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Managing Cotton Insects

in the High Plains, Rolling Plains and Trans Pecos Areas of Texas 2007

Contents

For recommended insecticides refer to E-6A, "Suggested Insecticides for Managing Cotton Insects in the High Plains, Rolling Plains and Trans Pecos Areas of Texas 2007" at the following web sites:
http://insects.tamu.edu/extension/publications/index.cfm
or
http://tcebookstore.org

Managing Cotton Insects in the High Plains, Rolling Plains and Trans Pecos Areas of Texas

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A committee of state and federal research personnel and Extension specialists meets annually to review cotton pest management research and management guidelines. These guidelines are directed toward maximizing profits for the Texas cotton producer by optimizing inputs and production.

Pest Management Principles

The term "pest management" applies to a philosophy used in the design of insect, mite, disease and weed pest control programs. It encourages the use of the most compatible and ecologically sound combination of available pest suppression techniques. These management techniques include: cultural control, such as manipulation of planting dates and stalk destruction; crop management practices, such as variety selection and timing of irrigation; biological control, involving conservation of existing natural enemies; host plant resistance; and the wise use of selective insecticides and rates to keep pest populations below economically damaging levels.

Major factors to be considered when using insecticides include protecting natural enemies of cotton pests, possible resurgence of primary pests, increased numbers of secondary pests following applications and pest resistance to insecticides. Therefore, insecticides should be applied at the proper rates and used only when necessary, as determined by frequent field inspections, to prevent economic losses from damaging pests.

The pest management concept rests on the assumption that pests will be present to some degree in a production system, and that at some levels they may not cause significant losses in production. The first line of defense against pests is prevention through the use of good agronomic practices or cultural methods which are unfavorable for the development of pest problems (discussed below). Properly selected control measures should be taken only when pest populations reach levels at which crop damage suffered could result in losses greater than the cost of the treatment. This potentially injurious population or plant damage level, determined through regular field scouting activities, is called an **economic threshold or action level.** Precise timing and execution of each production operation is essential. In short, pest management strives to optimize rather than maximize pest control efforts.

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Insecticide Resistance Management

Experience has shown that reliance on a single class of insecticides that act in the same way may cause pests to develop resistance to the entire group of insecticides. To delay resistance it is strongly recommended that growers use IPM principles and integrate other control methods into insect or mite control programs. One strategy to help avoid pest resistance is to rotate the use of insecticide groups, in order to take advantage of different modes of action. In addition, do not tank-mix products from the same insecticide class. Such insecticide management should delay the development of resistance and also provide better overall insect control.

Insecticides with similar chemical structures act on insects in similar ways. For example, pyrethroids (including esfenvalerate, bifenthrin, cyfluthrin, cyhalothrin and tralomethrin) all act on an insect's nervous system in the same way. Other types of insecticides such as organophosphates (methyl parathion, dicrotophos) or carbamates (thiodicarb) also affect the insect's nervous system but in a different way than do the pyrethroids.

The Insecticide Resistance Action Committee (IRAC) has developed a mode of action classification system that is based on a numbering system (see *http://www.irac-online.org/*). This system makes it simpler for producers and consultants to determine different modes of action among the insecticides. Insecticides with the same number (e.g., 1) are considered to have the same mode of action. Producers should rotate among different numbers where appropriate to delay resistance. The objective of successful insecticide resistance management is to prevent or delay the evolution of resistance to insecticides. The IRAC numbering system is used in the Suggested Insecticides for Cotton Insect Management publications to assist producers with their choices.

Biological Control

Insect and mite infestations are often held below damaging levels by weather, inadequate food sources and natural enemies such as disease, predators and parasites. It is important to recognize the impact of these natural control factors and, where possible, encourage their action. (See E-357, "Guide to the Predators, Parasites, and Pathogens Attacking Insect and Mite Pests of Cotton," Texas Cooperative Extension.)

Biological control is the use of predators, parasites and disease to control pests. Important natural enemies in cotton include minute pirate bugs, damsel bugs, big-eyed bugs, assassin bugs, lady beetles, lacewing larvae, syrphid fly larvae, spiders, ground beetles and a variety of tiny wasps that parasitize the eggs, larvae and pupae of many cotton pests.

Biological control includes the conservation, importation and augmentation of natural enemies. It is an environmentally safe method of pest control and is a component of integrated pest management programs in cotton. The Texas A&M University System is fully committed to the development of pest management tactics which use biological control.

Existing populations of natural enemies are conserved by avoiding the use of insecticides until they are needed to prevent the development of economically damaging pest infestations. Insecticide impact can also be minimized by using insecticides that are more toxic to the target pests than to the natural enemy. Classical biological control is the importation of natural enemies from other countries. This method has been effective where an exotic pest has entered Texas without its incumbent natural enemies, or to augment natural enemies of native pests.

Augmentation involves the purchase and release of natural enemies on a periodic basis. The most notable commercially available natural enemies include the egg parasite *Trichogramma*, and the predators lady beetles and lacewings. Although the control of both bollworms and tobacco budworms by the release of commercially reared *Trichogramma* wasps is theoretically possible, researchers have not been able to consistently achieve the level of parasitism necessary to reduce infestations below economically damaging levels. Multiple *Trichogramma* releases at high rates ranging from 50,000 to 150,000 parasitized eggs per acre were used in these studies. There are currently no economic thresholds established for augmentative releases of *Trichogramma* for bollworm/budworm control in cotton. Furthermore, parasite mortality from insecticides used to control other pests in or around parasite release areas would limit the effectiveness of augmentative releases.

Research has shown that releasing large numbers of lacewing larvae (30,000 or more per acre) can reduce bollworm infestations below damaging levels. However, these release rates are currently cost prohibitive because of the high production cost of rearing lace-wings. The release of lacewing eggs has been less successful and there is little information on the efficacy of releasing adult lacewings in cotton. There is even less information about releasing either lady beetles or lacewings for the control of economically damaging infestations of aphids. Because there is too little information about augmentation (when to apply, what density should be applied, etc.), entomologists with Texas Cooperative Extension cannot provide guidelines for augmentation as a management tool in cotton.

Bt Transgenic Cotton

Bt cottons are insect-resistant cultivars and one of the first such agricultural biotechnology products to be released for commercial production. Insect resistance in the Bt cottons was engineered by the introduction of a bacterial gene that produces a crystalline toxin, which, in turn, kills feeding larvae of several cotton pests.

The toxin in Bollgard® cottons has excellent activity against tobacco budworm, pink bollworm, cotton leaf perforator and European corn borer, and good activity against cotton bollworm, saltmarsh caterpillar and cabbage loopers. **Under heavy infestation pressure, supplemental insecticide treatment may be necessary for bollworm.** Bt cottons (Bollgard®) provide some suppression of beet armyworm and soybean looper, and little or no control of fall armyworm or cutworm. Recently released Bollgard® II and WideStrike® cotton varieties are more effective against all of the mentioned caterpillar pests, except cutworms.

In all cases, economic thresholds used for Bt cottons should be the same as those used for non-Bt cottons, **but should be based on larvae larger than 1/4 inch and damage, not on eggs or early instar larvae.**

Crop Management

Irrigated Production

Plan and conduct production practices to achieve early crop maturity in order to escape late-season insect attack and population buildup of insect pests. Production inputs should be directed toward maximum crop profit instead of maximum crop yield.

Crop management practices that have an impact on insect pest numbers and crop damage are:

- Varietal selection (short-season or full-season varieties). Short-season varieties usually mature earlier and escape late-season pest problems which often occur on late-season varieties.
- Uniform planting dates. Allow fields in an area to mature together. Pest infestations are prevented from developing in earlier planted fields and moving into later planted fields.
- Plant population on irrigated cotton should range from 35,000 to 65,000 plants per acre (2.5 to 4.5 plants per foot on 40-inch rows) in most areas. Larger plant populations can cause delayed crop maturity due to competition for water, nutrients and sunlight. Overcrowding may also contribute to undesirable stalk growth.
- Amount of nitrogen fertilizer used and application timing. Excessive or late nitrogen applications delay crop maturity, particularly when coupled with late irrigation, and subject the crop to intensified and prolonged attack by cotton bollworms, tobacco budworms, boll weevils and pink bollworms.

- Weed control. Weeds limit yield by competing directly with cotton plants for water and nutrients; they also attract various insect pests into cotton fields.
- Amount and timing of crop irrigations. Timing of irrigations often is more important than the total amount of water applied. Water use by the cotton plant is very low during the 35- to 40-day period from seed emergence to the appearance of the first square. Water use increases rapidly with the appearance of the first square. Maximum water use is reached during peak bloom. As the plant progresses toward maturity, water demands are reduced.

Flowering is the period of most rapid plant growth and development when more than half of the total water is used. Excessive irrigation during this period may make plants more attractive to bollworm and tobacco budworm moths because of additional vegetative growth. Excessive vegetative growth can be checked by allowing sufficient depletion of available water before each irrigation. Excessive water will delay crop maturity, thus increasing crop susceptibility to attack from bollworms, tobacco budworms, boll weevils and pink bollworms.

The final irrigation should be timed to provide enough moisture to mature the bolls set during the first 4 weeks of boll production in upland and acala cotton, and to mature the bolls set during the first 6 weeks in Pima cotton. Fruit produced as a result of late irrigations not only adds little to final yield, but also delays the opening of mature bolls, increases crop susceptibility to insects, induces boll rot and contributes to defoliation problems. Late set bolls normally have a poor probability of producing fiber and the lint produced from these bolls is generally of poorer quality because of immature fibers and insect damage.

Crop irrigation should terminate at least 10 days prior to a predicted peak in bollworm egg-laying. This will reduce plant attractiveness to bollworm and budworm moths, lower field humidity to suppress egg hatch and limit the amount of young, tender growth available for newly hatched worms to feed on.

Dryland Production

The primary factor limiting dryland cotton production is the lack of adequate moisture prior to and during the growing season. Due to the lack of moisture or the formation of a hardpan, cotton plants may be unable to develop an adequate root system. Dry conditions and moisture stress after cotton begins to fruit will cause the cotton plants to abort squares and small bolls, often reducing or completely negating any potential yield increase obtained from pest control. The amount of moisture in the soil profile at planting appears to be the most accurate predictor of potential yield. Each insecticidal control decision must be made based on the anticipated yield. Because the yield potential of dryland cotton is generally moderate to low, insecticides and other inputs such as fertilizers should be based on realistic yield goals.

The yield potential of cotton planted after June 20 is greatly reduced; average yields can be expected only in those years when warm conditions extend well into October. Because of the limited yield potential, additional benefits from the management of insects are also limited. An insecticidal application can be expected to result in a positive economic return only when expected damage equals or exceeds the insecticide and application cost.

Information on cotton varieties that perform best under dryland conditions can be obtained from county Extension agents who annually conduct cotton variety demonstrations. Short-season cottons fruit and mature more rapidly than Delta-type varieties; consequently, the short-season varieties are subject to insect damage for a shorter period of time and may escape the development of large late-season insect populations.

Fertilization of dryland cotton should be based on a soil test.

Plant dryland cotton so that there are 26,000 to 53,000 plants per acre (two to four plants per foot on 40-inch rows). Higher plant populations cause greater competition between plants for moisture and nutrients and can lead to increased pest damage.

Severe bollworm problems can occur in either wet or dry years; however, wet conditions, which favor succulent growth, are generally more favorable for bollworm survival. Bollworms and aphids may become a problem following an insecticide application which destroys beneficials. Insecticides should be applied only when necessary, as determined by frequent field inspection.

Monitoring Cotton Growth and Fruiting Rate

Early fruiting is desirable and facilitates early crop maturity. Frequent monitoring gives a good indication of crop set. Problem fields often can be detected early if growth and fruiting habits are accurately monitored, although the cause of a problem may not be immediately evident.

To monitor fruiting levels, mark a point on a row of plants and count 100 consecutive $^{1}/_{3}$ -grown ($^{1}/_{4}$ inch in diameter) or larger green squares; record the number of row feet required to gain that count. Record also the number of bolls observed. Later in the season, when bolls are more numerous, count 100 consecutive bolls, both green and open, and record the number of row feet required to make the count. To estimate the number of squares or bolls present per acre, divide the number of row feet recorded to gain a count of 100 consecutive squares or bolls into the number of row feet per acre (13,068 for 40-inch rows and 13,756 for 38-inch rows) and multiply by 100:

$$\text{Bolls and/or squares per acre} = \frac{13{,}068 \text{ or } 13{,}756}{\text{No. row feet recorded for 100 consecutive bolls or squares}} \times 100$$

To monitor the squaring rate, count fruiting sites and all squares on at least ten plants from each of four re-presentative areas in the field. Fruiting usually begins on nodes 6 to 9 depending on variety and environmental conditions. Node 1 is the first true leaf above the cotyledons (seed leaves). To calculate percent square set, divide the number of small squares counted by the number of fruiting sites recorded and multiply by 100. In normal fields, 75 percent or more of the small squares are retained during the first 3 to 4 weeks of squaring.

After moisture, the most important factor in development of squares and bolls is temperature. Researchers have devised a way to describe and measure the relationship between cotton development and temperature — the heat unit concept or DD60 (degree days using 60 degrees F). Heat units measure the amount of useful heat energy a cotton plant accumulates each day, each month, and for the season. The plant must accumulate a specified level of heat units to reach each development stage and to achieve complete physiological maturity.

Several systems have been developed to calcuate heat units, but the most universal approach is to use the formula ((Degrees F Maximum + Degrees F Minimum) / 2) - 60.

Knowing when a cotton crop is near cutout can help producers make effective end-of-season decisions. To estimate cutout, monitor the number of nodes above white flower (NAWF) during the bloom period. To determine NAWF, count the number of nodes above the upper most first position white flower on a cotton plant. The last node counted on a plant will have a leaf equal to the size of a quarter.

Cotton development by calendar days and heat units.

Growth interval	Calendar days Mean	Calendar days Range	Accumulated heat units (DD60's from planting required*)
Planting to:			
Stand establishment	7	5 - 13	78
First true leaf	16	11 - 25	
Squaring	36	29 - 41	526
1/3-grown square	44	36 - 49	
First bloom	61	45 - 81	1064
Peak bloom	79	59 - 102	
First open boll	96	88 - 106	1641
95% mature bolls	146	129 - 163	2271
Boll development:			
Fiber length established:	First 18-45 days		
Fiber micronaire and strength determined:	Next 20-60 days		

*Calculated by the formula:

$$DD\ 60 = \frac{\text{High daily temperature + low daily temperature}}{2} - 60$$

For each day in which the result is a positive number, heat units are accumulated. For example, if the high for the day is 90 and the low 60, then 90 + 60 = 150 / 2 = 75; 75 - 60 = 15; so 15 heat units would be accumulated for the day. This total would be added to those accumulated each day since planting to get accumulated heat units.

NAWF will range from 5 to 10 at first bloom, depending on the amount of soil moisture available to the plant before bloom. Other factors affecting NAWF include soil compaction, diseases and fruit retention.

When the average NAWF value of 5 is reached, the field is considered to be cut out. The flowers produced after NAWF is equal to 5 contribute less to yield because the bolls are smaller and boll retention is reduced.

Once the date of cutout (NAWF = 5) has been reached, growers can determine the insecticide applications for the season by calculating the daily heat units (DD60s) from cutout. The termination of insecticide applications depend on the insect pest and the number of DD60s that have accumulated.

Fields that have accumulated 325 DD60s are safe from plant bugs (*Lygus* and *Creontiades* species); fields accumulating 350 DD60s are safe from boll weevils and first and second instar bollworm/tobacco budworm larvae; and fields accumulating 475 DD60s are safe from stink bugs.

Early Stalk Destruction and Field Clean-Up

Early harvest and stalk destruction are among the most effective cultural and mechanical practices for managing overwintering boll weevils if done on an areawide basis. These practices reduce habitat and food available to the boll weevil, pink bollworm, bollworm and tobacco budworm. When cotton is not harvested until frost, stalks may be left standing in the field except in areas where the pink bollworm is a problem. Stalks should be shredded and plowed under to a depth of 6 inches in areas of pink bollworm infestation. Green or cracked bolls left at the ends of rows should be destroyed to reduce pink bollworm populations. Where cotton is harvested before a killing frost, plants should be shredded to prevent regrowth which can provide squares for weevils to feed on and allow them to successfully overwinter.

2,4-D amine applied at 1 pound of formulated product in 10 gallons of water per acre provides excellent control of cotton stalks when applied immediately after harvest or shredding. A second application is usually necessary to control seedlings and any remaining live stalks. For more information see the publication SCS-2003-10 "Cotton Stalk Destruction with Herbicides," at *http://lubbock.tamu.edu/cottoncd/* under the Eastern Region.

Stalk Destruction Laws

Upon request and petition of Texas Cotton Producers, the Texas Legislature passed the Cotton Pest Control Law in an effort to combat the boll weevil and pink bollworm. This law, which is enforced by the Texas Department of Agriculture, requires producers in a regulated county to culturally manage pest populations using habitat manipulations by planting and destroying cotton within an authorized time period. Appointed producers, who are members of local pest management zone committees, have established a series of cotton planting and stalk destruction deadlines for all producers in each regulated county.

The battle against pink bollworms has been extremely successful. Because farmers have adhered to authorized planting and stalk destruction deadlines over the past years, pink bollworm populations in most of the state have been reduced to levels that don't cause major economic damage. In addition, all of the cotton acreage in the state of Texas is now in the boll weevil eradication program. If producers or others have questions about boll weevil control and the impact on stalk destruction in their area they should call the local Texas Boll Weevil Eradication Foundation office or contact the Foundation at 325-672-2800.

Management Decisions

Control measures are needed when a pest population reaches a level at which further increases would result in excessive yield or quality losses. This level is known as the "economic threshold" or treatment level. The relationship between pest level, amount of damage, and ability of the cotton plant to compensate for insect damage is greatly influenced by crop phenology and seasonal weather. The economic threshold is not constant but varies with factors such as the price of cotton, the cost of control, and stage of plant development.

When a cotton field is properly scouted, accurate and timely decisions can be made to optimize control efforts while minimizing risk. Fields should be inspected every 3 to 7 days using the scouting procedures described in this guide for the various pests.

Scouting Decisions

Regular field scouting is a vital part of any pest management program because it is the only way reliable information can be obtained to determine if and when pest numbers reach the economic threshold. Scouting should involve more than just "checking bugs." Scouting determines the insect density and damage levels through the use of standardized, repeatable sampling techniques. Scouting should also include monitoring plant growth, fruiting, weeds, diseases, beneficial insect activity, and the effects of implemented pest suppression practices.

Scouting for predators. Predatory insects and spiders can sometimes maintain densities of bollworms, aphids and other pests below economic levels. Knowing the densities of common predators can be important when deciding whether to apply an insecticide for these pests. Also, monitoring densities of predators can alert the producer to those fields that are at risk of pest outbreaks because of low predator densities.

The number of predatory insects and spiders in cotton can be rapidly and accurately determined by the beat bucket method. This method requires less time than using a sweep net, drop cloth or visually searching the plant, and can accurately estimate predator densitities. The beat bucket method uses a common white, 5-gallon plastic bucket or pail about 14 inches deep and 10 inches in diameter. To use the beat bucket, carefully approach the sample plant and grasp the stem near the base of the plant. While holding the bucket at a 45-degree angle to the ground, quickly bend the plant into the bucket so that the terminal and as much of the plant as possible are inside the bucket. Still holding the stem near the base of the plant, rapidly beat the plant against the side of the bucket 12 to 15 times during a 3- to 4-second period. This dislodges predators from the plant so that they fall into the bottom of the bucket. Quickly take one step, sample a second plant, and then another step, and sample a third plant down the row. Banging the side of the bucket with the hand will knock down predators crawling up the side of the bucket while sampling. After the third plant is sampled, record the number of bollworm predators (pirate bugs, spiders, big-eyed bugs, lacewing larvae) and others of interest (lady beetles, etc.) captured in the bucket. Remove and examine any leaves and bolls that fall into the bucket to be sure all predators are visible for recording. Tapping the bottom of the bucket can sometimes encourage predators that are playing dead to begin moving and become apparent. The bucket must be kept clean so that the predators are easily seen.

Research has shown that 34 beat bucket samples (3 plants per sample or 102 plants/field) will, in most situations, accurately estimate densities of pirate bugs and spiders, which are key predators of bollworms, tobacco budworms and other caterpillar pests (see table below). Samples should be taken from three or more locations across the field. This will provide a more realistic predator density estimate for the entire field. Weekly sampling for predators is not as important as weekly sampling for pests because predator densities do not change as rapidly as do pest densities. Sampling predators once at first bloom and again 2 to 3 weeks later can provide information for using predator densities in mid- and late-season pest management decisions for caterpillar pests.

Number of beat bucket samples and total sampling time needed to estimate densities of key predator groups at a mean density of 0.5 per plant or all key predators at 1.5 per plant for 3 and 5 plants sampled per beat bucket sample.

Key predator group	3-plant sample unit: Samples required	3-plant sample unit: Time to take samples (min)	5-plant sample unit: Samples required	5-plant sample unit: Time to take samples (min)
Pirate bug adults	34	30.2	16	19.3
Pirate bug nymphs	60	52.9	38	44.9
Spiders	30	26.7	20	23.9
Lady beetles	45	39.8	52	61.3
All key predators	17	23.4	14	23.3

Refer to E-357, "Guide to the Predators, Parasites and Pathogens Attacking Insect and Mite Pests of Cotton" (see p. 17 to order) for information on identifying common predatory insects and spiders in cotton.

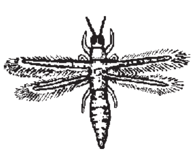
Scouting for pests. The following general discussion briefly reviews the insect pests of cotton (for more detail see B-933, "Identification, Biology and Sampling of Cotton Insects"). The insect pests are discussed as they normally would occur throughout the cotton production season. Growers should check fields at least once and preferably twice a week to determine the species present, the pest density and the amount of damage. Most pests can be monitored by visually checking the terminal and by making whole plant inspections. However, some pests, such as plant bugs (*Lygus* spp.), are more reliably sampled using a drop cloth. The drop cloth method uses an off-white cloth measuring 36 x 42 inches (on 40-inch rows). Staple a thin strip of wood, approximately 1 inch wide, to each short side of the cloth. Select a random site in the field and unroll the cloth from one row over to the next row. Mark off 18 inches on each row bordering the cloth and vigorously shake all the plants within that area. Two 1.5-row-foot sections (3 feet total) will be sampled simultaneously for insects. Count the number of lygus bug adults and nymphs that fall on the cloth. Repeat the process in at least 20 locations in the field (60 feet of row sampled). If the results show that populations are close to threshold levels, or if the field is very large (more than 100 acres), sample more areas to increase confidence in the results.

Early-Season Pests

The period from plant emergence to first $^{1}/_{3}$-grown squares requires about 5 to 6 weeks. The $^{1}/_{3}$-grown square is approximately $^{1}/_{4}$ inch in diameter. Major pests during this crop development period include thrips, cotton fleahoppers, plant bugs and overwintered boll weevils.

Cotton Square Diameter

$^{1}/_{16}$-inch	**$^{3}/_{16}$-inch**	**$^{1}/_{4}$-inch**
●	●	●
Pinhead	**Matchhead**	**$^{1}/_{3}$-grown**

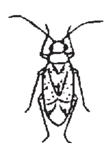


Thrips

Thrips are slender, straw colored insects about $^{1}/_{15}$ inch long, with piercing and sucking mouthparts. Adults are winged and capable of drifting long distances in the wind. Thrips attack leaves, leaf buds and very small squares and may cause a silvering of the lower leaf surface, deformed or blackened leaves, terminal loss and square loss. Under some conditions, heavy infestations may reduce stands, stunt plants and delay fruiting and maturity. Thrips damage is most evident during cool, wet periods when small cotton is growing slowly. Thrips damage often is further compounded by plant damage resulting from rain, wind, blowing sand and diseases. Under favorable growing conditions, cotton can sometimes recover completely from early thrips damage. In many areas thrips are considered minor cotton pests. Thrips problems are more prevalent in areas with large winter wheat acreages and where producers plant prior to late May or early June. Research has demonstrated that cotton varieties with hairy leaves are less injured by thrips than smooth-leaf varieties.

Management and decision making. In areas with a history of frequent, heavy thrips infestations, the use of systemic insecticides should be seriously considered. Research has shown that the application of foliar sprays after significant thrips damage has occurred generally does not result in increased yields. Where postemergence sprays are to be used, fields should be scouted as often as twice a week as cotton emerges. Thrips can migrate in heavy numbers from adjacent weeds or crops, especially small grains, and cause significant damage within a few days and prior to the appearance of true leaves.

Early infestations often reduce yield more than later infestations. Thrips often infest the folded small leaves of the plant terminal and are difficult to count unless the terminal area is dissected. This is especially true during rainy, windy conditions. The decision to apply insecticide should be based on the number of thrips present and the stage of plant development. The number of thrips per plant to use as a treatment level increases as plants add more leaves. **Control may be justified when the average number of thrips counted per plant is equal to the number of true leaves present at the time of inspection.** One thrips per plant should be used as the treatment level from plant emergence, through the cotyledon stage, to the first true leaf. Inspections should begin once cotton has reached approximately 50 percent stand emergence. Insecticidal control is rarely justified once plants reach the 5- to 7-true-leaf stage, or when plants begin to square.



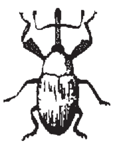
Cotton Fleahopper

Adult fleahoppers are about $^{1}/_{8}$ inch long and pale green. Nymphs resemble adults but lack wings and are light green. They move very rapidly when disturbed. Adults move into cotton from weed hosts when cotton begins to square. Both adults and nymphs suck sap from the tender portion of the plant, including small squares. Pinhead size and smaller squares are most susceptible to damage.

Management and decision making. The decision to apply insecticide should be based on the number of fleahoppers present, the squaring rate and the percent square set. If conditions are conducive to the rapid build up of cotton fleahoppers in alternate hosts, scouting intervals should be shortened (i.e., monitor fields every 3 to 4 days). **During the first week of squaring, the economic threshold is 25 to 30 cotton fleahoppers per 100 terminals combined with less than 90 percent square set. In the second week of squaring, the economic threshold is 25 to 30 cotton fleahoppers per 100 terminals combined with**

less than 85 percent square set. Starting with the third week of squaring up to first bloom, the economic threshold is 25 to 30 cotton fleahoppers per 100 terminals combined with less than 75 percent square set.

In cotton planted after May 15, treatment decisions should be made during the first week of squaring, if possible, to avoid a potential bollworm outbreak resulting from the destruction of beneficial insects and spiders. As plants increase in size and fruit load, larger fleahopper populations can be tolerated without yield reduction. In most years treatment is rarely justified after first bloom. However, occasionally, when cotton plants do not set an adequate square load during the first 3 weeks of squaring, fleahoppers can prevent the square set that is needed for an adequate crop.



Overwintered Boll Weevil

Emerging overwintered boll weevils usually move relatively short distances from hibernation sites and usually are confined to small areas in fields adjacent to good overwintering habitat. Overwintered weevil emergence begins during early spring and generally peaks during late May and early June. However, significant emergence can continue into early July in some years. The adult weevil is about 1/4 inch long, grayish brown, and has a prolonged snout with chewing mouthparts at its tip. The presence of two distinct spurs on the lower part of the first segment of the front leg will distinguish the boll weevil from other weevils with which it might be confused.

Weevil colonization in cotton is closely related to the fruiting of the plant, with the greatest numbers of overwintered weevils entering cotton fields after squares are present. Therefore, the extent of overwintered weevil infestation depends on the size of the emerging weevil population and the availability of squaring cotton. Thus, early-planted cotton and fields adjacent to ideal overwintering habitat are much more likely to have significant weevil infestation than cotton planted later in the season or fields farther away from good overwintering habitat. In areas where a uniform delayed planting date is recommended, volunteer cotton should be destroyed as early as possible.

Management and decision making. All of the cotton acreage in the High Plains, Trans Pecos and Rolling Plains is now in the boll weevil eradication program. If producers or others have questions about boll weevil control in their area, they should call the local Texas Boll Weevil Eradiction Foundation office or contact the foundation at (325) 672-2800. However, producers should still follow good management practices to aid boll weevil eradication. In the Rolling Plains, uniform planting of cotton on a community-wide basis after mid-May will often significantly reduce weevil infestations. When fruiting cotton is not available for feeding, the life span of newly emerged weevils is relatively short. Therefore, delayed, uniform planting of cotton increases suicidal emergence of overwintered weevils.

In addition, producers can help with eradication by doing the following:

- Avoid planting cotton in small fields that are difficult to treat (such as those surrounded by trees or building, or occupied by people or livestock).
- Make boll weevil eradication personnel aware of all cotton fields.
- Provide boll weevil eradication personnel access to all cotton fields.
- Assure that pheromone traps are kept standing and operational.
- Promptly alert eradication personnel of any field detections of live boll weevils or weevil-punctured squares.

Mid-Season and Late-Season Pests

Mid-season is the 6-week fruiting period following the appearance of the first 1/3-grown squares. Proper crop management and frequent field inspection of pests and beneficials will eliminate unnecessary insecticide applications during this period. The major concern during this period is ensuring adequate fruit set and preserving beneficial insect populations.

Late-season is the remainder of the production season when the major concern is boll protection. Monitoring boll set may aid in making spray decisions in the late-season period. Boll protection is of primary concern as long as bolls which will be harvested are immature.

Bollworm and Tobacco Budworm

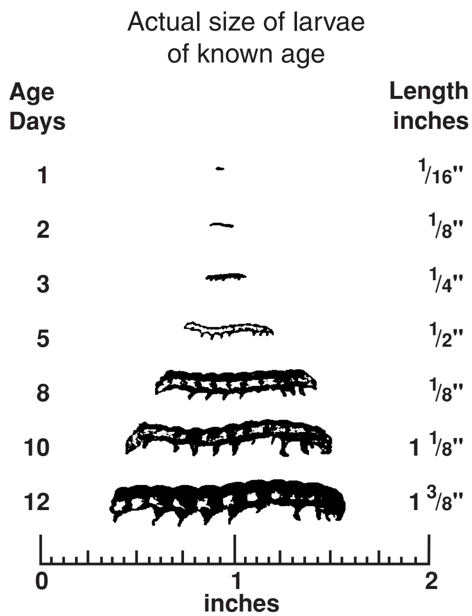
Bollworm and tobacco budworm larvae are similar in appearance and cause similar damage. Full-grown larvae are about 1 1/2 inches long and vary in color from pale green, pink or brownish to black, with longitudinal stripes along the back.

Tobacco budworm and bollworm moths are attracted to and lay eggs readily in cotton that is producing an abundance of new growth. Moths usually lay single eggs on the tops of young, tender terminal leaves in the upper third of the plant. Eggs are pearly white to cream color and about half the size of a pinhead. These should not be confused with looper eggs, which are flatter and usually laid singly on the undersides of leaves. Eggs hatch in 3 to 4 days, turning light brown before hatching. Young worms usually feed for a day or two on tender leaves, leaf buds and small squares in the plant terminal before moving down the plant to attack larger squares and bolls. When small worms are in the upper third of the plant, they are most vulnerable to control by insecticides and beneficial insects and spiders.

Sometimes moths deposit eggs on squares, bolls, stems and, in general, lower parts of the plant. This may occur when cotton plants are stressed and making little new growth, or during periods of high temperature and low humidity. Detection of eggs and control of small worms are more difficult when eggs are deposited in these locations.

Budworms are generally more resistant to insecticides than bollworms. Budworms are less numerous than bollworms until mid-August or early September, and rarely reach damaging levels. Once certain kinds of conventional insecticides are used to control bollworms and budworms, the percentage of budworms in the infestation increases with each additional application because of selection pressure. Aphid and other secondary pest infestations may increase following bollworm/budworm sprays, especially when pyrethroids are used.

BOLLWORM/BUDWORM IDENTIFICATION



Management and decision making. Cotton fields should be scouted carefully every 3 to 5 days during periods of predicted moth egg-laying activity. In fields with fewer than five squares per row foot (approximately 67,000 per acre), bollworm populations often collapse and cease to be a problem.

Eggs and newly hatched worms are usually found in the plant terminals and indicate possible outbreaks. Natural mortality agents such as weather and predators frequently control these pests before any damage occurs. Once worms have grown to larger than 1/2-inch long, natural and insecticidal control are less effective. Insecticides applied to control 1/2-inch long worms are only moderately effective.

Frequently, examination of the upper third of the plant (leaves, stems, squares, blooms and bolls) is all that is needed to make a sound management decision. However, when eggs are being laid all over the plants or when 60 percent or more of the bolls are mature, whole plant counts should be used. Mature, unopened bolls are firm, cannot be dented when pressed between the thumb and forefinger, and cannot be cut easily with a sharp knife.

Before bloom. The decision to apply conventional insecticides (as opposed to microbial insecticides, ovicides or no treatment) for bollworm and budworm control during this period should be made very carefully. Conventional insecticides often kill beneficial insects and spiders, thus allowing a rapid increase in bollworm numbers. Avoid making conventional insecticide treatments on the basis of egg numbers or first signs of crop damage. Under most conditions, do not use conventional insecticides before blooms are observed in the field. **Treatment may be warranted when 30 percent of the green squares examined are worm damaged and small worms (larvae) are present.** Consider using a microbial insecticide (larvae) to preserve beneficial insects and spiders. Microbial insecticide use is discussed further on page 15.

After bolls are present. Divide the cotton field into four or more manageable sections depending upon field size. Make whole plant inspections of five randomly chosen sets of three adjacent cotton plants in each section.

Count the number of eggs, worms and key predators encountered and estimate the number of eggs, worms or key predators per acre using the following formula:

$$\text{Worms, eggs or key predators per acre} = \frac{\text{No. eggs, worms or key predators counted}}{\text{No. of whole plants checked}} \times \text{no. of plants per acre}$$

The number of plants per cotton acre is calculated from counts of plants on at least 10 feet of row in four locations in the field:

$$\text{Plants per acre} = \frac{\text{Row feet per acre}}{\text{Row feet examined}} \times \text{Plants counted}$$

$$\text{Row feet per acre} = \frac{522{,}720}{\text{Row spacing in inches}}$$

Treatment may be justified when counts average 10,000 or more small (1/4 inch or less) larvae per acre. Some field scouts, consultants and entomologists have difficulty finding small larvae. Individuals unable to easily find the small larvae should consider reducing the threshold to 5,000 or more small larvae. However, if two or more key predators (see discussion under Scouting Decisions) are found for each small worm, control measures may not be needed or a microbial insecticide may be used. Once larvae reach 3/8 inch, the threshold for both Bt cotton and non-Bt cotton should be dropped to 5,000 per acre.

Bt transgenic cotton management. Research trials evaluating the Bollgard® transgenic Bt gene technology have determined it to be highly effective against tobacco budworms. Bollgard® cottons are also effective against cotton bollworm, but under heavy pressure from this species, insecticide treatment may be needed. Recently released Bollgard® II and WideStrike® cotton varieties are more effective against tobacco budworm and bollworm. However, under extreme environmental conditions or heavy insect pressure, they may still need to be treated.

The entire plant should be searched for tobacco budworm and bollworm larvae and injury. A proper sample includes squares, white blooms, pink blooms, bloom tags and bolls. Scouting intervals should be reduced to 3 to 4 days during periods of increasing bollworm egg laying, especially during peak bloom. Treatment should not be triggered by the presence of eggs alone. Hatching larvae must first feed on the cotton plant to receive a toxic dose. **Treatment with foliar insecticides for tobacco budworm or bollworm should be considered when 5,000 larvae per acre larger than $^{1}/_{4}$ inch are present (based on a population of 40,000 to 60,000 plants/acre) and 5 to 15 percent of the squares or bolls are worm damaged.**

As with non-Bt cotton, a range of treatment thresholds is provided since many factors in addition to density of larvae and square damage determine the need to treat Bt cotton with insecticides. Many of these factors are the same as those listed above for non-Bt cotton. As in non-Bt cotton, predators and parasites are very important in reducing the numbers of eggs and larvae and they complement the control provided by these varieties.

The use of a non-Bt cotton refuge is a requirement for planting Bt cotton and is an important component of resistance management.

Boll Weevil

Recently emerged adults feed on squares or bolls for 4 to 8 days before mating and laying eggs. Adult weevils puncture squares or bolls both for feeding and egg laying. Egg laying punctures can be distinguished from feeding punctures by the presence of a wartlike plug which the female places over the feeding site after she has deposited an egg in the cavity. The female deposits an average of 100 eggs during her life span of about 30 days.

Eggs hatch into larvae, or grubs, within 3 to 5 days under midsummer conditions. Grubs transform into pupae within the square or boll in approximately 7 to 11 days. Adults emerge 3 to 5 days later. The time required for development from egg to adult under summer field conditions averages 17 days, with a complete generation occurring in 21 to 25 days.

Punctured squares flare open and usually fall to the ground within a week. Small bolls that are punctured may also fall to the ground, but larger bolls remain on the plant. When direct sunlight and hot, dry conditions cause fallen squares to dry out rapidly, large numbers of weevil larvae do not survive.

Boll weevil populations reach the highest level late in the growing season. As cotton plants mature and the number of squares is reduced, the percentage of boll weevil-damaged squares becomes an unrealistic indicator of damage because boll weevils are competing for squares. As square numbers decrease, boll weevils may cause more damage to small bolls.

Management and decision making. All of the cotton acreage in the High Plains, Trans Pecos and Rolling Plains is now in the boll weevil eradication program. Producers should continue monitoring the plants for boll weevils and boll weevil damage. If boll weevils or boll weevil damage is found, producers should contact their local Texas Boll Weevil Eradication Foundation office or contact the foundation at (325) 672-2800.

Aphids

Three species of aphids, or plant lice, feed on cotton plants: the cotton aphid, the cowpea aphid and the green peach aphid. Cowpea aphids are shiny black with white patches on the legs and can be common on seedling plants. Aphid infestations can occur from plant emergence to open bolls. Cotton aphids range in color from light yellow to dark green to almost black. The immature or nymphal stage looks like the adult stage, only smaller. Most adults do not have wings. Aphids usually are found on the undersides of leaves, on stems, in terminals and sometimes on fruit. Heavy and prolonged infestations can cause leaves to curl downward, older leaves to turn yellow and shed, squares and small bolls to shed and bolls to be reduced in size, resulting in incomplete fiber development.

Honeydew excreted by aphids can drop on fibers of open bolls. A black, sooty fungus sometimes develops on the honeydew deposits during wet periods. Fiber from such bolls is stained, sticky and of lower quality, resulting in difficult harvest, ginning and yarn spinning. Natural control by unfavorable weather, predators, parasites and pathogens can be effective in holding populations below damaging levels. Sometimes aphid numbers increase to moderate or heavy levels and then decline for no apparent reason.

Management and decision making. Although high populations can develop prior to bloom, most economically damaging infestations generally develop later in the season during the month of August. Fields should be scouted twice per week since rapid increases in aphid numbers can occur in a short time. A total of 60 leaves divided between the top, middle and lower portion of the plant should be sampled from plants across the field to determine actual infestation levels. **Insecticidal control of cotton aphids should be delayed until infestations exceed 50 aphids per leaf.**

Pink Bollworm

Pink bollworms are primarily late-season insect pests. Larvae will feed on squares in the early season without economic damage to the crop. But once bolls are present, they become the preferred food supply. Pink bollworm larvae prefer 15- to 20-day-old upland cotton bolls. Pima cotton bolls remain susceptible to damage until they are 35 to 40 days old. It is essential that bolls set during the first 4 weeks of the boll-setting period be protected from pink bollworm damage. In Pima cotton it is important to protect the crop even longer, since it matures more slowly. To provide this protection normally requires continued scouting and treatments if necessary until mid-September for upland and the first of October on Pima.

Management and decision making. Pink bollworm pheromone traps should be placed in fields at seedling emergence and monitored at least weekly until the 4- to 5-leaf stage, then daily until the 1/3-grown square stage. **If more than five moths are caught per trap per night at the pinhead square stage, insecticides or pheromone mating disruption products or a combination should be applied.** Subsequent treatments may be needed if indicated by the trap catches. Terminate treatments prior to the 1/3-grown square stage.

In areas where moths are captured in pheromone traps, field inspections for rosetted blooms should be made after the crop is in the second week of bloom. Since rosetted blooms caused by pink bollworms do not result in economic damage, the rosetted bloom counts and pheromone trap data should be used for detection of infested fields and to time pheromone mating disruption sprays for population suppression. Generally, insecticide applications should be reserved for later in the season.

Where rosetted blooms are detected in a field, inspections of 40 to 50 quarter-sized bolls should be made twice weekly. Collect bolls when walking diagonally across the field. Bolls should be cracked or cut and examined for the presence of pink bollworms. Examine the inside of the carpel wall for the entrance wart or mines made by small larvae, and the lint and seed for evidence of feeding or larvae. Pheromone traps can be helpful in identifying infested fields and timing insecticide applications, but should not be used without boll inspections as a decision-making tool. **Oil trap catches of 60 to 100 moths per trap per night for three nights are a strong indicator that an adult flight is underway and treatment may be needed.**

When weekly boll counts indicate a 10 to 15 percent infestation during the first 6 weeks of boll set in upland cotton, or 5 to 10 percent in Pima cotton, insecticide treatments are warranted. Apply insecticide treatments using pheromone trap catches as a timing indicator or apply on a 5-day schedule. Where infestations occur late in September, 40 to 50 percent of the top-crop bolls may be infested without economic loss in upland cotton.

Termination of insecticide treatments. Terminate insecticide treatments in upland cotton when the last bolls expected to be harvested are 30 days old. Bolls of this age are "rock hard" in firmness. Newly hatched pink bollworm larvae have difficulty entering the more mature bolls and surviving in the dry fibers. In Pima cotton, treatments should be continued until 70 percent of the bolls are open.

Cultural control is the most desirable, satisfactory and economical method of controlling pink bollworms. Farming practices should be planned and conducted for early crop maturity and to permit crop termination by mid-September. The pink bollworm is an occasional pest in the High and Rolling Plains areas. Cotton should be harvested as early as possible. Stalks should be shredded and plowed (preferably with a moldboard) to a depth of at least 6 inches. Plowing should be completed as early as possible. By law, they must be plowed by February 1.

Beet Armyworm

Beet armyworm eggs are laid on both leaf surfaces in masses covered by a whitish, velvety material. Young beet armyworms "web up" and feed together on leaves, but eventually disperse and become more solitary in their feeding habits. Early-season infestations feed on leaves and terminal areas. Occasionally they destroy the terminal, causing extensive lateral branch development and delayed maturity. Early-season insecticide applications may be warranted when plants with undamaged terminals approach the lower optimal plant stand limits of two plants per row foot for dryland production and four plants per foot of row in irrigated production. Larvae skeletonize leaves rather than chewing large holes in them. Damaging infestations sometimes develop late in the season when beet armyworms also feed on terminals, squares, blooms and bolls. Several factors can contribute to these late-season beet armyworm outbreaks. These factors are: mild winters (e.g., absence of prolonged freezing temperatures); late planting; delayed crop maturity; heavy early-season organophosphate or pyrethroid insecticide use; prolonged hot, dry weather conditions; presence of beet armyworms prior to bloom; and weather conditions that support long-distance migration. Additional characteristics of high risk fields that consistently appear to fit a pattern for developing beet armyworm problems are: sandy and droughty soils; skip-row planting; fields with skippy, open canopies; drought stressed plants; and fields infested with pigweed. The likelihood of a heavy out-break increases as more of these factors occur in a given location. However, when beet armyworm populations are high all fields are susceptible. When beet armyworms begin to damage the fruit, control may be justified. Infestations usually are spotty within a field, and careful scouting is necessary to determine the need for, and field area requiring, control. Beet armyworms longer than 1/2 inch may be difficult to control.

Management and decision making. Scout the field by using the Whole Plant Inspection Method described in the bollworm and tobacco budworm section. **When infestations are mainly leaf feeding and small larvae (worm) counts exceed 20,000 larvae per acre (16 to 24 larvae per 100 plants) and at least 10 percent of the plants examined are infested, control may be warranted. If beet armyworm larvae have shifted from feeding on foliage to feeding on squares, blooms and bolls, thresholds should be lowered toward the bollworm threshold (4,000 to 8,000 larvae per acre or 8 to 12 larvae larger than 1/4 inch per 100 plants). When cotton matures and square feeding is not important, thresholds should be raised to 20,000 small larvae per acre.**

Occasional Pests

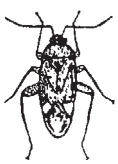
Grasshoppers

The lubber (Jumbo) grasshopper is a large, brown, clumsy grasshopper without fully developed wings. It cannot fly but its hind legs are greatly enlarged and it is a strong hopper. It can be extremely damaging to seedling cotton. Large numbers are capable of completely destroying stands, especially around field margins.

Management and decision making. Although no economic threshold has been established for this species, **field observations have indicated that populations of one per 3 row feet in the field or two per square yard in vegetation around the field may be capable of causing economic damage.**

Other species. A number of other grasshopper species are occasional cotton pests. They generally move into fields from adjacent fence rows, ditch banks or field margins.

Management and decision making. Damaging infestations need to be controlled early while grasshoppers are small and still in crop border areas. **Twenty or more grasshoppers per square yard in crop margins or 10 or more per 3 row feet in the field are suggested treatment levels.**



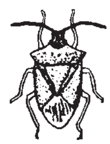
Lygus Bugs

The western tarnished plant bug (*Lygus hesperus* Knight) is one of several *Lygus* species that feeds on cotton terminals, squares and small bolls. Adults are 1/4 inch long, have a conspicuous triangle in the center of the back, are winged, and vary in color from pale green to yellowish brown with reddish brown to black markings. Immature lygus bugs are called nymphs. They are uniformly pale green with red-tipped antennae; late instars have four conspicuous black spots on the thorax and one large black spot near the base of the abdomen. The nymph's wings are not developed, but nymphs can move rapidly and are difficult to detect in cotton foliage. Small nymphs may be confused with aphids, cotton fleahoppers and leaf hopper nymphs. Plant bugs prefer legumes to cotton and usually are found in large numbers in areas of alfalfa or potato production or areas providing wild hosts such as clovers, vetches, mustard and dock. Lygus bugs are attracted to succulent growth; their feeding results in shedding of squares and small bolls, stunted growth and boll deformation. Feeding damage to small bolls is often characterized as small black spots or small, sunken lesions. The feeding that causes these spots or lesions may or may not penetrate the boll wall and damage developing seeds or lint. Damage to blooms appears as black anthers and puckered areas in petals.

Management and decision making. The need for lygus bug control is determined by their abundance in relation to the fruiting condition of the cotton plants. Fields should be inspected for lygus bugs at 4- to 5-day intervals using a drop cloth (see discussion on page 7). **During the first week of squaring, the economic threshold is one lygus bug adult or nymph per 3 feet of row combined with less than 90 percent square set. In the second week of squaring, the economic threshold is one lygus bug adult or nymph per 3 feet of row combined with less than 85 percent square set. In the third week of squaring, the economic threshold is one lygus bug adult or nymph per 3 feet of row combined with less than 75 percent square set. After the third week of squaring, the economic threshold is two lygus bug adults or nymphs per 3 feet of row with less than acceptable fruit retention.**

After peak bloom, begin treatment when drop cloth counts exceed two lygus bug adults or nymphs per 3 feet of row and plants have failed to retain squares and set bolls normally during the first 4 to 5 weeks of fruiting.

Research in Arizona and California indicates that the western tarnished plant bug (*Lygus hesperus*) may be more difficult to control with insecticides and may require the use of higher labeled rates of suggested insecticides.



Stink bugs

Several species of stink bugs feed on squares and bolls. Feeding on bolls may cause boll shed and/or seed damage and lint staining. Stink bugs may move into cotton when grain sorghum in the area starts to mature.

Management and decision making. Examine 6 row feet of cotton in several locations in the field. **When there is an average of one or more stink bugs per 6 feet of row, feeding can cause excessive loss of squares and small bolls and may stain lint. Additionally, at least 50 small bolls (the diameter of a quarter) should be examined. If 20 percent of the small bolls have internal injury from stink bugs and stink bugs are present then treatment should be considered.** Stink bugs often are clumped near field margins.

Cabbage Looper

Cabbage looper eggs are laid singly, mainly on the lower surfaces of leaves. Larval feeding damage is characterized by leaf ragging or large holes in the leaves. Looper larvae often are killed by a disease before economic foliage loss occurs.

Management and decision making. No economic threshold has been established for this pest. **Insecticide treatments generally are not recommended.**

Spider Mites

Spider mites infest the undersides of leaves, where they remove the sap from the plant and cause the leaves to discolor. They may also infest bracts of squares and bolls, causing the bracts to desiccate and squares or small bolls to shed. Severe infestations can defoliate the cotton plant. Mite infestations most often occur in spots and in field margins. Increased spider mite populations usually follow multiple applications of insecticides for other pests, since insecticides destroy natural spider mite predators.

Management and decision making. Treat when mites begin to cause noticeable leaf damage. Spot treatment of fields is encouraged when infestations are restricted to small areas.

Fall Armyworms

Fall armyworms have four life stages: egg, larva, pupa and adult. Eggs are very small, white, laid in clusters of 50 or more, and are covered with grayish, fuzzy scales from the body of the female moth. The eggs are difficult to find and are distributed throughout the plant on the undersides of leaves. Larvae will feed for 2 to 3 weeks and can be 1 to $1^1/_2$ inches long with various color patterns depending on the food source. The larvae have five instars (stages when molting occurs). When full grown, larvae enter the soil and form the pupal stage. Adult moths emerge from pupae. Moths mate and lay eggs, thus starting the life cycle over again.

The fall armyworm overwinters in the pupal stage in the southern regions of Texas. The adult is a moth that migrates northward as temperatures increase in the spring. The adult moth has a wingspan of about $1^1/_2$ inches. The hind wings are silver-white; the front wings are dark gray, mottled with lighter and darker splotches. Each front wing has a noticeable whitish spot near the extreme tip on the males. Larval color can vary from light tan to shades of green. The head is brown or black with a prominent white line between the eyes which forms an inverted "Y." The fall armyworm larva also has four large spots that form a square on the upper surface of the last segment of its body.

Small larvae are difficult to detect because they often feed on boll bracts and on the surface of bolls, hidden behind the bracts. Larger larvae are often the first to be detected while feeding in blooms. Fall armyworm infestations have been so sporadic in Texas that little is known about their ability to do damage. Observations made in the 2005 growing season indicated that fall armyworms feed on a relatively small number of bolls compared to bollworms. Thus, it takes more larvae to do as much damage as a smaller number of bollworm or tobacco budworm larvae.

The fall armyworm is inherently difficult to control with insecticides, and larvae are often found deep in the canopy in protected areas. Divide the field into four quadrants and examine 25 plant terminals, selected at random from each quadrant, for small larvae and eggs. Also, from each quadrant, examine 25 one-half grown and larger green squares for armyworms and armyworm damage. Squares should be selected at random and flared or yellow squares should not be included in the sample.

The threshold used is based on observations in Texas and other states. No threshold work has been conducted in Texas because of the sporadic infestations experienced. Based on these observations and other states' experiences, before first bloom, insecticide application may be justified when 30 percent of the green squares are worm damaged. Once bolls are present, an insecticide application may be justified when 15 to 25 or more small larvae are present per 100 plant terminals and 10 to 15 percent of the squares or bolls are worm damaged. If worm numbers are high, it may not be appropriate to wait until the damage threshold of 5 to 15 percent square damage is reached.

An alternative is to determine the number of fall armyworm larvae per acre. Divide the cotton field into four or more manageable sections depending upon field size. Make whole plant inspections of five randomly chosen groups of three adjacent cotton plants in each section. Count the number of eggs, worms and key predators per acre using the following formula:

The number of plants per acre is calculated from counts of plants on at least 10 feet of row in four locations in the field:

$$\text{Worms, eggs or key predators per acre} = \frac{\text{No. eggs, worms or key predators counted}}{\text{No. of whole plants checked}} + \text{No. of plants per acre}$$

$$\text{Plants per acre} = \frac{\text{Row feet per acre}}{\text{Row feet examined}} \times \text{Plants counted}$$

$$\text{Row feet per acre} = \frac{522720}{\text{Row spacing in inches}}$$

Treatment may be justified when counts average 10,000 to 20,000 small worms or more per acre. A range of treatment thresholds is provided under both the percent and worms per acre methods because many factors in addition to density of larvae determine the need to treat with insecticides for fall armyworms. One of these factors is the number of predatory insects and spiders that feed on fall armyworm eggs and small larvae. If previous insecticide treatments have eliminated these beneficial insects, then a lower treatment threshold should be considered. The number of fall armyworm eggs can also be considered along with worm densities in making treatment decisions. The treatment threshold will also vary according to the ability of the individual scout to locate small larvae, the age structure of the infestation, the stage of crop growth, the percent fruit set, the cost of insecticide treatment, the duration of the infestation (1 to 2 weeks vs. 3 to 4 weeks), the type of production system (high input/high yield or low input/low yield) and the market value of the crop.

Bt transgenic cotton management. Research trials evaluating the Bollgard® transgenic Bt gene technology have determined it to have no effect against fall armyworms. However, Bollgard® II and WideStrike® are both effective against fall armyworms.

Other Pests

Early season. Garden webworms, beet armyworms, yellowstriped armyworms, saltmarsh caterpillars and cotton square borers are occasional pests of cotton in this area. Cutworms can cause damage during the seedling stage. Keep fields as weed-free as possible 3 weeks before planting to avoid cutworm problems. Garden webworms can be a problem on seedling to 6-leaf-stage cotton. High numbers of beet armyworms, yellowstriped armyworms and saltmarsh caterpillars can reduce plant stands. Treatment of isolated areas within a field or along field borders can be effective in controlling these pests and reducing their spread across the field.

Late season. Yellowstriped armyworms and saltmarsh caterpillars rarely cause economic damage when they feed only on leaves of cotton late in the season. Whiteflies can sometimes reach high numbers in September and October.

Management and decision making. Economic thresholds have not been established for these pests. **Control is a matter of judgment.** Insecticides are most effective if applied when worms are small.

Systemic Insecticides at Planting

In areas where early-season thrips infestations consistently damage young cotton each year, preventative systemic insecticide treatments have proved more effective than postemergence spray applications. In choosing either approach to early-season thrips control, key factors to consider include the abundance of thrips on other host plants at cotton planting time, the variety planted, the acreage planted, the planting date, available equipment and labor, drought tendencies, and the probability of having to replant. Limitations and advantages of both systemics used at planting and postemergence spray applications should be evaluated carefully before making a choice.

Limitations of Systemics

- The decision to invest in systemics must be made before the severity of the thrips problem can be assessed; therefore, the net economic return is uncertain.
- If replanting is necessary, the initial systemic treatment is lost and a new treatment at additional expense may be required.
- Under unfavorable conditions for plant emergence (such as poor seed quality, planting too deeply, seedling disease, Asochyta blight or cool, wet weather), some systemics may contribute to further stand reduction.
- In areas where producers typically plant late (such as the Uniform Optimal Planting Date in the Rolling Plains) or where planting is delayed until late May or early June, the likelihood of having thrips problems is lessened significantly and the probability of economic returns from the use of systemics is diminished considerably.
- Heavy rains may leach systemics from the root zone, thus shortening the effective control period and necessitating a foliar spray for additional control.

Advantages of Systemics

- Systemics are effective when inclement weather or field conditions prevent sprayer operation.
- The activity of systemics within the plant is relatively unaffected by rain and weathering during their normal period of effectiveness.
- The use of systemics reduces pesticide drift to non-target sites and organisms and provides longer residual control than foliar sprays.
- Under certain conditions, some systemics often stimulate more rapid early growth and sometimes increase yields which apparently cannot be attributed to early-season pest control alone.
- Use of systemics at planting will prevent significant thrips damage when high thrips numbers infest plants as they emerge.
- Protection from early-season thrips damage can result in earlier maturity, which may be important during years of deficient moisture, early crop termination, or pest buildups during late season.
- At this time there is no research-based economic threshold for thrips control using postemergence applications. Therefore, the current foliar application suggestions may be inappropriate.

Ovicides

These insecticides effectively reduce numbers of bollworm and tobacco budworm eggs. Because large numbers of eggs often fail to produce economically damaging worm infestations, **insecticidal control of eggs alone is not recommended.** Environmental factors such as hot, dry weather can significantly reduce field levels of eggs. Some other important natural control factors include predacious insects and spiders and parasitic wasps. Natural egg control can vary greatly between fields and times of the season. Often, high numbers of sterile eggs are found. If larval infestations exceed suggested treatment levels and large numbers of eggs are present, the addition of an ovicide to the larvicide may be justified to enhance overall control.

Microbial Insecticides

Microbial products which are natural pathogens of the bollworm and tobacco budworm are commercially available as preparations of *Bacillus thuringiensis* (B.t.). Field studies indicate that microbials are best suited for square protection. They are slow acting and should be used against infestations of worms during the squaring period through the first 10 days of blooming. They are not suggested for use after that point.

Microbials are effective against worm numbers up to 6,000 per acre. They do not destroy beneficial arthropods (predators and parasites), a characteristic which sets them apart from conventional insecticides. When beneficial arthropod populations are absent, other insecticides provide more consistent control.

Treat fields in which most larvae are not more than 1/4-inch long. Infestations of larger worms should not be treated with microbials. Maximum effectiveness with B.t. requires precise sampling of cotton plants during the fruiting period. Sampling should be conducted at least twice a week while squares are developing. Apply microbials with ground equipment at the rate of 5 to 15 gallons of liquid per acre, or by air using 2 to 5 gallons per acre.

Registered *Bacillus thuringiensis* products and labeled rates for controlling bollworm and tobacco budworm.

Product	Rate per acre (formulated material)
Dipel DF	0.5-2.0 lb
Dipel ES	1.0-6.0 pt
Javelin WG	0.5-1.5 lb

Protecting Bees from Insecticides

Pollination is extremely important in producing many seed crops such as alfalfa, clover and vetch. Honey bee pollination also is critical in the production of cucurbits throughout the state, and supplements native pollinators. The role of honey bees and wild pollinators in contributing to increased yields and fiber length of cotton is unclear. The importance of insect pollinators in the production of hybrid cotton is well recognized, however. Where pollinating insects are required for flower fertilization, the crop producer, insecticide applicator and beekeeper should cooperate closely to minimize bee losses:

1. Apply insecticides, if practical, before bees are moved into fields or adjacent crops for pollination. When bees are in the vicinity, evening applications after bees have left the field are less hazardous than early morning applications.
2. Where insecticides are needed, consider their toxicity. "Highly toxic" insecticides include materials that kill bees on contact during application or for several days following application. Insecticides categorized as "moderately toxic" or "relatively nontoxic" should be applied in late evening or early morning when bees are not foraging. For information on hazards of insecticides to honey bees, refer to the table in E-6A, "Suggested Insecticides for Managing Cotton Insects in the High Plains, Rolling Plains and Trans Pecos Areas of Texas."
3. To prevent heavy losses of bees, do not spray any insecticide directly on colonies and prevent insecticide from drifting. Bees often cluster on the fronts of their hives on hot evenings. Pesticide drift or direct spray at this time generally results in high levels of mortality.

Policy Statement for Making Pest Management Suggestions

The information and suggestions included in this publication reflect the opinions of Extension entomologists based on field tests or use experience. Our management suggestions are a product of research and are believed to be reliable. However, it is impossible to eliminate all risks. Conditions or circumstances which are unforeseen or unexpected may result in less than satisfactory results even when these suggestions are used. Texas Cooperative Extension will not assume responsibility for such risks. Such responsibility shall be assumed by the user of this publication.

Suggested pesticides must be registered and labeled for use by the Environmental Protection Agency and the Texas Department of Agriculture. The status of pesticide label clearances is subject to change and may have changed since this publication was printed. County Extension agents and appropriate specialists are advised of changes as they occur.

The **USER** is always responsible for the effects of pesticide residues on his livestock and crops, as well as problems that could arise from drift or movement of the pesticide from his property to that of others. Always read and follow carefully the instructions on the container label.

For additional information, contact your county Extension staff or write the Extension Entomologist, Department of Entomology, Texas A&M University, College Station, Texas 77843-2475, (979) 845-7026.

Endangered Species Regulations

The Endangered Species Act is designed to protect and to assist in the recovery of animals and plants that are in danger of becoming extinct. In response to the Endangered Species Act, many pesticide labels now carry restrictions limiting the use of products or application methods in designated biologically sensitive areas. These restrictions are subject to change. Refer to the Environmental Hazards or Endangered Species discussion sections of product labels and/or call your local county Extension agent or Fish and Wildlife Service personnel to determine what restrictions apply to your area. Regardless of the law, pesticide users can be good neighbors by being aware of how their actions may affect people and the natural environment.

Worker Protection Standard

The Worker Protection Standard (WPS) is a set of federal regulations that applies to all pesticides used in agricultural plant production. If you employ any person to produce a plant or plant product for sale and apply any type of pesticide to that crop, WPS applies to you. The WPS requires you to protect your employees from pesticide exposure. It requires you to provide three basic types of protection: you must inform employees about exposure, protect employees from exposure, and mitigate pesticide exposures that employees might receive. The WPS requirements will appear in the "DIRECTIONS FOR USE" part of the pesticide label. For more detailed information, consult EPA publication 735-B-93-001 (GPO #055-000-0442-1) *The Worker Protection Standard for Agricultural Pesticides — How to Comply: What Employers Need to Know, or call Texas Department of Agriculture, Pesticide Worker Protection Program, (512) 463-7717.*

ADDITIONAL REFERENCES*

Number	Title
B-933	Identification, Biology and Sampling of Cotton Insects
E-5	Managing Cotton Insects in the Southern, Eastern and Blackland Areas of Texas-2007
E-5A	Suggested Insecticides for Managing Cotton Insects in the Southern, Eastern and Blackland Areas of Texas-2007
E-6A	Suggested Insecticides for Managing Cotton Insects in the High Plains, Rolling Plans and Trans Pecos Areas of Texas-2007
E-7	Managing Cotton Insects in the Lower Rio Grande Valley-2007
E-7A	Suggested Insecticides for Managing Cotton Insects in the Lower Rio Grande Valley-2007
L-5142	The Proper Use of Cotton Harvest-Aid Chemicals
B-1721	Cultural Control of the Boll Weevil: A Four Season Approach—Texas Rolling Plains
E-357	Guide to the Predators, Parasites and Pathogens Attacking Insect and Mite Pests of Cotton
B-6116	Texas Cotton Production — Emphasizing Integrated Pest Management ($15.00)
Cotton Resource CD at *http://lubbock.tamu.edu/cottoncd/*	
MP-1718	An Illustrated Guide to the Predaceous Insects of the Northern Texas Rolling Plains, is available at: *http://insects.tamu.edu/extension/bulletins/17180.pdf*

*These publications can also be found at: *http://insects.tamu.edu/extension/publications/results_all.cfm*

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Revised