes field margins are much more severely infested than the remainder of the field, particularly when another host crop, such as alfalfa, beans, sugarbeet, or safflower, is grown next to the cotton. In such cases, treatment of a field margin may be justified. Monitor field margins separately from the remainder of the field.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)

The use of pyrethroids or organophosphates is not recommended for spider mite control. These pesticides usually result in short-term population reduction, followed by a rapid resurgence of the population that can quickly exceed pretreatment levels.

A. ABAMECTIN*
(Agri-Mek 0.15EC) — 8–16 fl oz — 12 — 20
SELECTIVITY: High
PERSISTENCE: PEST: Long NE:[2] Long
RESISTANCE: A small number of resistant twospotted and Pacific spider mite populations were found in 1998-99.
MODE-OF-ACTION GROUP NUMBER[1]: 6
COMMENTS: An avermectin. Do not apply more than 16 oz/acre/application, or more than 32 oz/acre/season. Effect of miticides on predatory mites: dicofol has a greater toxic effect than abamectin, which has a greater effect than propargite. Certain formulations emit high amounts of volatile organic compounds (VOCs); use low-VOC formulations. **Regulations affect use for the San Joaquin Valley from May 1 to October 31, 2015 and 2016.** Review the Department of Pesticide Regulation's updated fact sheet.

B. ETOXAZOLE
(Zeal) — 0.66–1 oz — 12 — 28
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Unknown
MODE-OF-ACTION GROUP NUMBER[1]: 10B
COMMENTS: Do not apply more than once per growing season.

C. SPIROMESIFEN
(Oberon 2SC) — 8–16 fl oz — 12 — 30
SELECTIVITY: High
PERSISTENCE: PEST: Unknown NE:[2] Unknown
MODE-OF-ACTION GROUP NUMBER[1]: 23
COMMENTS: Rates given are for late season use, which is the best time to use this material for mite control. Also controls whitefly.

D. FENPROXIMATE
(FujiMite 5EC) — Label rates — 12 — 14
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 21A
COMMENTS: Best used early to mid-season before populations begin to build.

E. BIFENAZATE
(Acramite 4SC) — 16–24 fl oz — 12 — 60
SELECTIVITY: High
PERSISTENCE: PEST: Short NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: un
COMMENTS: Do not apply more than once per year.

F. HEXYTHIAZOX
(Onager) — 12–20 oz — 12 — 35
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
MODE-OF-ACTION GROUP NUMBER[1]: 10A
COMMENTS: A thiazolidinone. Apply before bolls open and before buildup of mite population. Do not make more than 1 application a year.

G. DICOFOL
(Dicofol 4E) — 3 pt — 12 — 30
SELECTIVITY: High
PERSISTENCE: PEST: Moderate NE:[2] Short
RESISTANCE: Some populations of twospotted and Pacific spider mites have resistance.
MODE OF ACTION: unknown
COMMENTS: An organochlorine. Ground application only. Do not allow drift to nearby food or forage crops. Effect of miticides on predatory mites: dicofol has a greater effect than abamectin, which has a greater effect than propargite. Do not make more than 1 application per season.

H. PROPARGITE

	Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
	(Comite)	Label rates	See label	50
	SELECTIVITY: High PERSISTENCE: PEST: Moderate NE:[2] Short RESISTANCE: Some populations of twospotted and Pacific spider mites have resistance. MODE-OF-ACTION GROUP NUMBER[1]: 12C COMMENTS: A sulfite. Apply before bolls open. May be phytotoxic to young cotton under 10 inches high. Do not apply when bees are present. Effect of miticides on predatory mites: dicofol has a greater effect than abamectin, which has a greater effect than propargite.			
I.	ALDICARB*	Label rates	48	90
	SELECTIVITY: High PERSISTENCE: PEST: Long NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 1A COMMENTS: A carbamate. Apply at planting. Do not graze or feed trash to livestock. Do not make more than 1 application at planting and 1 postemergence application per crop.			
J.	PHORATE*			
	(Thimet) 20G	Label rates	48–72	0
	SELECTIVITY: High PERSISTENCE: PEST: Moderate NE:[2] Moderate PERSISTENCE: (Pest) Moderate, (Natural Enemies) Moderate MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: An organophosphate. Apply at planting. Do not graze or feed trash to livestock.			
K.	SULFUR DUST#	25–35 lb	24	0
	SELECTIVITY: High PERSISTENCE: PEST: Short NE:[2] Short MODE OF ACTION: Unknown. An inorganic insecticide. COMMENTS: Sulfur is most effective when temperatures do not exceed 95°F. Early season applications will control strawberry spider mite and suppress other species of spider mites. Do not allow it to drift to susceptible melons, squash, or cucurbits.			
L.	INSECTICIDAL SOAP#			
	(M-Pede)	2.5 oz/gal	12	0
	SELECTIVITY: Low PERSISTENCE: PEST: Short NE:[2] Short MODE OF ACTION: A contact insecticide with smothering and barrier effects. COMMENTS: Spray to wet all infested plant surfaces and repeat treatments at weekly to biweekly intervals. Rotate sprays to avoid more than three consecutive sprays of this material.			
M.	NARROW RANGE OIL#			
	(TriTek, etc.)	1–2 gal/100 gal water	4	0
	SELECTIVITY: Low PERSISTENCE: PEST: Short NE:[2] Short MODE OF ACTION: Contact including smothering and barrier effects. COMMENTS: Works by suffocating eggs, nymphs, and adults. Requires total spray coverage.			

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown produce.

[1] Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

[2] NE = natural enemies

WESTERN YELLOWSTRIPED ARMYWORM (5/13)

Scientific name: *Spodoptera praefica*

DESCRIPTION OF THE PEST

Western yellowstriped armyworm larvae are dark-colored, usually nearly black (but occasionally gray) with a broad yellow stripe on each side. They have a black spot on the side of the first abdominal segment.

DAMAGE

If infestations occur early in the season, young cotton plants may be defoliated, but this is rare. Later-season infestations occur primarily on field edges and can cause defoliation and damage to fruit.

MANAGEMENT

This pest occurs infrequently in the San Joaquin Valley. It is a foliage feeder that may become abundant during the late season as a result of migration from nearby alfalfa. You can stop migrating larvae by plowing a trench with the steep side toward cotton and applying an insecticidal spray to kill trapped larvae. Treat only the infested area; it is rarely necessary to treat a whole cotton field.

Organically Acceptable Methods

Sprays of *Bacillus thuringiensis* (*Bt*) are acceptable for use on organically grown cotton.

Monitoring and Treatment Decisions

The degree of foliage damage is the best indicator for determining treatment thresholds. Early in the season, plants can sustain up to 50% loss of leaf surface without affecting yield. During the fruiting period, only 20 to 25% of the leaf surface can be lost without yield loss. After this period, up to 50% loss of leaf surface can again be tolerated.

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Always read the label of the product being used.			
A. BACILLUS THURINGIENSIS ssp. KURSTAKI# (various products) SELECTIVITY: High PERSISTENCE: PEST: Short NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 11 COMMENTS: Does not disrupt natural enemies.	Label rates	4	0
B. CHLORANTRANILIPROLE (Coragen) SELECTIVITY: High PERSISTENCE (PEST): unknown; PERSISTENCE (NE[2]): Short MODE-OF-ACTION GROUP NUMBER[1]: 28	3.5–7.0 fl oz	4	21
C. METHOXYFENOZIDE (Intrepid 2F) SELECTIVITY: High PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 18 COMMENTS: An insect growth regulator.	Label rates	4	14
D. INDOXACARB (Steward) SELECTIVITY: Moderate PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 22A	Label rates	12	14
E. ACEPHATE			

Common name (Example trade name)	Amount per acre**	REI‡ (hours)	PHI‡ (days)
(Orthene 97) SELECTIVITY: Low PERSISTENCE: PEST: Moderate NE:[2] Moderate MODE-OF-ACTION GROUP NUMBER[1]: 1B COMMENTS: May cause severe spider mite infestations.	1 lb	24	21
F. METHOMYL* (Lannate SP) SELECTIVITY: Low PERSISTENCE: PEST: Short NE:[2] Short MODE-OF-ACTION GROUP NUMBER[1]: 1A COMMENTS: Kills eggs and larvae. Use may redden cotton. According to the label, do not make more than 8 applications per season. Do not graze or feed cotton trash to livestock.	0.5 lb	72	15

* Permit required from county agricultural commissioner for purchase or use.

** Mix with sufficient water to provide complete coverage.

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Acceptable for use on organically grown produce.

1 Group numbers for insecticides and miticides are assigned by the Insecticide Resistance Action Committee (IRAC). Rotate pesticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance. For example, the organophosphates have a group number of 1B; insecticides with a 1B group number should be alternated with insecticides that have a group number other than 1B. For more information, see irac-online.org.

2 NE = natural enemies

WIREWORMS (9/15)

Scientific name: *Limonius* spp.

DESCRIPTION OF THE PESTS

Wireworms are the soil-dwelling larvae of click beetles. They resemble mealworms and are slender, elongate, yellowish to brown with smooth, tough skin. The body is usually cylindrical, but flat on the lower side. There are six short legs close together near the head, and the tip of the abdomen bears a flattened plate with a pair of short hooks.

DAMAGE

Wireworms destroy germinating seeds and tiny seedlings. Often the wireworm will be found near the damaged or missing seed or plant. Even if the damage does not completely destroy the plant, the feeding wounds may predispose the plant to seedling diseases.

MANAGEMENT

Wireworms may be a problem following an alfalfa rotation or in fields that were previously pastures. Cultivating, flooding, and dry fallowing can help reduce wireworm numbers.

Diseases

(Section reviewed 5/13)

FUSARIUM WILT (5/13)

Pathogen: *Fusarium oxysporum* f. sp. *vasinfectum*

SYMPTOMS AND SIGNS

Fusarium can cause severe symptoms in susceptible cotton varieties. These include a general wilt, which is especially evident on warm days, and yellowing and necrosis of lower leaf margins. The vascular system of infected plants is discolored brown in affected portions of the tissue. This is most apparent in the lower stem and upper taproot. The discoloration starts in the taproot, spreads into the stem, and is generally continuous in contrast to the speckling nature of the discoloration in plants affected by Verticillium wilt.

In seedlings and young plants, cotyledons and leaves wilt, may turn necrotic, and even fall off the plant, resulting in bare stems. Seedlings of susceptible Pima varieties often die and resemble plant losses caused by damping-off fungi. In mildly affected plants, lower leaves develop symptoms but plants survive, but with reduced vigor and noticeable stunting. Certain strains of the causal fungus only cause symptoms when plants are also infected with the root-knot nematode. In those cases, galls are usually prevalent on lateral roots.

COMMENTS ON THE DISEASE

Four genotypes (called races) of *Fusarium oxysporum* f. sp. *vasinfectum* presently occur in California. Races 1, 3, and 8 are mildly virulent and cause few, if any, symptoms on cotton cultivars currently in use unless the plants are also infected with root-knot nematodes. Race 1 is widely distributed in the San Joaquin Valley; races 3 and 8 are found in a limited number of fields in Tulare and Fresno counties. Race 4 is significantly more virulent than the other Fusarium races. It can infect plants and cause significant mortality even without root-knot nematodes present. Stand establishment in some fields is markedly reduced. The distribution of race 4 is not fully known, but it is becoming more common in Fresno, Merced, Tulare, Kings, and Kern counties.

The fungus sustains itself on the outer surface of roots of many crops and weeds and survives indefinitely in soil. In addition, the pathogen is seed-borne in cotton, which accounts for long-distance spread, and is also spread whenever infested soil is transported on boots, farm equipment, in flood irrigation, etc.

MANAGEMENT

Control of the root-knot nematode is important to managing Fusarium wilt caused by most genotypes (races 1, 3, and 8) of the causal fungus. Nematicides, root-knot-nematode-resistant varieties (e.g., NemX, NemX-HY), or both are often necessary in fields infested with the nematode. Most Acala and non-Acala Upland varieties of cotton are moderately susceptible to race 4 Fusarium. Among currently available Pima varieties, Phytogen 800, Phytogen 802RF, and DP-360 have been identified as possessing relatively high levels of resistance to Fusarium race 4. Field evaluations are being conducted to identify additional varieties with acceptable levels of resistance.

Rotation to any crop other than cotton prevents an increase in the soil population of *Fusarium* but may not significantly reduce the number of spores in the soil. The fungus will sustain itself on the roots of most plants, including weeds (without causing any symptoms), and cannot be eliminated by crop rotation alone.

Always use Fusarium-free seed produced in disease-free fields at all times. Avoid moving gin trash that originated in infested cotton fields to noninfested fields. Any field operation that moves soil from one location to another can spread spores of the fungus and introduce it to other fields. Washing soil from equipment with pressurized water will help limit the spread of Fusarium and should be considered in sites where race 4 has been confirmed.

Other containment options for Fusarium race 4 include restricting traffic in affected patches, especially when the soil is wet, destroying affected plants and surrounding nonsymptomatic plants, and stopping irrigation of affected patches in order to prevent movement of infested soil. Soil solarization under clear plastic for a minimum of 5 to 6 weeks may reduce fungal populations, but will not eradicate all spores of the pathogen.

Cotton seed intended for planting should never be produced in infested fields. This is especially true in fields infested with race 4, which can cause devastating yield losses in certain susceptible Acala, non-Acala Upland, and Pima varieties.

SEEDLING DISEASES (5/13)

Pathogens: Damping-off: *Pythium* spp.
Soreshin: *Rhizoctonia solani*
Black root rot: *Thielaviopsis basicola*
Fusarium wilt: *Fusarium oxysporum* f. sp. *vasinfectum*

SYMPTOMS AND SIGNS

Pythium causes water-soaked lesions on the roots or hypocotyl of infected seedlings. Lesions may collapse and turn light brown. Girdled plants often die. *Pythium* may rot seeds and seedlings before germination or emergence through the soil.

The main symptoms of soreshin, caused by *Rhizoctonia solani*, are sunken lesions on the hypocotyl, which are oval- to irregular-shaped and reddish brown. Girdled plants often die.

Black root rot, caused by *Thielaviopsis basicola*, is characterized by a dark brown to black discoloration and reduced diameter of the taproot of infected seedlings. As the plant ages, healthy tissue replaces decayed tissue, but affected plants may be stunted.

Virulent strains of *Fusarium oxysporum* f. sp. *vasinfectum*, the cause of Fusarium wilt, can also kill seedlings. Laboratory analysis is often needed for correct diagnosis of the presence of *Fusarium* spp. and the exact race of *Fusarium*.

COMMENTS ON THE DISEASE

All seedling diseases are caused by soilborne fungi common to most cultivated soils. The diseases are generally more severe during cool, damp weather that delays seedling growth. As cotton plants grow, they become more resistant to attack.

MANAGEMENT

To reduce seedling diseases, make sure that conditions at planting favor rapid germination and seedling growth so that cotton seedlings quickly outgrow the most vulnerable stage and infection is less likely. Fungicide seed treatments can usually prevent severe losses caused by seedling diseases as long as growing conditions are reasonably good.

Cultural Control

Always use the highest-quality seed you can afford. If possible, select seed that has shown a high rate of germination in a cold test. If you must use lower-quality seed, plant as late as possible to allow the soil to warm up. Regardless of seed quality, never plant if rain or cold weather (i.e. less than 15DD) is expected during the 4 or 5 days following planting. Follow UC Cotton Planting Forecasts issued during the planting season to plant into the most optimal conditions. (Forecast available online at https://ipm.ucanr.edu/weather/cotton-planting-forecast/)

Use an adequate seeding rate so that the loss of a few plants to seedling diseases will not leave skips that must be replanted. Don't plant deeper than 2 inches because excessive depth delays emergence and exposes more hypocotyl surface to invasion by fungi.

Soil that is too wet at planting or during germination favors seedling diseases. To avoid excess moisture, allow preirrigated beds to drain adequately before planting, and don't irrigate up the crop during cool weather. Firming wheels on planters operated in wet soil often create a shallow compacted layer that aggravates seedling disease problems. Roots growing through compacted layers may develop constricted, weakened areas vulnerable to infection by fungi and may restrict growth later in the season.

Rotate cotton with sorghum and small grains to reduce inoculum of *Pythium* and *Rhizoctonia*.

Monitoring and Treatment Decisions

Always use seed treated with fungicides effective against *Rhizoctonia solani* and *Pythium* spp. In cooler areas, especially in early plantings, it is advisable to include a material effective against *Thielaviopsis basicola.* Supplemental fungicides applied to the soil at planting provide extra protection when cool, wet weather is likely after planting, in fields with a history of severe seedling disease, and in fields that must be replanted due to seedling disease.

Assess stand establishment to determine if your crop is growing satisfactorily. Guidelines for stand assessment are available in the online version of this guideline.

Common name (Example trade name)	Amount to Use (rate per 100 lb seed)

Not all registered pesticides are listed. The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least likely to cause resistance are at the top of the table. When choosing a pesticide, consider information relating to the pesticide's properties and application timing, honey bees, and environmental impact. Always read the label of the product being used.

SEED TREATMENTS

To treat for PYTHIUM:

A. METALAXYL
(Apron XL LS) 0.32–0.64 fl oz/100 lbs of seed
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Phenylamide (4)
COMMENTS: Apply as a seed treatment to machine-delinted or acid-delinted cottonseed.

To treat for RHIZOCTONIA:

A. TRIADIMENOL
(Baytan 30) 0.25–0.75 fl oz/100 lbs of seed
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3)
COMMENTS: Higher rates are only for areas with a history of severe seedling disease problems.
. . . or . . .
B. MYCLOBUTANIL
(Nu-Flow M-HF) 1.25–1.75 fl oz/100 lbs of seed
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3)

To treat for THIELAVIOPSIS:

A. TRIADIMENOL
(Baytan) 30 1–3 fl oz/100 lbs of seed
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3)
COMMENTS: Higher rates are only for areas with a history of severe seedling disease problems.
. . . or . . .
B. MYCLOBUTANIL
(Nu-Flow M-HF) 1.25–1.75 fl oz/100 lbs of seed
MODE-OF-ACTION GROUP NAME (NUMBER[1]): Demethylation inhibitor (3)

[1] Group numbers are assigned by the Fungicide Resistance Action Committee (FRAC) according to different modes of action. Fungicides with different group numbers are suitable to alternate in a resistance management program. In California, make no more than one application of a fungicide with a mode-of-action group number associated with high resistance risk before rotating to a fungicide with a different mode-of-action group number; for other fungicides, make no more than two consecutive applications before rotating to fungicide with a different mode-of-action group number. For more information, see https://www.frac.info.

VERTICILLIUM WILT (5/13)

Pathogen: *Verticillium dahliae*

SYMPTOMS AND SIGNS

Leaves wilt and show interveinal yellowing before becoming necrotic. Light to dark brown vascular discoloration is prominent in the stem and branches. Defoliation and death of plants may occur. Symptoms caused by *Verticillium* generally appear after first flower. Symptoms on younger plants may be caused by *Fusarium*.

COMMENTS ON THE DISEASE

Verticillium survives in the soil as microsclerotia that germinate in the vicinity of roots. Disease severity depends on the number of root penetrations. Verticillium wilt is favored by cool air and soil temperatures.

MANAGEMENT

The concentration or density of inoculum in soil is a major factor in choosing management strategies for Verticillium wilt. Where the density is low, you can generally prevent increases by following a regular rotation with non-susceptible crops, particularly grass family crops such as corn and small grains. Tolerant cotton varieties reduce losses, but they do not prevent inoculum from increasing. Once the inoculum reaches a high level, it may be necessary to rotate out of cotton for several years or employ special techniques such as soil solarization to reduce it.

Cultural Control

- Use tolerant varieties. These may include most modern Acala and Pima varieties; however, the Verticillium resistance evaluation programs of the University of California and most seed companies are less rigorous than in the past. In areas with a history of Verticillium wilt, be cautious when planting large areas with varieties where resistance to Verticillium is unknown. Many of the non-Acala Upland varieties are more susceptible.
- Rotate cotton with corn, wheat, barley, sorghum, safflower, or rice.
- Delay first irrigation if disease pressure is high (more than 10 microsclerotia per gram of soil) and air temperatures are cool.

Monitoring and Treatment Decisions

If there is evidence of *Verticillium* in the field or a new variety of cotton with unknown resistance to *Verticillium* has been planted, sample stems from crop maturity through harvest. If the percent of stems with discoloration is high or if you want to determine the length of time to rotate out of cotton consider taking soil samples to determine the level of inoculum.

Take samples in summer and follow with these steps in each area with a different cropping history:

1. Before taking soil samples for *Verticillium* assay, contact the lab you will use and follow any special instructions
2. Take a sample from each area with a different cropping history; keep samples separate according to crop history
3. Use a shovel or soil tube to collect soil to a depth of 1 foot in at least three randomly chosen places per representative area
4. Place the soil in a bucket or bag
5. Mix thoroughly all the soil collected from one area and transfer about 50-100 g (2-4 oz) to a plastic bag or moisture proof container
6. Label each sample with a field number and other appropriate identification (i.e. cropping history)
7. Keep samples cool and deliver as soon as possible to the lab

Laboratories that analyze soil samples for *Verticillium* report results in number of microsclerotia per gram of soil. Where a single (susceptible) cotton variety is planted without rotation a level of 10 or more microsclerotia per gram usually results in significant yield loss.

Microsclerotia are produced gradually as infected plant debris decays, consequently the number found in the soil increases after plowdown and peaks in midsummer the following year. Therefore, take soil samples at the same time each year in order to monitor changes in inoculum level to determine if it is safe to plant *Verticillium*-susceptible cotton.

Nematodes *(5/13)*

Scientific name: Southern root-knot nematode: *Meloidogyne incognita*

DESCRIPTION OF THE PEST

Root-knot nematodes are microscopic roundworms that are widely distributed throughout California on many crops, and cause varying degrees of damage to cotton. Root-knot nematodes are damaging to cotton as a single pest problem and as part of the Fusarium wilt race 1 and race 4 disease complex. Nematode populations are more damaging to cotton in the presence of *Fusarium* than when nematodes are present without *Fusarium*. Fusarium wilt race 1 damage is consistently associated with root-knot nematode infection. Fusarium wilt race 4 is less often associated with root-knot nematode infections. Fusarium race 4 is by itself a serious problem in cotton, but may be exacerbated by the presence of root-knot nematodes.

DAMAGE

Nematodes damage cotton by attacking the young tap and secondary roots. Their feeding stimulates the production of galls. These galls interfere with the roots' ability to absorb water and nutrients, and provide locations for other disease-producing organisms, such as fungi (*Fusarium*) or bacteria, to readily enter the plant.

MANAGEMENT

To manage root-knot nematodes efficiently, you should know the cropping history, soil texture, and history of injury in local soils, and you need an estimate of the nematode population level. In sandy soil with a history of root-knot injury to cotton, injury is likely to recur each season as long as cotton or other susceptible crops are planted without soil fumigation. If injury is severe enough and if the affected area is extensive, soil fumigation may be needed, or it may be necessary to plant a resistant cotton variety or a resistant variety of another crop such as tomato or alfalfa. Good field sanitation helps prevent infestations from spreading, and weed control is important in eliminating weed hosts supporting root-knot nematodes.

Cultural Control

Clean fallowing (i.e., weed-free) during years when land is to be left unplanted is effective in controlling root-knot nematodes for cotton in California soils, but clean fallow can reduce beneficial mycorrhizal fungi to crop-damaging levels if the land is left plant-free for more than one year. Crop rotation is also useful for reducing root-knot nematode populations. For successful control of nematodes in a rotation program, susceptible weeds must be controlled completely in the rotation crop. Rotation crops that help to reduce cotton root-knot nematodes include alfalfa, winter small grains, corn, root-knot resistant cultivars of processing tomatoes, resistant cowpea (cvs. California Blackeye CB 46, CB 27, CB 50, and CB 5), sorghum and sudangrass. Corn is known to sustain several root-knot nematode species also found in cotton. So far there have been few problems reported in cotton following a rotation with corn.

Small Winter Grain Rotation

Delay fall planting until soil temperatures are below 65°F at planting depth; when soil temperatures are below 65°F, root invasion by root-knot nematodes ceases.

Alfalfa Rotation

Select an alfalfa variety with known resistance to the southern root-knot nematode. (See the publication *Winter Survival, Fall Dormancy & Pest Resistance Ratings for Alfalfa Varieties* from https://www.alfalfa.org.) The alfalfa crop must be grown for 2 to 3 years and weeds must be controlled to reduce root-knot nematode numbers enough so cotton can be grown for at least one season without soil treatment. Be sure to sample for nematodes before planting back to cotton.

Precision Tillage or Precision Ripping

Precision tillage or ripping increases yields when root-knot nematodes are present. This practice involves pulling a ripping shank through the soil where the center of the future cotton beds will be located. Typically the soil is ripped at least 18 inches deep during winter before the rains. While this practice does not reduce the nematode population, replicated tests have shown significant yield increases with this technique. It is thought that the channel created under the planting bed allows the cotton seedling to extend its taproot deeper into the soil earlier in the season, thus making use of more soil volume than in unripped soils. The resulting enhanced root system of the cotton plant has greater access to soil water and can escape some nematode infection by growing into deeper soils at an earlier stage of development.

Resistance

A resistant variety of Acala cotton, NemX HY, developed in the San Joaquin Valley of California, suppresses initial infection by southern root-knot nematode and thus reduces yield loss of cotton plants grown in infested soil. Because reproduction of the southern root-knot nematode on roots of NemX HY is limited, the population of this nematode in the soil in fall is much lower than the level in soil following susceptible cotton varieties. Check with seed companies for availability of this variety or its comparable replacements, as they are used on minimal acreages and may not be readily available.

The use of NemX HY is especially effective for managing root-knot nematode in rotations with other nematode susceptible crops. In addition to resisting the southern root-knot species, *Meloidogyne incognita*, it also acts as a nonhost for the other common species of root-knot nematodes, including *M. arenaria*, *M. hapla*, and *M. javanica*. Therefore, the resistant cotton can effectively prevent the buildup of all the root-knot nematode species likely to be encountered; this will relieve the nematode infection and damage potential on other crops grown in rotation.

Although resistant varieties provide excellent protection, do not plant them year after year in the same field. Experience with resistance in other crops has shown the root-knot nematode populations have the potential to overcome host plant resistance when exposed repeatedly to varieties with the same genetic resistance.

Monitoring and Treatment Decisions

Root galls are the only distinctive symptoms of root-knot nematode injury on cotton plants. Above ground, infested plants have a nonspecific poor growth appearance. Early in the season, check for galls on the roots of cotton to determine if root-knot nematodes are present. Later in the season, from harvest until plowdown, use the Weighted Nematode Rating.

Weighted Nematode Rating System

An easy and inexpensive way to rate root-knot nematode damage where cotton follows cotton is the weighted nematode rating system. This method does not require soil samples or a laboratory to extract nematodes, because roots are rated in the field. Rating is based on the relative intensity of root galling. Start sampling at harvest time. Before you begin, draw a map dividing any areas in the field that differ in soil texture, cropping history, or crop injury. Further divide the areas where conditions are most uniform into smaller blocks, using a grid pattern.

Sample each block separately; blocks should be no larger than 10 acres. Use a root lifter such as a carrot or beet lifter attached to a light tractor to lift cotton roots easily out of the soil. See the Monitoring procedures and form for Weighted Nematode ratings in the online version of this guideline.

Soil Samples

Sample soils of fields known or suspected to be infested with root-knot nematodes to establish the population density of each sub area. Find a laboratory that will process the samples and give population estimates of the number of juveniles per weight of soil. Details of the appropriate sampling procedure and handling samples are given in UC ANR Publication 3305, *Integrated Pest Management for Cotton*, 2nd edition.

Integrated Pest Management for Cotton, 2nd edition, gives a detailed explanation of sample interpretation. UC researchers have determined the relative yield loss expected for a given preplant nematode population level. Using this yield loss estimate, you can determine if nematode levels in your soil may lead to yield losses and whether a nematode management option is economically justified.

Chemical Control

When nematodes are at levels requiring treatment, Mymik (a replacement for Temik) at planting, which is pending registration, can increase cotton yields. Other products such as metam sodium (e.g., Vapam) are registered for preplant use on cotton, but extensive tests in California have not shown economic yield increases with treatable populations of nematodes. Also, the fumigant 1,3-dichloropropene (Telone II) is effective on nematodes in cotton but is currently not economic for southern root-knot nematode because of its high cost.

Weeds

(Section reviewed 5/13)

Integrated Weed Management (5/13)

Effective, economical weed control in cotton requires an integrated approach that includes cultural, mechanical, biological, and chemical methods. Controlling undesirable vegetation around field roadsides, fencerows, and ditch banks is also an integral part of an effective weed control program in cotton. These areas are prime sources of weed seed production for subsequent field infestation. Make a special effort to destroy perennial grasses, nightshades, field bindweed, and other competitive weeds in these areas.

An important component of a successful weed management program is crop rotation. Whenever the same crop is planted year after year, there is a good chance that one or more weed species will increase because they are adapted to the same conditions as the crop. Also, repeated use of the same herbicides (same mode of action) will favor increased populations of tolerant weed species. Rotating to another crop disrupts weeds adapted to cotton growing conditions and enables the use of different herbicides (different modes of action) so the tolerant weed species in cotton can be controlled. Annual weed problems can be minimized by a rotation system that includes cereals and alfalfa.

Herbicides

Herbicides can be used to minimize weed management costs. To reduce the need for chemical controls, select fields free of aggressive weeds such as nutsedge, field bindweed, and annual morningglory, which are difficult to control. Consider using herbicide-tolerant varieties of cotton. Herbicide-tolerant cotton varieties available to California cotton growers include Roundup Ready and Liberty Link.

To select the most effective herbicide(s), one must know the weed species present and consider the soil type, cropping sequence, and the timing of cultural operations. Records of weed infestations including weed species and their density should be kept on a field-by-field basis. Only through knowledge of the infestation can one plan an effective, economical weed control strategy.

Depending on the species and density of weeds present in a field, treatments may or may not be needed during any of the following cultural periods:

- **Preplant treatments** with dinitroanilines are almost always cost effective even with herbicide-resistant varieties.
- Mid-season cultivation can be used to control **emerging weeds**.
- If cotton stands are weak, **layby treatments** are especially beneficial.

Preplant-Incorporated Herbicides

These herbicides are applied to the soil surface and mechanically mixed into the soil before the crop is planted. Trash and large clods will reduce their effectiveness. Incorporate preplant-incorporated herbicides to a depth of 3 to 4 inches within 24 hours of application. Because most tillage equipment leaves the herbicide in the top half of the tilled soil, till twice the depth that herbicide placement is wanted.

Postemergence Herbicides

These herbicides are applied to emerged weeds. For effective control, apply when weeds are less than 2 inches tall. Many of the postemergence herbicides are applied as directed sprays to the base of the cotton plant to contact weed seedlings that have germinated in the row. To effectively and safely post-direct herbicides, the cotton needs to be 6 to 8 inches tall. When most postemergence herbicides contact the terminal growing point of the cotton plant, severe damage (and possibly death) may occur, causing growth retardation and delayed maturity.

Because no one herbicide controls all weeds present, herbicide combinations or sequential applications at preplant, postplant, layby, or two or three of these stages may be needed. On fallow beds carfentrazone (Shark), pyraflufen (ET), flumioxazin (Chateau), or either of these plus oxyfluorfen (Goal) are combined with either glyphosate (Roundup) or paraquat (Gramoxone Inteon) to increase efficacy on larger weeds and broaden the spectrum of weeds controlled. Prometryn (Caparol) can be combined with either trifluralin (Treflan) or pendimethalin (Prowl) and applied preplant incorporated, for control of nightshade. MSMA can be applied in combination with prometryn (Caparol) as a postdirected (post crop emergence, directed at weeds) spray for such hard-to-control weeds as nightshade. Pyrithiobac-sodium (Staple), applied over the top of cotton plants from the time the

cotyledons appear to the emergence of the first true leaves, is another management option for nightshade postemergence control.

Herbicide Resistance

Herbicide-resistant weed species develop through selection pressure imposed by repeated and often continuous use of an herbicide with the same mode of action. Long-residual preemergence herbicides, or repeated application of postemergence herbicides will further increase selection pressure. Factors that can lead to or accelerate the development of herbicide resistance include weed characteristics (e.g., weeds that produce many seeds), chemical properties (e.g., herbicides with long residuals), and lack of good cultural practices (e.g., lack of tillage).

Detection

The first step in preventing herbicide resistance is early detection. Be on the lookout when monitoring for patterns that indicate resistance. These include patches of dense weed populations with less dense populations radiating out from the central patch and escapes scattered in no particular pattern throughout the field.

Prevention and Management of Herbicide-Resistant Weeds

Important weed management strategies to help prevent the development of weed resistance to herbicides or to keep herbicide-resistant weeds under control include:

- Preirrigate, followed by tillage or herbicide applications to control emerging weeds
- Use certified seed that is free of weed seeds
- Rotate herbicides that have different modes of action and WSSA Group numbers (see Table 1)
- Rotate crops
- Monitor for weed survival after an herbicide application
- Use nonchemical weed-control methods such as cultivation or hand weeding with a hoe
- Use residual herbicides
- Clean equipment after working in weed-contaminated fields
- Control escaped weeds before they can produce seed

Table 1. Herbicides Registered for Cotton Production.[1]

Chemical Name	Example Trade Name[2]	Mode of Action[3]	WSSA[4] Group No.
carfentrazone	Shark	triazolinones	14
clethodim	Select Max	lipid biosynthesis inhibitor	1
diuron	Karmex	photosynthesis inhibitor	7
fluazifop-p-butyl	Fusilade	lipid biosynthesis inhibitor	1
flumioxazin	Chateau	N–phenylphthalimide	14
glyphosate	Roundup	amino acid synthesis inhibitor	9
metam sodium	Vapam	fumigant	27
MSMA	MSMA	organoarsenical	17
oxyfluorfen	Goal	diphenylethes	14
paraquat	Gramoxone Inteon	cell membrane disrupter	22
pendimethalin	Prowl	mitotic inhibitor	3
prometryn	Caparol	photosynthesis inhibitor	5
pyrithiobac sodium	Staple	amino acid synthesis inhibitor	2
pyraflufen	ET	phenylpyrazoles	14
s-metolachlor	Dual Magnum	shoot and root inhibitor	15
sethoxydim	Poast	lipid biosynthesis inhibitor	1
trifluralin	Treflan	mitotic inhibitor	3

1 Adapted from Vargas, R. And Wright, S. 2004. *Cotton Field Check: A Cotton Management Update from UC Cooperative Extension–Herbicide Resistance Management*

2 Use of trade names does not constitute an endorsement by the University of California.

3 to prevent or delay the development of herbicide resistance, rotate herbicides with different modes of actions and WSSA group numbers.

4 For additional information on herbicide resistance, visit Weed Science Society of America (WSSA). See https://www.weedscience.org/Home.aspx.

Monitoring

To select the most effective herbicide(s) and rotation crops, conduct surveys and keep records of weeds and how their populations are changing. Survey each field; adjacent fields can have very different weed populations as a result of cropping history or soil type. Conduct field surveys four times per growing season, once during each of the following periods: preplant to planting, crop emergence to seedling growth, early squaring, and from first open boll to preharvest. Keep records of your observations. Sampling forms.

Weed Management before Planting

Select fields that are free of perennial weeds such as nutsedge, field bindweed, bermudagrass, and johnsongrass, if possible. These weeds are usually easier to control in rotation crops (see CROP ROTATION) or during fallow periods. Laser leveling of fields will eliminate low spots where weed growth is favored. Tailwater return systems that prevent the accumulation of water at field ends will also reduce weed problems. Turn under crop and weed debris from previous crops soon after harvest to aid decomposition. Trash-free seedbeds will facilitate early cultivation and enhance herbicide incorporation and uniform stand establishment.

Conservation Tillage

In recent years, interest in conservation tillage systems has grown as a result of the increased number of herbicide-tolerant cotton varieties, higher fuel prices, access to better conservation tillage equipment, and environmental air quality issues. Conservation management plans, now required by the San Joaquin Valley Unified Air Pollution Control District, list the use of herbicide-tolerant cotton and reduction of cultivation as practices acceptable in dust reduction. The advantage of herbicide-tolerant cotton (mainly Roundup Ready) has been the ease in applying glyphosate with cotton in the field to provide effective control of weeds. Production costs decrease because growers make fewer trips across fields to apply herbicides, reduce the number of cultivations, and reduce or eliminate hand-weeding.

Conservation tillage systems are most often practiced with herbicide-tolerant cotton varieties, but conventional varieties and herbicides can also be used with conservation tillage systems. The Roundup Ready Flex system when coupled with a conservation tillage system increases the weed management flexibility. In the future, tillage and hand pulling may be needed because major weed shifts and some weed resistance is being observed in other states in cotton and similar cropping systems (corn) that use conservation tillage based on herbicides and glyphosate-only systems.

It is important to rotate glyphosate with an herbicide that has a different mode of action in order to reduce the potential for the development of weed resistance. If pyrithiobac sodium (Staple) is used in a conservation tillage system, injury to subsequent crops may be a problem. In contrast to tillage systems, not tilling the soil leaves residual herbicides such as pyrithiobac sodium undiluted in the soil profile. This may lead to injury of crops (e.g. Tomatoes) following cotton.

Cultivation

Winter Fallow Beds

Before establishing fallow beds, inverting the soil to the plow depth will bury problem species such as nutsedges, annual morningglory, and nightshades. Most weeds germinate in the top 1 to 1.5 inches of soil. Deep plowing with Kverneland-type plows before planting can be used to bury most seeds to prevent their germination. For weeds that do germinate, hand rogueing and removing them from the field will reduce seed production and reduce future infestations. Inverting the soil should be done infrequently to allow time for the buried seeds and tubers to decay. For nutsedges, this takes about 3 years. In some areas, deep plowing can bring salts back to the upper soil profile.

Mechanical cultivation of fallow cotton beds with the use of sectioned rolling cultivators can be effective if weeds are young. Two to three cultivations may be necessary to control weeds, depending on winter rainfall patterns. However, wet weather may prevent timely entry into the field and cultivating when soils are too wet can create soil compaction. Also, labor and fuel costs may limit the feasibility of multiple cultivations. Deferring preirrigation to late February can overcome some of these cultivation problems. Weed seedlings germinating as a result of preirrigation should be destroyed chemically or mechanically before planting the crop.

Preplant Cultivation

Cultivation just before planting controls small weed seedlings and prepares the bed for seeding. To give cotton a head start on nutsedge, use sweeps or other shallow cultivating tools to dislodge early nutsedge growth before planting. Mulching the beds also gives cotton a head start on nutsedge.

Herbicides

Herbicides in Winter Fallow Beds

A large percentage of fields planted to cotton using either conventional or herbicide-tolerant varieties are treated with a dinitroaniline herbicide (trifluralin or pendimethalin) and are listed or bedded up during fall and winter. For emerged broadleaf weeds not controlled by dinitroanilines (e.g., mustards), use oxyfluorfen (Goal), flumioxazin (Chateau), carfentrazone (Shark), pyraflufen (ET), or prometryn (Caparol). These herbicides can all be applied to fallow beds. To prevent damage to the cotton plants, work oxyfluorfen-treated beds with a rolling cultivator to a depth of at least 2 inches before planting to break the soil surface. Once the soil surface is broken, oxyfluorfen loses its effectiveness.

Applications of paraquat (Gramoxone) or glyphosate (Roundup) are often necessary for postemergence control of winter annual grasses and broadleaf weeds before planting. Both herbicides can be applied alone or in tank mix applications with a broadleaf herbicide. Do not spray during air inversions or when it is windy; special restrictions exist in the San Joaquin Valley as a result of past off-target movement of winter fallow bed herbicides.

Preplant Herbicides

Trifluralin (Treflan) and pendimethalin (Prowl), two dinitroaniline herbicides, are used extensively during the preplant period in cotton fields to be planted with either conventional or herbicide-tolerant varieties. These herbicides are effective against most annual grasses and many broadleaf annuals. However, weeds in the Solanaceae family (nightshade), Asteraceae family (sowthistle), and Brassicaceae family (mustards), and annual morningglory are not controlled by them. These herbicides also control seedling perennial grasses, but not regrowth from rhizomes.

Incorporate preemergence herbicides to a depth of 2 to 4 inches using an offset finishing disc with gauge wheels, springtooth harrows, rolling cultivators, or power-driven tillers. Depth of incorporation must be controlled to prevent growth retardation of the cotton plants. During planting, place the cotton seed at the lower zone of the treated soil layer for best results.

A shallow, preplant-incorporated application of trifluralin or pendimethalin is sometimes included as part of the planting operation. The herbicide is sprayed between the dirt pushers and planter, and incorporated by rolling cultivators mounted before the planter. This method, called ROCAP, provides good control when soil moisture is adequate.

A preplant treatment with the soil fumigant metam sodium can be used for control of nightshade and nutsedge. Nightshade control has been excellent; however nutsedge control is erratic on sandy soil and poor on clay loam soils. The high rates needed for good nutsedge control sometimes reduce seedling vigor. The ROCAP method and metam sodium are rarely used today for weed control.

Weed Management at Planting

To help establish a uniform and competitive stand of cotton, do not plant the crop unless the soil temperature is at least 58°F at 8:00 a.m. at the depth of seed placement. Once soil temperatures are above this threshold, plant only when a minimum of 15 degree-days are predicted for the next 5 days. For Acala cotton in the San Joaquin Valley, accumulate degree-days using a lower threshold of 60°F. Pima can be planted under slightly cooler conditions. Follow UC Cotton Planting Forecasts issued during the planting season to plant into the most optimal conditions (available online at https://ipm.ucanr.edu/weather/cotton-planting-forecast/). Proper timing of planting coupled with correct planting depth, adequate soil moisture, and fertilizer placement will ensure rapid and uniform crop emergence and seedling growth. A vigorous, uniform stand of cotton will compete with weeds more efficiently than one being established under adverse conditions.

Weed Management after Planting

Cultivation after Planting

Mechanical cultivation continues to be one of the most important methods of controlling weeds in cotton. For best results the cultivation equipment must be carefully aligned to follow the seed row precisely and as close to plants as possible. Weed seedlings are killed easily when they are small (1–2 inches in diameter); therefore, schedule cultivations before the weeds deplete soil moisture and while they are easily dislodged.

The equipment used for bedding, planting, and cultivation must be matched for row spacing and to cover the same number of rows with each pass. Effective equipment for cultivation includes sweeps, bed knives, rolling

cultivators, reversed disc hillers, and rod weeders. (Sweeps and bed knives are more effective on nutsedge and grasses.) When this equipment is used individually or in combination, effective early season weed control can be achieved.

For close, in-row cultivation in cotton, a guidance system can be used. The guidance system must be used for both the planter and cultivator, and both operations must be performed in the same direction for each row.

Layby Cultivation
Timing the last cultivation just as the rows close will protect cotton yields and quality from late-season weeds if cotton grows vigorously and there are not many skips. About 5 to 10 days after an irrigation, cultivate to throw soil over weed seedlings in the drill row; this cultivation need not be as precise as earlier cultivations because cotton plants will tolerate some soil covering the stem and leaves at this time. Be sure to cultivate shallowly to avoid pruning the roots. Layby cultivation also prepares furrows for subsequent irrigation.

Hand Weeding
Hand weeding with hoes can be an important and effective means of controlling weeds within the planted row where weed removal with cultivation is difficult. It can also be a useful tool in weed resistance management by removing weeds that have survived previous herbicide applications before they produce seed. Cotton can be thinned to a desired plant number, if necessary, with early hand hoeing.

When scattered weed infestations such as velvetleaf (less than 10 in a field) and other aggressive, hard-to-control weeds are present, pull by hand and remove these plants from the field to minimize seed production and distribution. A weed like annual morningglory must be hoed before it twines. Hand weeding requires large amounts of labor that may not be available and is costly, making this method less appealing and sometimes prohibitive.

Postplant Herbicides
During the postplant period, diuron (Karmex), prometryn (Caparol), s-metolachlor (Dual Magnum), oxyfluorfen (Goal), and pyrithiobac-sodium (Staple), can be applied to provide effective control of many weed species tolerant of dinitroanilines.

When the cotton plants are 6 inches tall, directed sprays of these herbicides can be used to control small seedlings of nightshade and other resistant species. While the herbicide is directed to the row, cultivation is used for weeds in the furrow.

Sethoxydim (Poast), fluazifop-p-butyl (Fusilade), and clethodim (Select Max) are effective against most grasses, including perennials such as johnsongrass and bermudagrass. In addition, clethodim controls annual bluegrass. Effective control of annual grasses is obtained when herbicides are applied to grasses that are actively growing and less than 6 inches tall. After treatment, adequate moisture is essential to insure uptake of the herbicide as well as a vigorous and uniform stand of cotton that can compete effectively with the grasses.

Cultivating about 5 to 7 days after treatment can further enhance johnsongrass control by exposing the rhizomes to the sun. Additionally, if the soil is dry, effective control of perennial grasses can also be obtained when rhizomes are cut into short segments by discing and cross discing during land preparation.

When pyrithiobac sodium (Staple) is tank mixed with sethoxydim or clethodim, or if an application of pyrithiobac sodium is followed by a sethoxydim or clethodim application, grass control may be delayed. If pyrithiobac sodium is tank mixed with fluazifop-p-butyl or applied within 7 days of a fluazifop-p-butyl application, reduced grass control may occur.

Glyphosate (Roundup) can be applied over the top of cotton plants (from the time the cotyledons appear to the emergence of the first true leaves) and postdirected (herbicides are applied to the base of cotton stems to target weeds smaller than cotton) to Roundup Ready varieties of cotton for the control of annual and perennial weeds. Best control is achieved when weeds are young seedlings.

With Roundup Ready Flex systems, glyphosate can be applied through layby (14th node) and beyond, which provides increased crop safety and enhances flexibility. There are no restrictions on timing of sequential applications, and there is the potential to combine insecticide or mepiquat into over-the-top applications.

With traditional, non-herbicide-tolerant varieties, glyphosate can be used as a spot treatment to control isolated infestations of perennials or applied with a hooded sprayer to control field bindweed and other persistent weeds.

The Liberty Link system uses glufosinate (Rely), which has a different mode of action than glyphosate. Glufosinate provides broad-spectrum weed control, and there are no growth stage restrictions for over-the-top applications. It can be applied to non-Liberty Link cotton with hooded sprayers or postdirected, and there are no rotational restrictions.

Layby Herbicides

Layby applications (an application at the final cultivation as the cotton closes over the furrow preventing further cultivation) of carfentrazone (Shark), pyraflufen (ET), flumioxazin (Chateau), oxyfluorfen (Goal), diuron (Karmex), prometryn (Carparol), and glufosinate (Rely) can help control existing broadleaves. Preemergence applications of s-metolachlor (Dual Magnum), diuron (Karmex), prometryn (Caparol), and oxyfluorfen (Goal) can be used to prevent the growth of nightshade, annual morningglory, groundcherry, and cocklebur when it is no longer possible to cultivate; in addition, s-metolachlor will suppress yellow nutsedge growth. The herbicides are usually applied to the furrow, as well as the bed, and incorporated with sectioned rolling cultivators. Layby applications are especially beneficial when cotton is short and the stand is poor because without such an application, weeds that escape the preplant treatment readily grow and mature with little or no competition from the cotton plant.

Preharvest Herbicides

Glyphosate can be used before harvest for control of johnsongrass, field bindweed, and annual morningglory and for the control of cotton regrowth in conventional cotton. When present at harvest, these weeds reduce the effectiveness of defoliants, reduce harvest efficiency, lower lint grades, add to the soil seed bank, and interfere with subsequent crop production.

Glyphosate can be either applied alone, as early as 8 nodes above cracked boll (NACB), or tank mixed with tribufos (Def or Folex) or thidazuron plus diuron (Ginstar). When applied alone at 8 NACB (about 40 to 50% boll opening), it can provide regrowth control in conventional (non-Roundup Ready) varieties with little to no impact on yield or fiber quality. This earlier application can also result in improved weed control as a result of greater moisture status in the weeds as opposed to a much lower moisture status at a 4 NABC defoliation treatment. When applied in combination with defoliants, continued defoliation and improved regrowth control can be achieved. **Do not apply glyphosate to cotton grown for seed**, because seed quality and germination percentage will be reduced, making seed undesirable or unfit for planting.

SPECIAL WEED PROBLEMS (5/13)

Annual weed species that may be especially troublesome include hairy nightshade, black nightshade, and annual morningglory. Perennials include yellow and purple nutsedge, field bindweed, bermudagrass, and johnsongrass. Control of these hard-to-control weeds can be enhanced by growing a Roundup Ready cotton variety.

Nightshade

Many weeds, such as hairy, black, and silverleaf nightshade, germinate in the top 1 to 1.5 inches of soil. In fields heavily infested with nightshade or other difficult-to-control weeds, deep plowing with Kverneland-type plows before planting can be used to bury most seeds to a depth of 1 to 1.5 feet to prevent their germination. For weeds that do germinate, hand-rogueing and removing them from the field will reduce seed production and reduce future infestations.

Tank mix applications of trifluralin (Treflan) with prometryn (Caparol) or pendimethalin (Prowl) with prometryn as a preplant incorporated treatment, provides successful control when adequate soil moisture is present. A preplant treatment with the soil fumigant metam sodium can also be effective. Pyrithiobac sodium (Staple) applied at the 4-leaf cotton stage provides excellent control, especially when combined with a cultivation.

Cotton often turns slightly yellow for 1 to 2 weeks if cold weather follows an application. Pima is more sensitive to these symptoms and there is no guarantee that plants will recover sufficiently. Well-timed postdirected (after crop emergence, directed at weeds) treatments of carfentrazone (Shark), oxyfluorfen (Goal), and prometryn (Caparol) when nightshade is in the cotyledon to two-leaf stage also can be successful. Be sure to follow product labels for minimum cotton height to avoid crop injury.

In transgenic cotton varieties, glyphosate (Roundup) in Roundup Ready cotton and glufosinate (Rely) in Liberty Link cotton provide effective nightshade control. (Control is reduced when nightshade is past the fourth-leaf stage.) Cultivation also effectively controls nightshade in the early stages.

Annual Morningglory

Annual morningglory normally does not cause a problem at cotton emergence because it normally germinates later in the season. A postdirected treatment of carfentrazone (Shark), pyraflufen (ET), flumioxazin (Chateau), trifloxysulfuron sodium (Envoke), oxyfluorfen (Goal), diuron (Karmex), or prometryn (Caparol) to morningglory seedlings before they twine onto the cotton plant has provided control.

Tank mix applications of pyrithiobac sodium (Staple) and MSMA, when applied up to the four-to six-leaf stage, have provided excellent control. Be sure to follow product labels for minimum cotton height to avoid crop injury.

For transgenic cotton varieties, two to three applications of glyphosate (Roundup) to Roundup Ready cotton or glufosinate (Rely) in Liberty Link cotton applied before morningglory has more than two leaves provide effective control. In non-Liberty-Link cotton, a late application of glufosinate, before the weed has two leaves, is effective.

Nutsedge

To give cotton a head start on nutsedge, sweeps or other shallow cultivating tools can be used to dislodge emerging nutsedge growth before planting. After cotton emergence, the use of precision equipment to cultivate as closely as possible and hand or mechanical thinning can also help reduce nutsedge competition.

Directed sprays after the cotton plants have two or more leaves reduce crop injury. MSMA can be applied broadcast or as a directed spray. S-metolachlor (Dual Magnum) can be applied either over the top of cotton plants (from the time the cotyledons appear to the emergence of the first true leaves) or as a directed spray for preemergence control of yellow nutsedge. If these herbicides accidentally get on the growing point of the cotton plant, they will stunt the plant's growth. Because nutsedge is sensitive to competition by shade, early chemical control will allow later shading from the cotton canopy to provide additional control. Rotation to corn with the use of a thiocarbamate herbicide, Roundup Ready corn, or halsulfuron (Sandea), has also significantly reduced both yellow and purple nutsedge infestations. Roundup applied to Roundup Ready cotton effectively suppresses nutsedge growth when applied early over the top and followed by a second, postdirected treatment.

Dry fallowing in summer on sandy loam soils has reduced purple nutsedge populations. Purple nutsedge tubers can be destroyed with repeated summer tillage of dry soil because tubers are susceptible to drying. Springtooth

harrows have been the best tool for this method, but this method has not been effective for control of yellow nutsedge.

Field Bindweed

During fallow periods, apply glyphosate (Roundup) to field bindweed to achieve control. During the growing season, control can be achieved with glyphosate applied through a hooded sprayer in traditional cotton varieties. Belting on the bottom of the hood will keep the spray off the lower leaves and stems of the cotton plant. Adequate growth of field bindweed that is not moisture stressed is essential for this method to work. Two to three applications of glyphosate (Roundup) in Roundup Ready cotton will provide good control. Layby applications of glufosinate (Rely) suppress this weed.

Perennial Grasses

Prevention is the best method to control perennial grasses such as bermudagrass and johnsongrass. Dry fallow during summer when moisture is depleted has significantly reduced bermudagrass and johnsongrass. Cultivation can control these weeds between rows, but hand weeding is not effective. Sethoxydim (Poast), fluazifop-p-butyl (Fusilade), or clethodim (Select Max) applied two to three times per season can provide season-long control. Glyphosate (Roundup) applied with a hooded sprayer to traditional cotton varieties will provide satisfactory control of bermudagrass. For Roundup Flex cotton, over-the-top applications can be made up to the 14th node in cotton; in Roundup Ready varieties they can only be made up to the fourth-leaf stage. Directed sprays, depending on the cotton size, can also be effective.

COMMON AND SCIENTIFIC NAMES OF WEEDS (5/13)

Common name	Scientific Name
barley, foxtail	*Hordeum jubatum*
barley, hare	*Hordeum murinum ssp. leporinum*
barnyardgrass	*Echinochloa crus-galli*
bermudagrass	*Cynodon dactylon*
bindweed, field	*Convolvulus arvensis*
bluegrass, annual	*Poa annua*
bromegrasses	*Bromus* spp.
canarygrasses	*Phalaris* spp.
chickweeds	*Stellaria* spp.
clovers	*Trifolium* spp.
cockleburs	*Xanthium* spp.
crabgrass, large	*Digitaria sanguinalis*
cudweeds	*Gnaphalium* spp.
cupgrasses	*Eriochloa* spp.
datura, sacred	*Datura wrightii*
fescues	*Festuca* spp.
fiddlenecks	*Amsinckia* spp.
filarees	*Erodium* spp.
fingergrasses	*Chloris* spp.
fleabane, hairy	*Conyza bonariensis*
foxtails	*Setaria* spp.
goosefoot, nettleleaf	*Chenopodium murale*
groundcherries	*Physalis* spp.
groundsels	*Senecio vulgaris*
henbit	*Lamium amplexicaule*
horseweed	*Conyza* spp.
johnsongrass	*Sorghum halepense*
knapweed, Russian	*Acroptilon repens*
knotweed, common	*Polygonum arenastrum*
lambsquarters, common	*Chenopodium album*
lettuce, prickly	*Lactuca serriola*
lovegrasses	*Eragrostis* spp.
mallow, little (cheeseweed)	*Malva parviflora*
miner's lettuce	*Claytonia perfoliata*
morningglories	*Ipomoea* spp.
mustards	*Brassica* spp.
nettles	*Urtica* spp.
nightshade, silverleaf	*Solanum elaeagnifolium*
nightshades	*Solanum* spp.
nutsedges	*Cyperus* spp.
oat, wild	*Avena fatua*
pigweeds	*Amaranthus* spp.
pineappleweed	*Chamomilla suaveolens*
polypogon, rabbitfoot	*Polypogon monospeliensis*

(continued next page)

Common name	Scientific Name
punctureVine	*Tribulus terrestris*
purslane, common	*Portulaca oleracea*
radish, wild	*Raphanus raphanistrum*
redmaids (desert rockpurslane)	*Calandrinia ciliata*
rocket, London	*Sisymbrium irio*
ryegrasses	*Lolium* spp.
sandburs	*Cenchrus* spp.
shepherd's-purse	*Capsella bursa-pastoris*
sida, alkali	*Malva leprosa*
sowthistles	*Sonchus* spp.
speedwells	*Veronica* spp.
sprangletops	*Leptochloa* spp.
spurges	*Euphorbia (=Chamaesyce)* spp.
sunflower, common	*Helianthus annuus*
thistle, Russian	*Salsola tragus*
thornapple, chinese	*Datura ferox*
velvetleaf	*Abutilon theophrasti*
witchgrass	*Panicum capillare*

SUSCEPTIBILITY OF WEEDS IN COTTON TO HERBICIDE CONTROL (5/13)

	PREEMERGENCE							POSTEMERGENCE										
ANNUAL WEEDS	**DIU**	**MEO**	**MET***	**OXY**	**PEN**	**PRM**	**TRI**	**CAR**	**CLE**	**FLM**	**FLU**	**GLU**	**GLY**	**MSM**	**PAR***	**PRS**	**PYR**	**SET**
barley, foxtail	—	—	—	—	—	—	—	N	—	—	—	—	—	—	—	—	N	—
barley, hare	C	P	C	P	C	P	C	N	C	—	C	—	C	N	C	N	N	C
barnyardgrass	C	C	C	P	C	N	C	N	C	C	P	P	C	N	N	N	N	C
bluegrass, annual	C	C	C	P	C	C	C	N	C	C	N	C	C	C	C	N	N	N
bromegrasses	C	—	C	P	C	N	C	N	P	—	P	C	C	P	C	N	N	P
canarygrass	C	C	C	P	C	P	C	N	C	—	C	C	C	N	C	N	N	C
chickweeds	C	C	C	P	C	C	C	C	N	C	N	C	C	C	C	—	C	N
clovers	C	N	N	C	N	C	N	–	N	C	N	C	C	N	P	N	—	N
cockleburs	C	—	C	P	N	C	N	P	N	—	N	C	C	P	C	C	C	N
crabgrass, large	C	C	C	C	C	P	C	N	C	C	C	C	C	N	C	N	N	C
cudweeds	C	N	C	P	N	P	N	–	N	—	N	C	C	N	N	N	—	N
cupgrasses	C	C	C	P	C	P	C	N	C	—	C	C	C	P	C	N	N	C
fescues	C	—	C	P	C	P	C	N	P	—	P	–	C	N	C	N	N	P
fiddlenecks	C	N	C	C	C	C	C	C	N	—	N	C	C	N	C	N	C	N
filarees	C	N	C	C	P	C	P	C	N	—	N	C	P	N	P	—	—	N
fingergrasses	C	—	C	—	—	P	C	N	C	—	C	—	C	C	C	N	N	—
fleabane, hairy	C	N	C	P	N	C	N	N	N	C	N	C	N	N	C	—	N	N
foxtails (bristlegrass)	C	C	C	P	C	C	C	N	C	—	N	C	C	P	C	N	N	C
goosefoot, nettleleaf	C	P	C	C	C	C	C	—	N	—	N	C	C	N	C	C	—	N
groundcherries	C	C	C	C	N	C	N	C	N	C	N	C	C	P	C	P	C	N
groundsels	C	N	C	C	N	C	N	C	N	C	N	C	C	N	C	—	C	N
henbit	N	—	C	C	P	C	P	–	N	C	N	C	C	N	C	—	—	N
horseweed	C	N	C	P	N	C	N	P	N	C	N	C	N	N	C	—	P	N
junglerice	C	C	C	P	C	P	C	N	C	C	C	C	N	N	P	N	N	C
knotweed, common	C	N	C	C	C	C	C	—	N	—	N	C	C	N	P	C	—	N
lambsquarters, common	C	P	C	C	C	C	C	C	N	C	N	C	P	N	P	N	C	N
lettuce, prickly	C	—	C	C	N	P	N	—	N	—	N	C	C	N	C	N	—	N
lovegrasses	C	C	C	P	C	P	C	N	C	—	C	—	C	N	C	N	N	C
mallow, little (cheeseweed)	P	P	C	C	N	P	N	C	N	C	N	C	P	N	N	N	C	N
miner's lettuce	C	—	C	C	C	C	C	—	N	—	N	—	C	N	C	—	—	N
morningglory	N	N	C	P	N	P	N	C	N	C	N	C	C	P	P	P	C	N
mustards	C	N	C	C	N	C	N	P	N	—	N	C	C	N	C	C	C	N
nettles	C	C	C	C	P	C	P	C	N	C	N	C	C	N	C	P	C	N
nightshades	C	C	C	C	N	C	N	P	N	C	N	C	C	P	C	C	C	N
oat, wild	P	N	C	P	N	P	N	N	C	C	C	C	C	N	P	N	N	C
pigweeds	C	C	C	C	C	C	C	C	N	C	N	C	P	N	C	C	C	N
pineappleweed	C	—	C	P	N	C	N	N	N	—	N	C	C	N	C	—	—	N
polypogon, rabbitsfoot	C	C	C	P	C	C	C	N	C	—	C	—	C	N	C	N	N	C
punctureweed	N	—	C	P	P	P	P	—	N	C	N	C	C	P	C	P	—	N
purslane, common	C	C	C	C	C	C	C	N	N	C	N	C	C	P	C	P	C	N
radish, wild	C	N	C	C	N	C	N	P	N	–	N	C	C	N	P	—	—	N

(continued next page)

	PREEMERGENCE							POSTEMERGENCE										
ANNUAL WEEDS	**DIU**	**MEO**	**MET***	**OXY**	**PEN**	**PRM**	**TRI**	**CAR**	**CLE**	**FLM**	**FLU**	**GLU**	**GLY**	**MSM**	**PAR***	**PRS**	**PYR**	**SET**
redmaids	C	—	C	C	C	C	C	—	N	C	N	—	C	P	C	—	—	N
rocket, London	C	N	C	C	N	C	N	C	N	—	N	C	C	N	C	C	—	N
ryegrasses	C	C	C	P	C	P	C	N	C	—	C	–	P	P	C	N	N	C
sandburs	N	C	C	N	C	N	C	N	C	—	C	C	C	C	C	N	N	C
shepherd's-purse	C	P	C	C	N	N	N	P	N	C	N	C	C	N	C	C	—	N
sowthistles	C	P	C	C	N	C	N	N	N	C	N	C	C	N	C	—	C	N
speedwells	N	—	C	C	P	C	P	N	N	—	N	—	C	N	C	—	—	N
sprangletops	N	C	C	P	—	N	C	N	C	—	C	C	P	N	C	N	N	C
spurges	N	N	C	P	N	P	N	P	N	—	N	C	C	N	C	N	N	N
sunflower, common	C	N	P	C	N	C	N	—	N	—	N	C	C	N	P	C	—	N
thistle, Russian	N	P	C	P	P	P	P	—	N	—	N	C	C	C	P	N	—	N
thornapple, Chinese	—	—	—	—	—	—	—	—	–	—	—	—	—	—	—	—	—	—
velvetleaf	—	P	C	—	N	—	N	C	N	—	N	C	C	P	C	C	C	N
witchgrass	C	—	C	P	C	P	C	N	C	—	C	C	C	P	C	N	N	C
PERENNIAL WEEDS																		
bermudagrass (established)	N	N	P	N	N	N	N	N	P	—	P	P	P	N	N	N	N	P
bermudagrass (seedling)	N	N	C	N	C	P	C	N	C	—	C	P	C	N	P	N	N	C
bindweed, field (established)	N	N	P	N	N	N	N	P	N	N	N	P	P	N	N	P	P	N
bindweed, field (seedling)	P	N	P	N	N	P	N	C	N	N	N	P	C	C	C	P	C	N
datura, sacred	N	—	P	N	N	N	N	—	N	—	N	—	C	N	C	P	–	N
johnsongrass (established)	N	N	P	N	N	N	N	N	C	—	C	P	C	P	N	N	N	C
johnsongrass (seedling)	N	C	P	N	P	N	P	N	C	—	C	P	C	C	C	N	N	C
knapweed, Russian	N	—	P	N	N	N	N	—	N	—	N	—	P	N	N	—	—	N
nightshade, silverleaf	N	N	P	N	N	N	N	—	N	N	N	—	P	N	N	P	—	N
nutsedge, purple	N	N	P	N	N	N	N	N	N	N	N	P	P	P	N	N	N	N
nutsedge, yellow	N	P	C	N	N	N	N	N	N	P	N	P	P	C	N	N	N	N
sida, alkali	N	—	P	N	N	N	N	—	N	N	N	—	P	N	N	N	—	N

C = Control P = Partial control N = No control — = no information

CAR = carfentrazone (Shark)
CLE = clethodim (Select Max)
DIU = diuron (Karmex)
FLM = flumioxazin (Chateau)
FLU = fluazifop-p-butyl (Fusilade)
GLU = gluphosinate (Rely)
GLY = glyphosate (Roundup)
MEO = s-metolachlor (Dual Magnum)
MET = metam-sodium* (Vapam)
MSM = MSMA
OXY = oxyfluorfen (Goal)
PAR = paraquat* (Gramoxone Inteon)
PEN = pendimethalin (Prowl)
PRM = prometryn (Caparol)
PRS = pyrithiobac sodium (Staple)
PYR = pyraflufen ethyl (ET)
SET = sethoxydim (Poast)
TRI = trifluralin (Treflan)

* Permit required from county agricultural commissioner for purchase or use.

HERBICIDE TREATMENT TABLE (5/13)

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

Not all registered pesticides are listed. The following are listed alphabetically. When choosing a pesticide, consider information relating to environmental impact, resistance management, the pesticide's properties, and application timing. Tank mixes may be necessary to achieve desired control; see Susceptibility of Weeds in Cotton to Herbicide Control for information on specific weed control. Always read the label of the product being used.

WINTER FALLOW BEDS

Before weeds emerge

A. OXYFLUORFEN (Goal 2XL) — 0.25–0.5 lb a.i.; 1–2 pt; REI 24 hours; PHI NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
COMMENTS: Apply before weeds germinate or seedlings are more than 6 inches tall, depending on species. (Provides both pre- and postemergence control.) Aerial applications can be made between Oct 1 and 31 in Fresno, Kern, Kings, Madera, Merced, and Tulare counties. Preirrigation or rainfall should occur within 3–4 weeks for best preemergence activity. Incorporate at least 2 inches deep before planting. Do not rotate to any crop other than cotton for 10 months following application. Certain formulations emit high amounts of volatile organic compounds (VOCs); use low-VOC formulations. **Regulations affect use for the San Joaquin Valley from May 1 to October 31, 2015 and 2016.** Review the Department of Pesticide Regulation's updated fact sheet.

B. PROMETRYN (Caparol 4L) — 1.6–2 lb a.i.; 3.2–4 pt; REI 12 hours; PHI NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Apply before weeds germinate or weed seedlings are more than 2 inches tall, depending on species. Rainfall or sprinkler irrigation is required for soil activity. Do not use on sand or loamy sand soils. To avoid illegal residues do not apply more than 10.3 pt on sandy loam or 11.9 pt on medium to fine soils per year. See label for plantback restrictions.

After weeds emerge

A. CARFENTRAZONE (Shark) — 0.016–0.024 lb a.i.; 1.0–1.5 oz; REI 12 hours; PHI NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
COMMENTS: Provides postemergence broadleaf control. Often combined with glyphosate for both grass and broadleaf control. Avoid drift to prevent injury to nontarget crops.

B. FLUMIOXAZIN (Chateau) — Up to 2.04 oz a.i.; 4 oz; REI 12 hours; PHI NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
COMMENTS: Provides both pre- and postemergence control. The 2 oz rate can be applied 30 days before planting and the 3 oz rate at 60 days before planting. Needs at least 1/4 inch of rainfall or irrigation to activate preemergence control. See label for plantback restrictions. Avoid drift to prevent injury to nontarget crops. Often combined with glyphosate for both grass and broadleaf control.

C. GLYPHOSATE (Roundup) — Label rates; See label; PHI NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 9
COMMENTS: Apply after maximum weed emergence, but before weeds are greater than 6 inches tall. Allow at least 3 days after treatment before tillage. Avoid drift to prevent injury to nontarget crops.

D. PARAQUAT* (Gramoxone Inteon) — 0.5–1 lb a.i.; 2–4 pt; REI 12 hours; PHI NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 22
COMMENTS: Apply with a nonionic surfactant to weeds 1–6 inches tall. Avoid drift to prevent injury to non-target crops.

Herbicide combinations: for tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

PREPLANT

A. METAM SODIUM* — 213–319.5 lb a.i.
(Vapam) — 50–75 gal — See label — NA
COMMENTS: A soil fumigant used for preplant control of annual broadleaves (including nightshade) and grasses; provides partial control of perennials. Nutsedge control is erratic on sandy soils and poor on clay loam soils. Prepare a firm, trash- and clod-free seedbed and preirrigate the soil to ensure that weed seeds have imbibed water. Soil temperatures should be between 50° and 90°F. Use a shallow 6- to 8-inch spray blade to apply a band on top of the cotton bed. Nutsedge control is improved with a 2-3 tiered spray blade or using staggered fertilizer knives. Cover or cap with a 2- to 3-inch layer of soil; place the material deep enough so that treated soil will not be disturbed by the planting operation. Planting may take place 14–21 days after treatment, depending on amount applied as indicated on label. Be sure not to contaminate treated soil with untreated soil during planting or subsequent cultivations. Best results are obtained if soil is undisturbed between application and planting. Apply preplant fertilizer before the metam sodium. Yield reduction can occur because of the reduction of mycorrhizal fungi in the soil; the addition of phosphorus fertilizer has helped correct this problem. Either tank mix the phosphorus with metam or apply it at planting.

B. PENDIMETHALIN — 0.5–1.425 lb a.i.
(Prowl 3.3 EC) — 1.2–3.5 pt — 24 — NA
(Prowl H2O) — 1–3 pt — 24 — NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Can be applied after Oct 15, up to 140 days before planting or immediately before planting. Apply higher rates when application is 140 days before planting. Incorporate within 7 days of application into the top 2–4 inches of soil. May be combined with liquid fertilizers. Tank mixing with prometryn provides fair-to-good control of nightshades, depending on soil moisture (See combinations below).

C. PROMETRYN — 1.2–2.4 lb a.i.
(Caparol 4L) — 2.0–4.8 pt — 12 — NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 5
COMMENTS: Preirrigate before application. Apply immediately before planting cotton. Incorporate to 4 inches immediately after application. Do not use on sand, loamy sand, calcareous soil, or soil high in salts. Do not use more than 10.3 pt prometryn on sandy loam soil or 11.9 pt on medium- to fine-textured soils per season. Cabbage, okra, peas, and sweet corn can be planted in fall following one preplant or one layby application per season. Onions and red beets may not be planted within 8 months of applying Caparol 4L. Spring-seeded crops should not be planted until after April 1.

D. TRIFLURALIN — 0.5–1.25 lb a.i.
(various Treflan formulations) — 1.0–2.5 pt — 12 — 90
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3
COMMENTS: Can be applied after Oct 15 or immediately before planting. If applied in fall, use higher rates. Incorporate into 2–3 inches of soil within 24 hours after application. Sugarbeet, red beets, or spinach should not be planted for 12 months after spring application, or 14 months after fall application. Sorghum, corn, or oats should not be planted for 12 months after a spring application or 14 months after a fall application. If land is not preirrigated, plantback restrictions increase. Tank mixing with prometryn provides fair-to-good control of nightshades, depending on soil moisture (See combinations below).

Herbicide combinations: for tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.

POSTPLANT: OVER-THE-TOP (OT)[2] OR POSTDIRECTED SPRAY (PDS)[3]

A. CLETHODIM — 0.06–0.12 lb a.i.
(Select Max) — 8–16 fl oz — 24
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1
COMMENTS: Apply to actively growing grasses. Tank mix with a crop oil concentrate. Can be applied by air or ground.

B. DIURON — 0.4 lb a.i.
(Karmex, Direx) — 12 — NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 7

	Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
	COMMENTS: Apply when cotton is at least 6 inches tall and weeds do not exceed 2 inches. Contact with cotton foliage will result in injury. Cotton, corn, or grain sorghum may be planted the next spring, but do not replant treated areas to any other crop within 1 year following the last application. Use in Kern County is not advisable. Considered to be a ground water contaminant and requires a use permit within Ground Water Protection Areas.			
C.	FLUAZIFOP-P-BUTYL (OT)	0.125–0.375 lb a.i.		
	(Fusilade DX)	8–16 oz	12	90
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1			
	COMMENTS: Apply to control both annual and perennial grasses. Use a crop oil concentrate or nonionic surfactant. Apply to annual grasses when 1–4 inches and actively growing without water stress; apply to perennials such as bermudagrass when stolons are 4–8 inches long and johnsongrass is 8–18 inches high. Re-treatment may be necessary. Do not apply after boll set or within 90 days of harvest. Do not apply more than 48 oz/acre per season.			
D.	GLYPHOSATE	(Label rates for Roundup Ready varieties)		
	(Roundup)	See label	See label	See label
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 9			
	COMMENTS: For traditional cotton varieties, spot-treat perennial weeds just at or before seedhead or flower formation. Repeat treatments may be necessary, but do not exceed 5.3 qt/acre/year. Do not till for at least 7–10 days after application or harvest within 7 days of application. Will kill or severely injure cotton. With Roundup Ready Flex systems there are no restrictions on timing of sequential applications. There is also the potential to combine insecticide or mepiquat into over-the-top applications[2]. Over-the-top[2] applications can be made in Roundup-Ready cotton up until the fourth leaf stage. Applications after cotton has more than four leaves must be directed or applied with a hooded sprayer.			
E.	MSMA (OT)	1–1.875 lb a.i.		
	6.6/6 Plus (OT)	1.2–2.3/1.3–2.5 pt	12	NA
	MSMA (PDS)	1–1.995 lb a.i.		
	6.6/6 Plus (PDS)	1.2–2.4/1.3–2.66 pt	12	NA
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 17			
	COMMENTS: Apply to cotton after 3 inches tall; injury is less when cotton is small. Later applications are better applied as a directed spray. Weeds should be no more than 2 inches tall. Reddish discoloration will disappear with next irrigation. Do not apply more than once per season OT or twice PDS, however, the label allows up to two applications per season for both. Generally for nutsedge. Do not apply after first bloom.			
F.	OXYFLUORFEN (PDS)	0.25–0.50 lb a.i.		
	(Goal) (PDS)	1–2 pt	24	
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14			
	COMMENTS: Apply to cotton that is at least 8 inches tall. Weed seedlings should have no more than 4 true leaves and be actively growing. Contact with cotton foliage will result in injury. Apply with a nonionic surfactant. Do not apply more than 2 pt in a single application or more than 4 pt/season. Certain formulations emit high amounts of volatile organic compounds (VOCs); use low-VOC formulations. **Regulations affect use for the San Joaquin Valley from May 1 to October 31, 2015 and 2016.** Review the Department of Pesticide Regulation's updated fact sheet.			
G.	PROMETRYN	0.5–0.65 lb a.i.		
	(Caparol) 4L	1.0–1.3 pt	12	NA
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 5			
	COMMENTS: Apply to cotton that is 6 or more inches high. Weeds should be less than 2 inches tall. Apply with a nonionic surfactant. Contact with cotton foliage will result in injury. Do not apply more than 10.3 pt on sandy loam soils or 11.9 pt on medium- or fine-textured soils. Don't plant spring-seeded crops until after April 1.			
H.	PYRITHIOBAC SODIUM (OT)	1–1.4 oz a.i.		
	(Staple) (OT)	1.2–1.6 oz	24	60
	MODE OF ACTION: Unknown			

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

COMMENTS: Make a band application 8–10 inches wide over-the-top[2] of the cotton. Applications, which may also be applied as a postdirected spray[3], can be made anytime after the cotton has reached the first visible true leaf; weeds should be in the seedling stage and actively growing. Pyrithiobac sodium causes temporary yellowing, bronzing, or crinkling of cotton leaves when applied over the top[2], especially under cool conditions. Symptoms are more evident and remain longer in Pima cotton than in Acala cottons. Plantback intervals for pyrithiobac sodium include: tomatoes 8 months; wheat 6 months; and cotton anytime. All other crops require a minimum of 10 months and a field bioassay. Double disc or plow fields before planting.

I. S-METOLACHLOR — 0.95–1.26 lb a.i.
(Dual Magnum) — 1.0–1.33 pt — 24 — 80-100
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15
COMMENT: Incorporate with rolling cultivator and irrigate. Apply before weeds emerge 14 days before planting. Rates will vary with soil type. Check label for plantback restrictions. PHI: 80 days for directed sprays, 100 days for over-the-top[2] applications.

J. SETHOXYDIM (OT) — 0.28–0.39 lb a.i.
(Poast) (OT) — 1.5–2.0 pt — 12 — 40
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 1
COMMENTS: Apply to control both annual and perennial grasses. Use 2 pt crop oil concentrate per acre. Apply to actively growing annual grasses that are not water stressed and between 4–8 inches high. Perennials such as bermudagrass should have stolons 6 inches or less; johnsongrass 6–10 inches tall. Re-treatment may be necessary. Do not cultivate within 5 days of application or harvest within 40 days following application. Cotton at all stages of growth is tolerant to sethoxydim.

Herbicide combinations: for tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.

LAYBY

Before weeds emerge

A. DIURON — 0.8–1.6 lb a.i.
(Karmex) — 12 — NA
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 7
COMMENTS: Apply as a band treatment when cotton is at least 12 inches tall (20 inches for Pima S-2) to soil beneath cotton plants and between rows immediately after last cultivation. Irrigate within 3–4 days after application. Do not apply to sandy soils or soils with organic matter less than 1%. To avoid crop injury do not exceed 1 lb/acre on sandy loam, 1.8 lb/acre on clay loam or 2.75 lb/acre on clay during the crop season. Cotton, corn, or grain sorghum may be planted the following spring, but do not replant treated area to any other crops within 1 year of application. Use in Kern County is not advisable. Considered to be a ground water contaminant and requires a use permit within Ground Water Protection Areas.

B. OXYFLUORFEN — 0.5 lb a.i.
(Goal) — 2 pt — 24 — 75
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14
COMMENTS: at application weed seedlings should have no more than 4 true leaves. Cotton must be at least 8 inches tall**.** Irrigate before spraying and within 2 weeks following application to maximize control of nightshade and ground cherries. Crop injury will occur if cotton foliage is sprayed. Do not apply more than 2 pt in a single application or 4 pt per season. Do not plant any crop other than cotton and onions within 10 months of application. Certain formulations emit high amounts of volatile organic compounds (VOCs); use low-VOC formulations. **Regulations affect use for the San Joaquin Valley from May 1 to October 31, 2015 and 2016.** Review the Department of Pesticide Regulation's updated fact sheet.

C S-METOLACHLOR — 0.95–1.26 lb a.i.
(Dual Magnum) — 24 — 80–100
WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15
COMMENT: Incorporate with rolling cultivator and irrigate. Apply before weeds emerge. Rates will vary with soil type. Check label for plantback restrictions. PHI: 80 days for directed sprays, 100 days for over-the-top[2] applications.

D. TRIFLURALIN — 0.5–0.75 lb a.i.

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
(various Treflan formulations)	1.0–1.5 pt	12	90

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3

COMMENTS: Direct applications between the rows and beneath cotton plants after last cultivation. Incorporate in top 2–3 inches of soil immediately. Do not apply within 90 days of harvest. Sugarbeets, red beets, or spinach should not be planted for 12 months after spring application or 14 months after fall application. Sorghum, corn, or oats should not be planted for 12 months after spring or 14 months after fall application. If land is not preirrigated, plantback restrictions increase.

After weeds emerge

A.	CARFENTRAZONE	0.016–0.024 lb a.i.		
	(Shark)	1.0–1.5 oz	12	7

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14

COMMENTS: Apply to actively growing weeds less than 4 inches high or 3-inch rosettes. Apply layby to 12-inch tall or taller cotton with callused bark on the lower stem. Use directed, hooded, or shielded spray equipment. To minimize cotton injury, direct spray at the base of the cotton plant. Check label for plantback restrictions.

B.	DIURON	0.8–1.6 lb a.i.	12	NA

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 7

COMMENTS: Apply as a band treatment when cotton is at least 12 inches tall (20 inches for Pima S-2) to soil beneath cotton plants and between rows immediately after last cultivation. Irrigate within 3–4 days after application. Do not apply to sandy soils or soils with organic matter less than 1%. To avoid crop injury do not exceed 1 lb/acre on sandy loam, 1.8 lb/acre on clay loam or 2.75 lb/acre on clay during the crop season. Cotton, corn, or grain sorghum may be planted the following spring, but do not replant treated area to any other crops within 1 year of application. Use of diuron in Kern County is not advisable. Considered to be a ground water contaminant and requires a use permit within Ground Water Protection Areas.

C.	GLUFOSINATE	0.786 lb a.i.		
	(Rely)	43 oz	12	70

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 10

With the Liberty Link cotton, spray according to weed size, not cotton growth stage; however, weeds should be sprayed when less than 5 true leaves for best control. There are no stage-of-growth restrictions for over-the-top[2] applications. Provides broad-spectrum weed control and grass suppression at label rates with a maximum of 72 oz per season. Can be applied to non-Liberty Link cotton with hooded sprayers or postdirected[3]. There are no rotational restrictions.

D.	OXYFLUORFEN	0.5 lb a.i.		
	(Goal)	2pt	24	75

WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14

COMMENTS: at application weed seedlings should have no more than 4 true leaves. Cotton must be at least 8 inches tall. Do not apply within 75 days of harvest. Irrigate before spraying and within 2 weeks following application to maximize control of nightshade and ground cherries. Crop injury will occur if cotton foliage is sprayed. Do not apply more than 2 pt in a single application or 4 pt per season. Do not plant any crop other than cotton and onions within 10 months of application. Certain formulations emit high amounts of volatile organic compounds (VOCs); use low-VOC formulations. **Regulations affect use for the San Joaquin Valley from May 1 to October 31, 2015 and 2016.** Review the Department of Pesticide Regulation's updated fact sheet.

	Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
E.	PROMETRYN	1.2–1.6 lb a.i.		
	(Caparol) 4L	2.4–3.2 pt	12	NA
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 5			
	COMMENTS: Apply before weeds are 2 inches tall; include a nonionic surfactant. Cotton must be at least 12 inches tall (18 inches when flood nozzles used). Contact of spray on cotton foliage will result in injury. Do not use on sand, loamy sand, calcareous soils, or soil high in salts. Do not use more than 10.3 pt on sandy loam soils or 11.9 pt on medium or fine soil per year. Spring-seeded crops in California should not be planted until after April 1. Do not use in Coachella Valley.			
F.	PYRAFLUFEN ETHYL			
	(ET)	0.5–2.0 fl oz	12	7
	MODE OF ACTION: Unknown			
	COMMENTS: Provides good postemergence control of many broadleaf weeds. Apply to actively growing weeds less than 4 inches high or 3-inch rosettes. Apply layby to 12-inch tall or taller cotton with callused bark on the lower stem. Use directed, hooded, or shielded spray equipment. To minimize cotton injury, direct spray at the base of the cotton plant. Check label for plantback restrictions.			
G.	S-METOLACHLOR	0.95–1.26 lb a.i.		
	(Dual Magnum)		24	80–100
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 15			
	COMMENT: Incorporate with rolling cultivator and irrigate. Apply before weeds emerge. Rates will vary with soil type. Check label for plantback restrictions. PHI: 80 days for directed sprays, 100 days for over-the-top[2] applications.			
H.	TRIFLURALIN	0.5–0.75 lb a.i.		
	(various Treflan formulations)	1.0–1.5 pt	12	90
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 3			
	COMMENTS: Direct applications between the rows and beneath cotton plants after last cultivation. Incorporate in top 2–3 inches of soil immediately. Do not apply within 90 days of harvest. Sugarbeets, red beets, or spinach should not be planted for 12 months after spring application or 14 months after fall application. Sorghum, corn, or oats should not be planted for 12 months after spring or 14 months after fall application. If land is not preirrigated, plantback restrictions increase.			

PREHARVEST

A.	CARFENTRAZONE	0.016–0.024 lb a.i.		
	(Shark)	1.0–1.5 oz	12	7
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 14			
B.	GLYPHOSATE	1–1.89 lb a.i.		
	(Roundup)	22–44 oz	See label	See label
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 9			
	COMMENTS: Apply after 60% of the cotton bolls have opened or at 8 nodes above cracked boll (NACB). Do not harvest for at least 7 days after application. Do not exceed 5.3 qt/acre in any one year or apply during this period to cotton grown for seed. Avoid drift to nontarget crops.			
C.	GLYPHOSATE	1 lb a.i.		
	(Roundup)	22oz	See label	See label
	WSSA MODE-OF-ACTION GROUP NUMBER[1]: 9			
	. . . PLUS . . .			
	TRIBUPHOS*	0.75–1.87 lb a.i.		
	(Folex 6)	1.0–2.5 pt	See label	See label
	MODE OF ACTION: Unknown			
	COMMENTS: Apply after 60% of the cotton bolls are open for control of perennial grasses and field bindweed at time of defoliation. Use higher rates of DEF for rank and long staple cotton.			

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

Herbicide (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

* Permit required from county agricultural commissioner for purchase or use.

1 Group numbers are assigned by the Weed Science Society of America (WSSA) according to different modes of action. Although weeds may exhibit multiple resistance across many groups, mode-of-action numbers are useful in planning mixtures or rotations of herbicides with different modes of action. For more information, see https://wssa.net.

2 Over-the-top: in cotton that is tolerant of certain herbicides (e.g., Round-up Ready), herbicides can be applied after cotton has emerged. Applications can be made from the time cotyledons emerge to the appearance of the first true leaves.

3 Postdirected: A height differential between cotton plants (taller) and weeds (smaller) is necessary. Using a shielded or hooded sprayer, the herbicide is applied to cotton stems, targeting weeds at their base.

NA Not applicable

Harvest Aid Chemicals

(Section reviewed 5/13)

Harvest aid chemicals are applied to cotton to increase the rate of leaf loss and desiccation before harvest. Use of these materials allows timely harvesting operations. The primary goals of applying these materials are:

1. Stimulate boll opening and maturation.
2. Achieve more efficient mechanical harvesting at a time during good weather conditions and the availability of harvest equipment. It is critical to harvest before rain and fog conditions arrive.
3. Maximize the collection of harvestable crop.
4. Preserve high fiber quality to provide maximum economic returns.

Determining which harvest aid chemicals to use is a complex management decision. Factors such as late-season crop vigor, nitrogen status, and plant water status exert a significant influence on the success of cotton defoliation and desiccation efforts in preparation for harvest. Decisions on whether one or more chemical materials should be used and proper rates and timing will vary according to crop conditions. Generally the process from application to harvest is a 14- to 21-day period. It can take longer with a delayed crop and cool fall weather. Weather conditions (principally air temperature), patterns of boll set and relative boll maturity, crop vigor, and desired harvest schedule also impact choice of materials and their relative efficacy.

The basic categories of chemicals used as harvest aids include boll openers-conditioners, boll openers-enhancers, true defoliants, desiccants, and regrowth inhibitors. Some harvest aid chemicals impact the cotton plant in more than one of these ways.

- **Boll openers-conditioners** are often recommended in combination with a range of defoliant materials to increase the percentage of open bolls in preparation for a once-over harvest. They are often used with late-maturing crops when the weather may be too cool to provide enough heat units to open late bolls.
- **Boll openers-enhancers** have an effect similar to openers-conditioners but have been found in most cases to also reduce vegetative regrowth.
- **Defoliants** are chemicals that either impact plant hormonal activity related to leaf loss or cause direct injury to leaves, both at a level that promotes leaf drop (abscission). Their activity varies with chemical and conditions but takes days or weeks to remove leaves from the plants.
- **Desiccants** produce quick injury that is more severe than that seen with defoliants, causing leaf dehydration and death within one to several days. Desiccants are often applied as a follow up after application of defoliants.
- **Regrowth inhibitors** are applied primarily to inhibit late vegetative growth (regrowth) or to enhance activity of defoliant materials.

For more details on harvest aid materials, how they work and application information, see *Harvest Aid Materials and Practices for California Cotton*, UC ANR Publication 4043. If used improperly, harvest aid materials can injure cotton or neighboring crops. Always follow labels and consult with County Agricultural Commissioners for local regulations.

Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)

For tank mixes, observe all directions for use on all labels, and employ the most restrictive limits and precautions. Never exceed the maximum a.i. on any label when tank mixing products that contain the same a.i.

BOLL OPENERS–CONDITIONERS

A.	ETHEPHON	1–1.995 lb a.i.		
	(Prep, Ethephon 6, Super Boll)	1.3–2.6 pt	72	7

COMMENTS: Not labeled as a defoliant but may result in defoliation at higher rates or when crop is well prepared for defoliation. Can reduce micronaire and fiber strength if immature bolls are opened when applied too early (before 4th node above cracked boll [NACB]). Often combined with defoliant materials such as Def, Folex, Ginstar, Harvade, or Dropp. Is not compatible with sodium chlorate because the mix can release chlorine fumes. Do not apply if rain is expected within 6 hours.

BOLL OPENERS–ENHANCERS

	Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
A.	ETHEPHON+AMADS	1.7–1.995 lb a.i.		
	(CottonQuik)	3–3.5 qt	72	7
	COMMENTS: Ethephon plus the synergist AMADS (aminomethanamide dihydrogen tetraoxysulfate) to improve defoliation. Results are best with cotton that is cutout, with mature leaves. Limited regrowth control unless mixed with other harvest aids. Do not mix with sodium chlorate because chlorine gas will be formed.			
B.	ETHEPHON+CYCLANILIDE	1–1.995 lb a.i.		
	(Finish-6 Pro)	1.3–2.6 pt	72	7
	COMMENTS: Ethephon plus a synergist to improve defoliation, particularly of cutout cotton with mature leaves. Also provides some regrowth control but gives best regrowth control in combination with other materials such as tribufos. Can be tank mixed with other materials (except for sodium chlorate because mixture releases chlorine gas).			

DEFOLIANTS

A.	CARFENTRAZONE	0.0097–0.0148 lb a.i.		
	(Shark)	0.66–1 oz	12	7
	COMMENTS: Has activity as both a defoliant and a desiccant. May be used alone or tank mixed with other harvest aids. Use a crop oil concentrate at 1% volume per volume. Apply when 65% of harvestable bolls are open. Good coverage is essential for defoliation. May require a second application. Do not apply more than 2 oz/acre total as a harvest aid. Usually used as a secondary treatment. Provides burndown of remaining annual morningglory.			
B.	PYRAFLUFEN ETHYL	0.00446875 lb a.i.		
	(ET)	2.75 fl oz	12	7
	COMMENTS: Has activity as both a defoliant and a desiccant. May be used alone or tank mixed with other harvest aids. Use a crop oil concentrate at 1% volume per volume. Apply when 65% of harvestable bolls are open. Good coverage is essential for defoliation. May require a second application. Do not exceed 2 applications or 5.5 fl oz/acre. Usually used as a secondary treatment. Provides burndown of remaining annual morningglory.			
C.	SODIUM CHLORATE	3–4.5 lb a.i.		
	(Defol 750)	1.6–2.4 qt	12	7
	COMMENTS: Can be used as both defoliant and desiccant, depending on timing and rate of application. When used at lower rate for defoliation, is less effective than thidiazuron plus diuron (Ginstar) or organophosphate defoliants on Acala and Pima cotton. Higher rated used for desiccation may stick leaves to plants. No major effect on limiting regrowth and is usually ineffective in preparing young leaves for senescence. Usually used as a secondary treatment in combination with paraquat, carfentrazone (Shark), or pyraflufen (ET). Provides burndown of remaining annual morningglory.			
D.	THIDIAZURON	0.1–0.2 lb a.i.		
	(Dropp)	3.2–6.4 oz	24	5
	COMMENTS: Works well in controlling regrowth and in removing younger leaves.			
E.	THIDIAZURON+DIURON (preconditioning)	0.046875–0.07 lb a.i.		
	(Ginstar)	4–6 oz	24	5
	. . . or . . .			
	THIDIAZURON+DIURON (defoliation)	0.075–0.1875 lb a.i.		
	(Ginstar)	6.4–16 oz	24	5
	COMMENTS: Has better activity than thidiazuron alone in California. Low to medium rates work well under warm-to-hot conditions and have good activity on young leaves. Use highest allowed rate only under cool conditions and when applying to Pima or very vigorous Upland varieties; high rate during warm conditions can desiccate and stick leaves. Label allows mixing with ethephon products but not with tribufos or other phosphate defoliants. Do not apply more than 1 pt/acre/season. Under cool conditions or when cotton is vigorous works best combined with ethephon treatments. Apply at least 5 days before harvest.			

	Common name (Example trade name)	Amount per acre	REI‡ (hours)	PHI‡ (days)
F.	TRIBUFOS*	0.9975–1.875 lb a.i.		
	(Folex 6)	1.33–2.5 pt	7 days	7
	COMMENTS: Organophosphate –based defoliant. Effective for defoliation in both Pima and Acala cotton under a wide range of crop and environmental conditions. Very good and fairly quick at removing mature leaves. Works best if tank mixed with ethephon. Not effective in regrowth control or in removing younger leaves. Do not apply more than 2.5 pt/acre per crop season. Effective in reducing whiteflies, especially in combination with a pyrethroid.			

DESICCANTS

A.	PARAQUAT*	0.0578–0.325 a.i.		
	(Gramoxone Inteon)	3.7–20.8 oz	24	3
	COMMENTS: Considered a desiccant because at label rates it rapidly desiccates leaves and can cause them to stick to the plants rather than to abscise. Used to help open mature bolls by causing direct injury but is not generally applied as a desiccant until after 80% or more of bolls are open because it can prevent further boll development and opening if applied too early. Other crops may be sensitive to paraquat; follow label precautions and control drift carefully. See local restrictions for use.			
B.	SODIUM CHLORATE	3–4.5 lb a.i.		
	(Defol 750)	1.6–2.4 qt	12	7
	COMMENTS: Can be used both as a desiccant or defoliant, depending on timing and rate of application. Is effective in combination with paraquat, Shark, or ET to desiccate young leaves and control regrowth before harvest. Is low cost and has relatively low mammalian toxicity for applications near dwellings and public buildings; less damaging to some other crops than paraquat. Check label for plantback restrictions. With 2 applications, toxicity can occur to following crops.			

REGROWTH INHIBITORS & OTHER CHEMICAL ACTIVITIES

A.	ENDOTHALL	0.0325–0.097 lb a.i.		
	(Accelerate)	0.5–1.5 pt	48	0
	COMMENTS: Usually considered an additive rather than a true desiccant or defoliant. Can be added to sodium chlorate or to organophosphate defoliants (Def, Folex) to increase the rate of early leaf drop, but used alone is not effective.			
B.	GLYPHOSATE	0.6875–1.89 lb a.i.		
	(Roundup)	16–44 oz	See label	See label
	COMMENTS: Do not apply to cotton grown for seed because seed quality and germination percentage will be affected. Works as a pretreatment applied 7–14 days before defoliation to improve regrowth control, enhance defoliation, and control some late-season weeds. Can provide regrowth control with little impact on yields or fiber quality if applied when 40-50% of bolls are open.			

‡ Restricted entry interval (REI) is the number of hours (unless otherwise noted) from treatment until the treated area can be safely entered without protective clothing. Preharvest interval (PHI) is the number of days from treatment to harvest. In some cases, the REI exceeds the PHI. The longer of the two intervals is the minimum time that must elapse before harvest.

* Permit required from county agricultural commissioner for purchase or use.

1 Group numbers are assigned by the Weed Science Society of America (WSSA) according to different modes of action. Although weeds may exhibit multiple resistance across many groups, mode-of-action numbers are useful in planning mixtures or rotations of herbicides with different modes of action. For more information, see https://wssa.net.

NA Not applicable

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PRECAUTIONS FOR USING PESTICIDES

Pesticides are poisonous and must be used with caution. READ THE LABEL BEFORE OPENING A PESTICIDE CONTAINER. Follow all label precautions and directions, including requirements for protective equipment. Apply pesticides only on the crops or in the situations listed on the label. Apply pesticides at the rates specified on the label or at lower rates if suggested in this publication. In California, all agricultural uses of pesticides must be reported. Contact your county agricultural commissioner for further details. Laws, regulations, and information concerning pesticides change frequently. This publication reflects legal restrictions current on the date next to each pest's name.

Legal Responsibility

The user is legally responsible for any damage due to misuse of pesticides. Responsibility extends to effects caused by drift, runoff, or residues.

Transportation

Do not ship or carry pesticides together with food or feed in a way that allows contamination of the edible items. Never transport pesticides in a closed passenger vehicle or in a closed cab.

Storage

Keep pesticides in original containers until used. Store them in a locked cabinet, building, or fenced area where they are not accessible to children, unauthorized persons, pets, or livestock. DO NOT store pesticides with foods, feed, fertilizers, or other materials that may become contaminated by the pesticides.

Container Disposal

Dispose of empty containers carefully. Never reuse them. Make sure empty containers are not accessible to children or animals. Never dispose of containers where they may contaminate water supplies or natural waterways. Consult your county agricultural commissioner for correct procedures for handling and disposal of large quantities of empty containers.

Protection of Nonpest Animals and Plants

Many pesticides are toxic to useful or desirable animals, including honey bees, natural enemies, fish, domestic animals, and birds. Crops and other plants may also be damaged by misapplied pesticides. Take precautions to protect nonpest species from direct exposure to pesticides and from contamination due to drift, runoff, or residues. Certain rodenticides may pose a special hazard to animals that eat poisoned rodents.

Posting Treated Fields

For some materials, *restricted entry intervals* are established to protect field workers. Keep workers out of the field for the required time after application and, when required by regulations, post the treated areas with signs indicating the safe re-entry date. Check with your county agricultural commissioner for latest restricted entry interval.

Preharvest Intervals

Some materials or rates cannot be used in certain crops within a specified time before harvest. Follow pesticide label instructions and allow the required time between application and harvest.

Permit Requirements

Many pesticides require a permit from the county agricultural commissioner before possession or use. When such materials are recommended, they are marked with an asterisk (*) in the treatment tables or chemical sections of this publication.

Maximum residue levels

Before applying pesticides to crops destined for export, check maximum residue levels (MRLs) of importing country.

Processed Crops

Some processors will not accept a crop treated with certain chemicals. If your crop is going to a processor, be sure to check with the processor before applying a pesticide.

Crop Injury

Certain chemicals may cause injury to crops (phytotoxicity) under certain conditions. Always consult the label for limitations. Before applying any pesticide, take into account the stage of plant development, the soil type and condition, the temperature, moisture, and wind. Injury may also result from the use of incompatible materials.

Personal Safety

Follow label directions carefully. Avoid splashing, spilling, leaks, spray drift, and contamination of clothing. NEVER eat, smoke, drink, or chew while using pesticides. Provide for emergency medical care IN ADVANCE as required by regulation.