

## Chapter 12

# Insect Management in Cotton

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Insect management decisions are crucial to the success or failure of the overall cotton crop. Under irrigation, cotton normally can't be produced in Oklahoma without severe insect problems. Annual inputs of \$25 to \$100 per acre for insect control must be made under irrigation to maintain high yields. Dryland cotton decisions are even more difficult because yield and fiber quality levels are usually lower and more uncertain due to more limited and erratic and those decisions must be carefully weighed before inputs are applied.

## Sampling Insect Populations

Management decisions should be based on actual field observations (i.e., sampling). Sampling correctly is a vital component of cotton insect control. It must be done frequently and in a manner that reduces risk. All sampling in insect pest management is done to estimate insect pest populations, pest damage, or beneficial insects. How well fields are sampled influences the accuracy of the decision. The ultimate goals of sampling are to give the most precise estimate of total insect populations in the shortest possible time and to reduce the risk of making a wrong decision.

The most widely used sampling method in Oklahoma and across the Cotton Belt is fixed sample size (FSS). In this type of sampling, a fixed (or previously determined) sample size is taken (commonly either 100 squares or terminals). The FSS method can be highly dependable if the entire field is sampled and if the insect being sampled has a high population density. The general rule in sampling is that large populations are easier to detect, and small populations are more difficult. FSS is fairly accurate for sampling boll weevils (15 to 25 infested squares per 100 examined is the economic threshold) and cotton fleahoppers (40 insects per 100 terminals is the economic threshold). Accuracy diminishes with FSS with bollworm

estimation since the economic threshold for that insect is low (5 to 10 larvae per 100 plants).

## Insecticide Applications

The decision to control cotton pests with insecticides should be made with care. The goal of insect management is the maximum net return per acre, not maximum yield. Highest net returns will be obtained when insect pests are kept below their economic thresholds, thus preventing unacceptable losses. Some yield losses due to insects invariably occur, but will not justify control. Information on economic thresholds for major pests in Oklahoma, currently recommended chemical treatments, and recommended rates can be found in OSU Extension Current Report CR-7162.

Use insecticides only if the economic threshold has been reached. All insecticides registered on cotton (except for a few microbial insecticides) also repress beneficial populations that are important natural control agents. The degree of reduction will depend on the insecticide and rate. Low rates of certain insecticides, such as ovicides, minimize the impact on beneficial populations.

Applying insecticides while cultivating has become a popular practice to reduce the overhead cost of producing a crop. However, repeated application when insects are below their economic threshold is not a sound management practice. Keeping the field sterile of insects is expensive, and this practice may lead to future insect shifts and/or resistance problems. A field sterile of all insects is neither necessary nor desirable.

Thorough knowledge of each potential pest and its susceptible growth stage can help reduce most cases, quick action to control early-season pests at the appropriate growth stage will allow time for beneficials to repopulate before the cotton becomes attractive to mid- and late-season cotton pests. For example, a properly timed pinhead square application for overwintering boll weevils before the squares are one-

third grown will control both boll weevil and cotton fleahopper, yet allow sufficient time for beneficials to reestablish to levels where they can reduce the late June/early July bollworm population. However, planting dates will influence whatever bollworm oviposition occurs immediately following early-season applications. Fields planted after May 25 will likely suffer a higher probability of a bollworm outbreak.

## Termination of Sampling and Insecticide Applications

Prior to the development of plant mapping techniques, plant monitoring was accomplished by parting the canopy to examine total boll load. Cotton's unique growing pattern of branches and fruit allows the age of each square and boll to be correlated with the number of heat units accumulated (Table 12-1).

**Table 12-1. Range of published growing degree day (base 60 °F) summations for individual phases of crop growth and maturation and the seasonal sum at which those phases occur<sup>1</sup>.**

Growth phase	Growing degree days	
	Phase	Seasonal sum
Emergence (stand estab.)	45-130	45-130
Appearance of first square	350-450	480-530
Square period	250-500	
Appearance of first flower		740-1150
Peak blooming rate	200-800	850-1625
Boll period	910-950	
First open boll		1690-2050
Defoliation		2550-4600

<sup>1</sup>Adapted from Mauney, J.R. 1986. Vegetative growth and development of fruiting sites. p 11-28. Cotton physiology. In J.R. Mauney and J.D. McStewart (ed.). The Cotton Foundation, Memphis, TN.

Plant mapping focuses on the development and retention of the first position bolls on the first 10 fruiting branches. The degree and type of shed at these key fruiting positions affects management decisions such as use of growth regulators, insect management, irrigation, fertilization, termination of scouting and insecticide control, timing harvest-aid applications, and yield predictions. This discussion highlights how to predict which bolls will contribute to the crop's yield by

monitoring flower-to-node ratio in the top portion of the plant.

The number of main-stem nodes above the uppermost white flower (NAWF) can give a quick appraisal of the plant's stress status and its vegetative potential relative to fruit load. As a plant's fruit load increases relative to its capacity to mature set fruit, development of new nodes in the terminal slows, then ceases. Consequently, first position white flowers occur progressively closer to the plant's apex until the plant "blooms at the top." A plant in a well-managed field will initiate fruiting with 7 to 10 NAWF. Extensive research in Arkansas and California indicates that bolls produced on the top 4 or 5 NAWF contribute less than 5 percent of the total number of first-position bolls. Subsequent research by University of Arkansas entomologists indicated that the greater the heat units, the fewer bolls are penetrated by boll weevils and bollworms. Greatest reduction in successful boll penetrations occurred between 300 and 400 heat units after the insects were released. This suggests that as heat unit totals build, the endocarp undergoes lignification - a process causing the tissue to become more woody.

Crop termination studies based on NAWF in Oklahoma in 1993 and 1994 confirmed the previous findings. Hand harvesting bolls by position on the plant revealed that neither variety used ('Deltapine Acala 90' or 'Paymaster HS-26') produced lint above the 4 NAWF. Also, none of the 4 NAWF bolls sustained insect damage in either year. In both years, near ideal growing conditions prevailed for the season (May 1 to October 31) with heat unit totals exceeding 2,800, followed by killing freeze in November (40 yr average = 3,005). Summers with below-average heat unit accumulations because of planting delays, replanting, unseasonable cool temperatures, and/or early killing frosts will reduce the percentage of 4 and 5 NAWF bolls contribution to yield.

Prior to the use of heat unit accumulations, producers cut bolls to determine the level of boll maturity. They randomly selected bolls to slice in the terminal area of plants. Fields were judged to be insect safe when most of the uppermost bolls resisted cutting with a sharp knife. Field test were initiated to determine if NAWF was as accurate as cutting bolls to terminate insect sampling and insecticide control without sacrificing yields. In 1993 and 1994, the 4 NAWF method accurately predicted when to terminate sampling and insect control. In fact, the 4 NAWF

method prevented on or two late-season applications compared to basing termination decisions on the boll-cutting method. Besides reducing insecticide inputs and environmental risk, more precise termination also saved labor by earlier termination of sampling. The main discrepancy between the two methods is the value and position of the last, harvestable boll that will contribute top yield. Before plant mapping, the Extension Service suggested that bolls set on or before September 1 had sufficient time to mature and contribute to yield. This view is still correct if the bolls in question are 4 or 5 NAWF position bolls. However, many producers and consultants continue to protect the top crop consisting of 2 and 3 NAWF position bolls until they are 20 days old if they are set on or before September 1.

## Predicting Crop Termination Using NAWF

Several types of information are required to ensure the NAWF method will accurately predict the termination of insect scouting and control. Failure to incorporate all steps will reduce its accuracy thus increasing the chance of late-season insect damage. These steps include:

- 1) Record individual field's planting dates.
- 2) Keep track of daily heat unit accumulations throughout the season.
- 3) Begin monitoring NAWF when heat units exceed 1,650.
- 4) Follow proper plant selection or sampling guidelines.
- 5) Record NAWF data weekly.

### 1) Planting Date.

Planting date for each field must be recorded if cotton producers and consultants are interested in using the 4 NAWF method. Without the actual planting date (or at least the week planted) you cannot accurately heat units accumulated throughout the summer.

### 2) Heat Units.

Determining heat units can be accomplished by manually using the formula of  $[(\text{daily high temperature} + \text{daily low temperature}) \div 2] - 60 \text{ }^\circ\text{F}$ ; by subscribing to the Oklahoma Mesonet - a unique, statewide environmental monitoring network; or by periodically contacting your county or area extension office.

### 3) Begin Monitoring NAWF.

Irrigated cotton planted in 1993 and 1994 approached 4 NAWF when heat units exceeded 1,650 (Figure 12-1). At that time, careful monitoring should begin.

**Figure 12-1. Nodes above white flower (NAWF) relative to heat units from data of planting.**

### 4) Plant Selection.

Sample at least 10 plants per field at random. If variability in stand age, plant vigor, or development is large, increase the number sampled to 20 or 30. Before mapping a plant, check to ensure that the uppermost white flower is located at the first position on the fruiting branch. If not, disregard; and select another plant.

### 5) Record NAWF Weekly.

Proceed if the uppermost white flower is located at the first position. This flower is the reference point to count the nodes above it. Record that number above it and the first fully expanded quarter-size leaf in the terminal area (Figure 12-2). If the field average is above 4 NAWF, repeat procedure in 3-to-5 days. Bolls set after this growth stage may be damaged, but will not contribute to yield.

**Figure 12-2. Upper portion of a cotton plant showing the white flower used to decide if plants are “insect safe,” following NAWF procedures.**

## **Other Insect Management Decisions**

Agronomic practices influence insect pest infestations. Excessive use of nitrogen fertilizer and/or irrigation stimulates vegetative growth. The excessive growth can delay maturity, reduce yields, and increase bollworm pressure. Control difficulties also can result because rank growth retards spray coverage. Basing fertilizer needs on yearly soil sample and applying an amount for reasonable projected yields will tend to eliminate this plant growth.

Cotton planted too thick becomes tall and spindly before setting squares. In many instances, this condition is wrongly blamed on cotton fleahoppers. Maximum yields are produced when the cotton stand is 2 to 4 plants per row foot. Seed size variation among modern varieties is often to blame. Planters calibrated for one variety may plant 50 percent more seed of another variety.

Late-season foliage and fruit are important food sources for bollworms and boll weevils. Availability of food increases the number of overwintering pests. The use of growth regulators, crop conditioners, defoliant, and desiccants can reduce this source of food late in the season decreasing the survival of those pests. Shred stalks and plow the fields immediately after harvest to reduce overwintering sites.

## **Dryland Cotton Production**

Economic thresholds for cotton insect pests have been established for Oklahoma conditions. Those thresholds are the same for both dryland and irrigated production. Insect pests in dryland cotton should be treated the same as in irrigated cotton if adequate moisture exists. Protecting dryland cotton from insect damage until moisture becomes limited will ensure the greater returns. Scout dryland cotton at least once a

week. During periods of heavy insect pressure, reduce scouting intervals to every 3 to 4 days. Continue scouting until the crop is mature enough to resist insect attack.

Once dryland cotton encounters drouth stress, plant growth begins to slow down, and fruit are shed, spray decisions become progressively more difficult because fruit may also be shed naturally after rainfall. In most instances, cotton becomes less attractive to insects as squares and vegetative growth cease. At this point, spray decisions must be based on the bolls that are still susceptible to insect attack and will be retained by the plant.

Weather conditions in some years (i.e., dry early in the season with rain in August) stimulate dryland cotton in Oklahoma to initiate new growth into September. This scenario usually affects late-season bollworm and boll weevil populations, making decisions more difficult since squares produced in late August and early September will not have sufficient growing degree days (GDD) to mature. However, the regrowth could provide the bollworm with sufficient food to attain a size capable of damaging harvestable bolls. Bolls set on September 1 will be sufficiently mature to resist insect attack by September 21 with average temperatures. Slice bolls in question with a sharp knife to determine if they are still susceptible to bollworm damage. Bolls easily sliced are still susceptible. Those which cannot be sliced are less likely to be damaged. If 70 to 90 percent of the harvestable bolls (located three to four nodes below the terminal) are still immature and bollworms or boll weevils exceed their economic threshold, the field should be sprayed. If most of the bolls are mature, the field should not be sprayed.

## **Irrigated Cotton Production**

Insect management decisions under irrigation are easier to make because water is not a limiting factor. However, irrigation intensifies insect pressure, requiring more timely management decisions.

To ensure that proper decisions are made in irrigated cotton, scouting at least twice a week is mandatory. Close scrutiny of the crop will ensure that application is properly timed to achieve optimal control.

The most difficult decision to make is to determine when insect control in the field should be terminated. A common mistake that irrigated cotton producers make is to quit a control program

prematurely. In most cases, this is the result of a producer reaching the monetary limit he has imposed on himself for the season's insect control. Severe damage can be inflicted late in the season by quitting 7 to 14 days early. The cost of continuing a spray program to mature harvestable bolls will be less than the loss incurred by letting a damaging infestation go unchecked.

With irrigation terminated the last of August, the bolls that should be protected are those set before August 25. Without timely rainfall, bolls set after that date stand little chance of maturing.

Fall weather prevents most bolls set after September 1 from maturing. The key to determining if the field is near the termination point is the stage of the plant growth. If the cotton has been protected from insects and an adequate boll set has occurred, plant growth rate will decline markedly. The terminal will initiate no new growth or squares. At this point, insect pressure should diminish because the plant is less attractive to insects. Without lush terminal growth, bollworms cannot achieve the size necessary to attack the bolls set before September 1.

Late-season bollworm decisions (after September 15) should be based solely on numbers of worms present and their size, not eggs. Cooler temperatures usually occur at this time of year, thereby delaying hatching and/or reducing egg viability. Even if the eggs hatch, cooler temperatures will delay larval development. Seven to 10 days may be required for a worm to damage harvestable bolls. Unless extreme insect pressure occurs, most fields need not be protected after September 20.

Late-season (after September 1) boll weevil-invested square counts usually escalate as squaring declines. Increase in boll damage will occur as squares decline. Boll maturity should be the final factor in determining when to discontinue the spray program for boll weevils. Unlike bollworms which must obtain a certain size to damage bolls, boll weevil adults can damage large bolls. Control programs must be continued until 70 to 90 percent of harvestable bolls resist the sharp knife test or after plants have reached four NAWF and 350 additional heat units have accumulated.

## Arthropod Management

Many different kinds of insects and mites are found in cotton fields with relatively few considered as

major pests. Fortunately, many are beneficial while a small number have no demonstrable effect on the plants or insects/mites present in the field. Since beneficial insects help regulate pests (especially in dryland cotton), the first step in an insect management program is to identify the various insects (beneficial or pest) and their damage (if any). Listed below are the major insect pests that infest Oklahoma cotton. Information which affects pest management decisions is discussed.

## Early-Season Pests

### Thrips (*Frankliniella* spp.)

Thrips (Photo 12-1) generally are not considered a serious pest of cotton, except in years when favorable growing conditions permit early planting. Heavy thrips infestations will occur if plants have emerged before wheat or other small grains mature. In Oklahoma, mature thrips often move into stands of succulent cotton seedlings, causing curled and misshapen leaves. Thrips infestations vary from field to field and from year to year and should be dealt with accordingly.

### Photo 12-1. Thrips adult.

Thrips damage cotton by injecting their stylets into the plant epidermis. Ruptured cells release plant fluids which are sucked up by the insects. Injury first appears as dark brown spots which assume a silvery appearance several days later. Feeding occurs on the lower side of the leaf and may injure the terminal bud so that new leaves fail to develop and growth is

retarded. Leaves will be crinkles and cupped (Photo 12-2). In some cases, 2,4-D damaged cotton can be mistaken for thrips injury (Photo 12-3).

If adequate moisture and warm temperatures exist, plants will quickly outgrow this pest. Thrips may persist on the plant throughout the growing season, although they do little damage after the seedling stage. One species, the western flower thrips (*Frankliniella occidentalis*), occasionally builds up in large numbers during the growing season when cotton is blooming. Damage to blooms and boll development has been reported.

**Photo 12-2. Thrips damage on cotton seedlings.**

**Photo 12-3. 2,4-D damage on a cotton seedling.**

Thrips are small, approximately one-sixteenth inch in length. The color varies according to species. It may be similar to the color of wheat straw, yellow, black, or light brown. The adults have two pairs of long, narrow, fringed wings which enable them to fly from one crop to another.

The life cycle contains four stages: egg, larva, pupa, and adult. Larvae and adults will overwinter in

debris and trash near the field. In the spring, the adult females lay eggs by inserting them into the plant tissue. The creamy white eggs hatch into small larvae which begin to feed on the plant. After a short time, they burrow into the soil and transform into a nonfeeding stage called the pupae. They emerge as adults and continue to feed on the plant. Many generations may be produced each season.

Generally, thrips control is not recommended in Oklahoma except when climatic conditions and cotton growth are favorable for their development.

Economically damaging infestations occur when plants average 3 thrips per plant. Seed treatment, in-furrow sprays, or granules applied in-furrow will give adequate control (during the susceptible growth stage from the cotyledon to the 4th true leaf). Foliar sprays work equally well if properly timed to control thrips before excessive damage occurs.

**Cotton Fleahopper (*Pseudatomoscelis seriatus*)**

In Oklahoma, the cotton fleahopper (Photo 12-4) is the most controversial insect in terms of damage. Research workers, cotton producers, and consultants have argued for years over the degree of damage and yield losses, if any, caused by this pest.

**Photo 12-4. Cotton fleahopper adult.**

The cotton fleahopper usually feeds on young succulent weeds in early spring such as croton, goatweed, and horsenettle. These weeds also provide an overwintering site for eggs. As the weeds mature, adults migrate to cotton which is beginning to put on pinhead squares. Fleahoppers insert their sucking mouthparts into the small squares. These damaged

squares (Photo 12-5) later turn brown and are shed from the plant. In addition to squares, the cotton fleahopper will also feed on other parts of the plant. If heavy infestations exist, new growth will be abnormal and whip-like in appearance. All stages of the life cycle will feed on the plant as long as it remains succulent. As soon as the cotton matures, these insects migrate to weeds or other host crops. In southwest Oklahoma, the highest population generally occurs in cotton in early August, although it is not generally a problem that late in the season.

**Photo 12-5. Cotton fleahopper damage to a square.**

The life cycle begins with the female placing her eggs into the plant tissue by means of an ovipositor. The eggs hatch in approximately 1 week, and small nymphs (which are similar to the adults, except for being wingless) undergo five molts before reaching the adult stage. Egg to adult takes approximately 3 weeks with six to eight generations per year.

The cotton fleahopper adults are approximately one-eighth inch long, winged, and pale green in color. They are covered with small black spots and have four characteristic black spots near the wing tip. The nymphs are about one-twenty-fifth inch long, wingless, and pale green in color.

Numerous chemicals are registered for control of fleahoppers. Cotton fleahopper control should be minimized to protect bollworm predators and parasites. Delay in chemical applications for fleahoppers often delays the need for bollworm control. After July 25, the control of cotton fleahoppers generally is not economical due to Oklahoma's short growing season.

In most cases, low yield potential coupled with the chance of unleashing bollworms in August offset the advantages of protecting the first squares set by a late-season application.

Research has demonstrated a significant difference in the preference of the cotton fleahopper to different cotton varieties. The rapid-fruited varieties are preferred with any variety related to Acala, such as Deltapine Acala 90' being less attractive.

Spray decisions should be based on the squaring rate and level of cotton leafhopper infestations. Usually when cotton fleahoppers (adults and nymphs) reach or exceed 40 per 100 terminals, squaring rates begin to decline, justifying treatment. However, if cotton fleahopper numbers build slowly, fields can tolerate higher number of cotton fleahoppers before a reduction in squaring rate will occur. In most cases, fields will no longer be vulnerable to cotton fleahoppers once they begin to bloom.

## Mid- and Late-Season Pests

### Boll Weevil (*Anthonomus grandis*)

The boll weevil can be an important pest of cotton in Oklahoma if climatic conditions favor development. Widespread economic loss can result from the boll weevil in years with high adult weevil survival over the winter followed by a growing season with ample rainfall. Historically, highest survival occurs in the following counties: Harmon, Jackson, and Tillman. Percentage of boll weevils that are able to survive generally decreases in a northerly direction. Most years, boll weevils cannot survive over the winter north of Interstate 40.

The percentage of overwintering boll weevils that are able to survive and infest cotton is low. Typically, percent survival ranges from less than 1 percent to about 5 percent, with up to about 10 percent in the most favorable years. Boll weevil survival depends on many factors; however, abundance of food in September and winter severity are very important. Greatest natural mortality occurs during cold, dry weather (prolonged temperatures below 32 °F). Increase in moisture and/or mean temperature reduces mortality.

Adult boll weevils are approximately three-sixteenths inch long, gray or brown, and have a snout, half as long as the body, containing chewing mouthparts. Boll weevil adults can be distinguished from

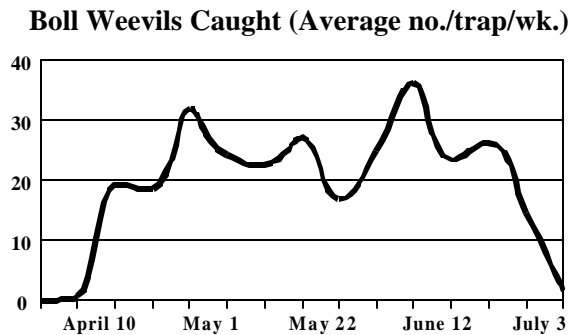
other weevils found in cotton by the pair of spurs on the femur of each front leg. Larvae are approximately three-sixteenths to one-half inch in length, grub-like, legless, and white with a brown head.

In the spring adult boll weevils begin emerging from overwintering habitats, e.g., grassy areas, mesquite thickets, weedy fence rows, ditch banks, and other areas that offer shelter. Broadleaf litter provides the best winter protection.

Annually, pheromone traps begin catching weevils in early April and continue throughout the summer. When boll weevils break diapause (their inactive state) depends on many factors. Some of these factors include:

- ?? When the boll weevil entered diapause,
- ?? The amount of fat reserves,
- ?? Winter conditions, and
- ?? Spring weather patterns.

Peak emergence usually occurs during mid-June (Figure 12-3). Emergence before the first of July is called suicidal emergence since boll weevils cannot find a food source. Most boll weevils will die within 10 to 14 days, unless they feed on squaring cotton.



**Figure 12-3. Boll weevil emergence trends (Jackson and Tillman Counties, 1984-1995).**

Effective emergence is by that portion of the weevils whose emergence coincides with square initiation. Newly emerged boll weevils will feed on young terminal growth, but prefer to feed on squares. Boll weevil injury consists of damaged squares, bolls, blooms, and terminals. In some instances, they will even feed on the foliage.

Adult weevils enter fields and begin feeding on young tender cotton plants destroying terminals and buds (Photo 12-6). They continue feeding on squares and later on flowers and small bolls as they are formed. Feeding damage consists of small punctures

which may be surrounded by an orange-colored excrement. Bracts on the damaged squares flare open, and these squares are generally shed from the plant.

**Photo 12-6. Boll weevil adult.**

After feeding, the female injects her ovipositor into the square depositing one egg. Several eggs may be deposited in a single boll. The oviposition site (Photo 12-7) is sealed, and a small protrusion develops over the wound called an “oviposition puncture” (OP). Eggs hatch in 3 to 5 days, and the small larvae feed on the immature anthers and/or other parts of the square (Photo 12-8). Larvae reach maturity in 7 to 10 days and then enter the pupa stage (Photo 12-8). When the insect reaches the adult stage, it chews its way out of the square or boll signaling the start of the next generation. Reproducing generations continue until frost when adults seek a protective habitat.

**Photo 12-7. Boll weevil oviposition puncture on bud.**

**Photo 12-8. Boll weevil pupa and larvae.**

Boll weevil management is extremely important due to the insect's rapid buildup, voracious appetite, and rapid dispersal across the field. There are a number of production practices that will help reduce and/or delay weevil establishment. The extent of the delay will depend on acceptance of practices on a community-wide basis. Boll weevil management practices include:

- ?? Plant rapid fruiting and early maturing varieties,
- ?? Delay planting until after May 20,
- ?? Apply an overwintering boll weevil insecticide application if cotton is planted before May 20,
- ?? Provide in-season control of insect pest (economically by damaging infestations),
- ?? Use growth regulators (Pix and Prep) to enhance crop maturity and harvest,
- ?? Apply a diapause insecticide to prevent boll weevils from entering overwintering sites, and
- ?? Rapidly destroy cotton stalks after harvest.

By effective use of the uniform delayed planting-date of cotton along with the semi-arid conditions of most Oklahoma summers, producers have been able to reduce insecticide use for boll weevil control. Adjusted planting dates let most of the overwintering boll weevils emerge and die before they can deposit eggs in cotton squares. Uniform delayed planting results in a shorter growing season with a compact fruiting period eliminating up to 1 generation of boll weevils.

In addition, uniform delayed planting-date limits the availability of one-third grown squares. Squares one-third grown (or one-fourth inch in diameter) must be produced to sustain larval development (Photo 12-9).

**Photo 12-9. Square development before flowering.**

With a uniform delayed planting-date of May 20, the first one-third grown squares will be produced after the fourth of July. Therefore, only a very small fraction of the total overwintered boll weevil population will survive to deposit eggs in squares to contribute to the next boll weevil generation.

Variety selection is crucial to the success or failure of a uniform delayed planting. A rapid fruiting, early maturing variety will ensure that the highest possible yields can be produced in a shorter growing season. Planting a later-maturing variety could negate the benefits of delayed planting by providing late-season boll weevils with a food source to store fat reserves.

Excessive rainfall and favorable growing conditions for plant growth could cause the plant to remain vegetative, delaying maturity. Use of Pix, a growth regulator, may prevent unnecessary plant growth thereby, reducing late-season weevil damage.

Overwintering boll weevil insecticide application exploits one of the two weak links in the boll weevil life cycle. Fields planted before May 20 are likely candidates for this application. This application is necessary during years of high weevil survival because early-planted cotton will initiate square production before July 1 helping weevils become established.

Fields sprayed between pinhead square and one-third grown square stage will prevent the adult weevils from depositing eggs in squares large enough to sustain larval development. Success of this treatment to hinder boll weevil establishment diminishes as the number of one-third grown squares increase.

Regular field scouting is important to the success or failure of these overwintering sprays. Mistimed pinhead square insecticide application could increase in-season insecticide applications which are costly to the overall management program. Boll weevil pheromone traps are available to help monitor influx of boll weevils. Trap catches are useful in helping decide whether applications are necessary. Control measures

are not necessary to prevent boll weevil establishment if traps average less than three weevils prior to one-third grown squares. However, overwintering sprays are needed if traps exceed that number of weevils per trap between square initiation and July 1st. Additional applications can be timed prior to first bloom if weevil emergence continues into July. Contact your county Agricultural Extension Agent for more information concerning pheromone traps and their application in a boll weevil management program. Many producers are hesitant to apply an insecticide prior to first bloom, unless a damaging insect infestation exists, to preserve beneficial insects. In most cases in early planted cotton (prior to May 20), quick action to control early-season pests will allow time for beneficial insects to repopulate before the cotton becomes attractive to mid- to late-season cotton pests.

Boll weevils tend to gradually move into squaring cotton from adjacent overwintering sites. Strip spraying 10 to 20 rows of cotton next to overwintering sites will effectively delay boll weevil establishment and preserve most of the beneficial insects present. However, timing is important since limited coverage could allow weevils to escape.

All insecticides recommended for use to control boll weevil adversely affect beneficial insects. Proper selection of the product and the rate can reduce the impact on non-target insects. Also, selecting an insecticide that is efficacious against both boll weevils and cotton fleahoppers will save money and reduce the chance of adverse effect occurring from an additional application.

Once boll weevils are established, chemical control is necessary (due to the lack of predators) to reduce the threat. Many insecticides are available, but satisfactory results are only obtained when applications are applied in a timely manner (3- to 5-day intervals depending on the infestation). Treat when 25 percent of the squares are punctured; repeat a 3- to 5-day intervals until the infestation drops below 15 percent infested squares. In traditional weevil areas, one should consider starting control early when fields average 15 percent infested squares to minimize the potential problem. If weevil populations are large in late-season, control should be continued until the majority of the harvestable bolls can no longer be sliced with a sharp knife.

Late-season foliage and fruit are important food sources for boll weevils. Availability of food increases the number of overwintering pests. The use

of growth regulators, crop conditioners, defoliant, and desiccants can reduce this source of late-season food decreasing boll weevil survival. Tank mixing an insecticide with a harvest aid chemical will reduce the number of boll weevils entering overwintering sites. Properly-timed diapause applications in October kill most of the boll weevils capable of overwintering. Boll weevils emerging after this diapause application will stand little chance of storing sufficient fat reserves to withstand the winter. Shred stalks and plow fields immediately after harvest to reduce overwinter sites.

## **Tobacco Budworm (*Heliothis virescens*)** **Cotton Bollworm (*Helicoverpa zea*)**

The tobacco budworm (Photo 12-10) and cotton bollworm (Photo 12-11) inflict similar damage to cotton, and infestations occur simultaneously throughout the growing season. In the field, cotton consultants and producers commonly refer to both insects as bollworms. In Oklahoma, they are generally regarded as the most important insects pest of cotton. Although commonly referred to as mid- and late-season pests, they can attack cotton from the seedling stage through maturity. During certain years, a small percentage of fields may require treatments in June, especially if cotton was planted in late April.

**Photo 12-10. Tobacco budworm adult.**

**Photo 12-11. Bollworm adult.**

Bollworms cause damage by feeding on squares and bolls. Larvae enter the fruit, feed on its contents, and cause the smaller fruit to shed (Photo 12-12). One bollworm can damage as many as 10 squares, 1 bloom, and 2 bolls before it pupates.

**Photo 12-12. Tobacco budworm or bollworm damage on boll.**

Infestations of bollworms may first appear in cotton at pinhead square. Generally, it is desirable to delay chemical applications, thereby preventing the disruption of beneficial insect populations. Bollworms normally increase as cotton begins to bloom and develop bolls. By mid-July through August, populations should be carefully monitored so that a control program can be initiated when populations reach economic thresholds. The tobacco budworm is generally more prominent in late August and early September and more difficult to control than bollworms.

Bollworm eggs (Photo 12-13) are about the size of a pinhead, dome shaped with minute ribs, and waxy white when laid. The eggs turn a light brown prior to hatching (Photo 12-14). Females generally prefer to lay eggs singly in the terminals or on the bracts of small squares. During hot weather, eggs are often deposited on the underside of leaves on the lower part of the plant and in the blooms. After hatching (3 to 5 days depending on temperature and humidity), first instar larvae begin feeding in the succulent terminals or on a large number of different crops and weeds. As they mature in cotton, they feed first on terminals, then on small squares, moving to larger squares, then finally to small bolls. Larvae can be traced down the plant

from the terminals to the bolls as they complete their life cycle. They undergo six molts during this period. When they reach the last larval instar, they leave the plant and tunnel into the soil to a depth of 1 to 10 inches. The larvae then transform into pupae and emerge as adults. It takes approximately 30 days to complete a life cycle; although in reality, overlapping generations are observed. Generally, three to four generations occur per year in Oklahoma. Moths may migrate into an area by upper-level air currents or emerge locally. Bollworms overwinter as pupae (Photo 12-15) in the soil.

**Photo 12-13. Tobacco budworm or bollworm eggs.**

**Photo 12-14. Tobacco budworm or bollworm egg at various stages of development.**

**Photo 12-15. Tobacco budworm or bollworm pupa.**

Full-grown larvae are approximately 1 5/8 inches long. They exhibit many color variations ranging from pale green to yellow to black to pink or to crimson. This color variation makes it difficult to identify by color alone. Bollworm larvae (Photo 12-16) can usually be separated from other larvae found on cotton by the small spines covering the body. The tobacco budworm larvae can be distinguished from the bollworm larvae by the tooth-like projection on the inside surface of the mandible. In the bollworm, this structure is lacking (Figure 12-4). Third instar and larger larvae are needed to make this distinction. Presence or absence of microspines at the base of first seta of abdominal segments 1, 2, and 8 is also a diagnostic character.

**Photo 12-16. Tobacco budworm or bollworm larvae.**

Bollworm	Tobacco Budworm
Mandible <b>without</b> retinaculum	Mandible <b>with</b> retinaculum
Base of first seta of abdominal segments 1, 2, and 8 <b>without</b> microspines	Base of first seta of abdominal segments 1, 2, and 8 <b>with</b> microspines

**Figure 12-4. Field characters to distinguish tobacco budworm from bollworm larvae.**

The adults are more easily separated in that both have a wingspan of approximately 1 1/2 inches, but the bollworm's front wings are light grayish brown marked with dark-gray, irregular lines with a dark area near the tip of the wing (Photo 12-11). The tobacco budworm's front wings are light-green crossed by four oblique light bands with the inner three edged in black (Photo 12-10).

More intense bollworm pressure is experienced annually in irrigated cotton than in dryland cotton. Insecticide resistance has been a problem with this pest since widespread use of DDT. After the arrival of pyrethroids in the mid-1970s, resistance problems subsided. However, in 1985, pyrethroid resistance in this pest surfaced across the Cotton Belt.

The primary mechanism of resistance to pyrethroids in tobacco budworms appears to be nerve (target site) insensitivity called "knock down" resistance. Knock down resistance is probably a recessive trait. Under a normal agri-ecosystem without chemical control, a high likelihood exists that a resistant moth would mate with a susceptible one; and the offspring would be susceptible. The susceptible individuals (in the absence of chemicals) readily out-compete the resistant larvae, keeping the gene frequency for resistance at a low level. However, under insecticide pressure, the resistant individuals readily survive compared to the susceptible ones increasing the gene frequency for resistance in the population.

Proper insect management, based on scouting and waiting to spray until the economic threshold has been reached, will help postpone or prevent resistance from developing. Resistance in the population fades rapidly as pyrethroid usage diminishes. Within a couple of generations, highly resistant infestations will approach normal levels. Pyrethroid resistance management strategies entail a number of steps to keep the resistant genes low throughout the summer. These steps include:

- ?? Avoid late planting or any practice (e.g., excessive irrigation or nitrogen fertilizer) which may delay maturity;
- ?? Apply insecticides only after the economic threshold has been reached;

- ?? Use classes of insecticides other than pyrethroids before July 10 and after September 5;
- ?? Apply insecticides only at label rates;
- ?? For in-season control, shorten the spray intervals and time of application to coincide with worms hatching;
- ?? If control difficulties occur after a pyrethroid application, switch insecticide classes (or use mixtures) instead of a higher rate of a pyrethroid (alone);
- ?? Use a tank mixture of various classes of insecticides instead of relying on a single class;
- ?? Limit worm spraying to the cool part of the day (not during midday);
- ?? Use crop oil to enhance coverage; and
- ?? Apply at least 2 gallons of water from the air or 10 gallons from the ground (if spraying during midday, always include either an emulsifiable crop oil or some type of spreader/sticker).

Economic thresholds are based on the plant growth stage related to the amount of damage that can be tolerated before control measures must be enacted to prevent economic loss. Treat when 10 small larvae and/or eggs are found per 100 plants during the first week of bloom (June 25-July 10) or 5 small larvae and eggs are found per 100 plants the remainder of the season (July 11-September 5). For late-season control (after September 5), treat fields if worms exceed 10 per 100 plants.

## Other Pests That Occasionally Attack Cotton

### Cotton Aphid (*Aphis gossypii*)

Cotton aphids (Photo 12-17) are small, soft-bodied insects commonly referred to as “plant lice”. Aphids occasionally occur on cotton in such high numbers that control measures should be implemented. Build ups are localized and usually occur after cool damp weather or during the season after the use of certain insecticides. The insects are found on the underside of leaves and along the terminal stem, causing misshapen leaves with a downward curl and stunted plants. The insect damages cotton (Photo 12-18) directly by sucking juices from the plant and indirectly by secreting honeydew. The honeydew is sticky and can lower the grade of lint. A sooty mold

can grow on the honeydew further damaging the lint. Consult Leaflet L-233 for more information concerning the cotton aphid.

**Photo 12-17. Cotton aphid adults.**

### Spider Mites (*Tetranychus* spp.)

Spider mites (Photo 12-19) can be distinguished from insects by their having eight legs rather than six. Spider mites often attack cotton when insecticides have destroyed the beneficial insects. Infestations are generally aided by hot, dry weather. In most cases, infestations will be localized in a field. Spider mites damage cotton by feeding on the plant juices. Foliage will turn a reddish or yellowish color under a heavy infestation (Photo 12-20). Mites are small in size and are generally found on the underside of the leaves. A close inspection is necessary to determine if mites are present.

**Photo 12-18. Cotton aphid damage on bud.**

**Photo 12-19. Twospotted spider mite adult.**

**Photo 12-20. Twospotted spider mite damage on leaves.**

### **Cabbage Looper (*Trichoplusia ni*)**

Cabbage loopers are larvae that are easy to distinguish by their habit of arching into a loop as they crawl. They have only two pairs of prolegs in the middle of their body instead of the four pairs found on most other caterpillars.

The cabbage looper (Photo 12-21) is normally found in cotton in light populations throughout the growing season. Generally, control is unnecessary. In late season, they may actually be beneficial in that defoliation will allow sunlight and air to more readily enter the plant canopy, drying out the soil, and reducing boll rot. In many instances, larvae are destroyed in mid-and late-season environments by a polyhedral virus.

**Photo 12-21. Cabbage looper larvae.**

### **Armyworms (*Spodoptera* spp.)**

Several armyworms attack cotton. The most common is the beet armyworm (Photo 12-22) that feeds on all parts of the plant. Beet armyworm can be recognized by the black spot on the side of the body above the second true leg. Small larvae often feed on the bracts of squares and small bolls causing them to shed. In addition, damage may be found to the foliage where larvae commonly skeletonize the leaf tissue. As larvae mature, they chew holes in leaves, squares, and small bolls. Weed control along ditch banks and fence rows during the growing season will help eliminate this problem. Photo 12-23 show a typical egg mass for the insect.

**Photo 12-22. Beet armyworm larvae.**

The fall and yellow striped armyworm (Photo 12-24) are close relatives of the beet armyworm. These insects apparently prefer cool and moist conditions, and population build ups often occur after that type of weather. Damage is similar to the beet armyworm.

**Photo 12-23. Beet armyworm egg mass.**

**Photo 12-24. Yellow striped armyworm larvae.**

### **Whiteflies (*Trialeurodes abutilonea*)**

Whiteflies (Photo 12-25) occasionally become pests in the late season. Adults appear superficially like white specks on the leaves and exhibit a jerky zigzag flight when disturbed. They damage the plant by sucking plant juices and excreting honeydew.

**Photo 12-25. Whitefly adults.**

## **Transgenic (Bt) Cotton - Management Tool for Lepidopterous Pests**

Cotton was first genetically engineered in 1987, and transgenic varieties resistant to herbicides and insects are now commercially available. Beginning in 1996, cotton producers had the opportunity to grow varieties with the Bollgard® gene (Bt cotton) technology ('NuCotn 33B' and 'NuCotn 35B') on their farms. Both varieties carry the delta-endotoxin gene from *Bacillus thuringiensis*. Impressive results have

occurred in research and demonstration trials where these transgenic varieties were compared to their recurrent parents ('DP 5415' and 'DP 5690', respectively). Transgenic varieties produced comparable yields without most of the insecticide applications normally applied to prevent lepidopterous damage. The relationship between dollar costs vs. Benefits of this technology remains foremost to the question of its adoption.

This advance in insect management has also brought changes in marketing of planting seed. Due to the very high cost of producing this technology, Monsanto Company and Delta & Pine L and Company devised a licensing procedure to prevent the unauthorized production of this patented product. To grow varieties with the Bollgard® gene, producers must:

- ?? Attend a Monsanto licensing meeting,
- ?? Sign a license to purchase and grow Bollgard® cotton,
- ?? Pay a premium for D&PL seed,
- ?? Pay a license fee for every acre planted to Bollgard® seed (rental fee for use of technology),
- ?? Plant a non-Bt cotton refuge to help manage potential resistance problems by maintaining some Bt susceptible lepidopterans (tobacco budworm, bollworm, and pink bollworm), and
- ?? Agree not to catch or save seed - must purchase certified seed annually.

Producers must weigh the advantages and disadvantages of this new technology before deciding whether to participate. The major advantage of growing Bollgard cotton is the ability to produce a comparable crop with fewer insecticide inputs. Reduced insecticide applications lessen the chance for secondary insect outbreaks. Disadvantages that may reduce the amount grown in Oklahoma include increased at-planting costs including the seed premium and license fee, having to plant non-Bt cotton in a refuge and to manage it differently than Bt cotton, and having to buy certified seed each year.

Some producers will try this new technology, regardless of the cost, just to be different. The increase in at-planting costs and limited variety selection all but eliminates its use in dryland production, since few such fields are annually sprayed enough times for worms to justify the extra expense. Producers should review their insect control records for the last 3 to 5 years to see if the license agreement

and fee are worth it to them. Cotton fields which average three to four insecticide applications each year to control bollworms are candidates for this technology. The Bollgard® gene is only effective against lepidopterans; other insecticides will be needed to curb cotton fleahopper, boll weevil, and cotton aphid infestations.

Scouting techniques and economic thresholds triggering insecticide applications against lepidopteran pests will differ to account for the technology's "mode of action." Larvae must ingest the Bt gene product before it become active. The midgut of the insect is the site where the Bt gene product is transformed into a toxin. Gut paralysis occurs in as little as 1 hour or less, accompanied by a loss of appetite. In most caterpillars, gut paralysis and feeding cessation result in starvation. Death occurs within a few hours up to 3 weeks with most larvae dying 1 to 7 days.

Scouting techniques employed in Bollgard® fields will concentrate on detecting 2nd to 3rd instar larvae instead of eggs and newly hatched worms. As long as the Bt toxin remain effective, very little damage and large bollworms will be observed. Scouting producers or consultants will see slight feeding. This evidence of some grazing indicates that bollworms are acquiring the Bt gene. Most of the damage will be concentrated in the terminal area of the plant or fruiting branches where young tender growth (grazing on small leaves, bracts, and calyx of squares) occurs. Such feeding is not an economic injury since most of these squares will remain on the plant and produce a boll if the flower bud is not damaged.

If there is any yield advantage to growing Bollgard® gene cotton, it is because the Bt gene is uniformly distributed throughout the plant and is expressed at all times (unlike foliar-applied insecticides which are expressed for a relatively short period leaving the plant susceptible to injury between applications). This constant protection by the Bt gene results in better season-long control of insect injury. When injured squares from bollworm exceed 20 percent, a yield advantage of 10 percent or more will be realized. Since bollworm square damage very seldom exceeds 20 percent in Oklahoma, a slight increase in yield (if any) can be expected. This main advantage of Bt cotton is in reduced spraying costs. With heavy infestations, some spraying will still be necessary. Bollworms and injury must be present before measurable yield differential is noticed.

## **Insects Beneficial to Cotton Insect Pest Management**

Native predaceous insects and spiders play an important role in regulating insect pest populations. In many instances, especially in dryland situations, beneficial insects and abiotic factors such as heat, cold, lack of moisture, etc., often suppress cotton insect pests below numbers that cause economic crop loss. The time of peak predator densities varies in Oklahoma depending on prey availability, growth stage of the cotton plant, predator distribution, etc.

Most predators are general feeders in cotton fields, not relying on a single insect species for food. If one prey species becomes scarce, predators simply switch to other species or even to plant nectar or juices to survive. In nature, many species of predators can coexist and bring stability to the system. Prey selections depend on abundance and availability. As any one prey increases causing unbalance within the field, predators switch to that new food source reducing the infestations and tending to bring the pest into equilibrium.

"Too little, too late" is an expression often heard in criticism of biological control for not controlling certain insect pest populations. This criticism deals with the time delay between the influx of the pest species and the reaction of predator populations to return the pest to equilibrium. The lag time for predators to react is influenced by population dynamics of the insect pest species and predators present, weather conditions, time of year, stage of growth, etc. In many instances, this lapse period allow pest populations to exceed the economic threshold and inflict damage before the predators again bring the pest into equilibrium (Figure 12-5).

Natural enemy preservation and augmentation are means of reducing the recovery time of predators thereby preventing serious damage. Research continues in areas of nutritional augmentation with natural or artificial foodstuff and use of behavioral chemicals to favor natural enemy activity. Cultural or other environmental manipulations to favor beneficial insects can be followed to improve control. Strip cropping and/or spot spraying can be practiced to conserve predators. In most cases, preservation of beneficial insects will take more effort than conventional cropping practices.

### Figure 12-5. Biological control lag period.

Periodic colonization of beneficial insects (lady beetles, green lacewings, praying mantis, and trichogramma wasps) is widely practiced due to advertised success. Many individuals swear by the results of these releases. However, little (if any) of the predators released remain in the field after dispersement. Many of the factors that influence the lag period also affect released predators—number of predators already present, pest insect density, etc. In addition, released insects require a period of time to become acclimated to the new surroundings.

Lack of control of cotton insect pests in Oklahoma is not only having enough species of predators to establish. It's a complex problem dealing with all aspects of the agri-ecosystem which affects population dynamics of all insects present, both pest and beneficial species. Lady beetles and collops beetles are two of the most commonly found predators in cotton. Field studies of these predators show that fields will be protected from bollworm damage if fields average 1 lady beetle and/or collops beetle per row foot. Maintaining those native predators at or near this level throughout the growing season is the key to success or failure of biological control for the bollworm.

Beneficial insects are of two general types, i.e., predators and parasites. Parasites (or parasitoids) are small wasps or flies that lay their eggs on pest

insects, and their larvae devour or kill the insect. Predators include insects, spiders, and mites that actively hunt and kill or disable their prey on contact. Predators include primarily beetles and true bugs.

Parasites are of little importance in regulating cotton insect pests in Oklahoma. Studies have consistently indicated that a low percentage of boll weevils are parasitized, but this has no appreciable effect on regulating infestations. This scenario holds true across the entire Cotton Belt.

More than 15 species of parasites from two families of wasps and one family of flies have been collected from bollworm larvae in Oklahoma. The two most common types of wasp are braconids and ichneumids, and the most common fly is the tachinid. Unfortunately in cotton, they are generally found in low numbers on bollworms.

Predators do not affect boll weevil populations, but they can have a significant impact on bollworms. Predators also have an impact on regulating cotton fleahoppers, beet armyworms, and cabbage loopers. Convergent lady beetles and collops beetles are the two most common predators in upland cotton.

**Lady Beetles** (*Coleomegilla* spp., *Hippodamia* spp. and *Coccinella* spp.)

Although several species of lady beetles are common in cotton fields, over 90 percent of those present are the convergent (or common) lady beetle. Most of the lady beetles present in cotton fields are adults. Larvae are generally not common unless aphids occur. The larvae are excellent predators of bollworm eggs and small larvae (1st and 2nd instar). They will also prey on cotton fleahoppers, preferring to feed on nymphs. The eggs of lady beetles are orange and laid in small masses of two to three dozen. The eggs are laid on end in tight clusters. (See Photo 12-26)

**Photo 12-26. Lady beetle eggs (upper left), larvae feeding on a fleahopper (upper right), and adult (lower photo).**

### **Collops Beetles (*Collops* spp.)**

Collops (or soft-flower) beetles (Photo 12-27) are extremely common in cotton fields. They are red and black in color. Adults are the most common life stage present in upland cotton. They are important

predators of bollworm eggs and 1st instar larvae. They also feed on cotton fleahopper nymphs and aphids.

### **Nabids (*Nabis* spp.)**

Nabids (Photo 12-28) are slender, tan or grayish true bugs. The front legs are slightly modified for holding their prey, usually small bollworm larvae. Both adults and nymphs are present in cotton fields, but in low numbers.

The eggs are laid in clusters, and each egg has a cap or opercula on it.

**Photo 12-27. Collops beetle adult.**

**Photo 12-28. Nabid adult.**

### **Green Lacewings (*Chrysoperla* spp.)**

The larvae of green lacewings (aphid-lions) are good predators of bollworm larvae and aphids. Aphid-lions are similar to lady beetle larvae in shape; however, aphid-lions are usually light brown in color and have a pair of curved jaws sticking out from the front of the head.

Green lacewings (Photo 12-29) lay individual, yellow, stalked eggs on leaves.

**Photo 12-30. Big-eyed bug.  
Minute**

**Photo 12-31.  
pirate bug adult.**

**Photo 12-29. Green lacewing eggs (upper photo),  
larvae (lower left), and adult (lower right).**

### **Big-Eyed Bugs (*Geocoris* spp.)**

Big-eyed bugs (Photo 12-30) are commonly found in cotton fields in low numbers. Eggs, nymphs, and adults are found on cotton plants. The adults and nymphs (without wings) have the same appearance with black bodies and large bulging eyes. They prey on bollworm eggs and small larvae as well as cotton fleahopper nymphs.

### **Bugs (*Orius* spp.)**

These are tiny bugs more-or-less black with translucent wings (Photo 12-31). They are common in cotton fields in low numbers and are not considered important in most years. They feed on bollworm eggs and cotton fleahopper nymphs. Nymphs are easily recognized by their orange color.

**Spiders (*Lycosa* spp., *Xysticus* spp., and  
*Hentzia* spp.)**

Numerous species of spiders (Photo 12-32) occur naturally in cotton fields. Some of the most common are the green crab spider, several wolf spiders, and jumping spiders. They appear in cotton shortly after emergence, and they remain all season. They are general feeders preying on all life stages of most insects. Spiders at times may be detrimental to the beneficial populations, depending upon where they occur. They require very little food and feed infrequently, preventing them from regulating pest populations consistently.

**Photo 12-32. Spider adult feed on a larvae.**