Chapter 2

BIOLOGY AND ECOLOGY OF IMPORTANT INSECT AND MITE PESTS OF COTTON

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INTRODUCTION

More than 100 species of insects and spider mites are pests of cotton in the United States. Fortunately less than two dozen species are common on a yearly basis and will cause major crop losses to extensive acreage if not controlled. The remaining species can cause severe economic loss, but usually only in limited geographic areas during occasional years or when a particular beneficial arthropod complex has been disrupted.

This chapter provides a brief description of the developmental stages of major pests, enabling their identification, and provides general information on development of the life stages of particular species or for species groups. Damage symptoms, geographic distribution, hosts, pest phenology and ecological conditions that favor or limit pest outbreaks also are discussed. For a complete list of the pest species attacking cotton in the United States see Anonymous (1984a). More detailed information on the major and minor pests not mentioned is usually available through the cooperative extension services and the state universities in the cotton producing states.

SQUARE AND BOLL FEEDING INSECTS

BOLL WEEVIL

Boll weevil, *Anthonomus grandis grandis* Boheman

Identification and Development of the Stages—Three forms of *Anthonomus grandis grandis*—the Mexican boll weevil, the thurberia weevil and the southeastern boll weevil—occur in the United States with only the southeastern boll weevil being found in all cotton growing areas except the California San Joaquin Valley. Anatomically, they are very similar and can intermate, but genetic differences exist between these strains (Bartlett *et al.*, 1983) and their identity can be differentiated. The adult boll weevil (Plate 2-1[1]) is a snout weevil that is somewhat variable in size and color, ranging from 1/8 to 1/3 inch (3.2-8 mm) long, and from reddish brown to dark gray. Overall weevil size is due largely to the nutritional condition of the host squares or bolls. Color changes from reddish to dark brown or gray with aging. Weevils with black integument may occur, but this color strain is not common under field conditions (Bartlett, 1967; McGovern *et al.*, 1974).

The immature stages of the boll weevil are always found within cotton squares and bolls which they hollow out as they feed. Eggs, which may be found by dissecting squares in which boll weevils have recently oviposited (laid eggs), are slightly elliptical in shape, opaque and about 1/25th inch (1 mm) long. Shortly before hatching, the brown head capsule of the larva may be seen through the egg wall. Total developmental time of the boll weevil from egg to adult ranges from 11 to 67 days, depending on temperature. At a typical summertime temperature of 86F (30C), development takes between 14 and 22 days (Hunter and Pierce, 1912; Isely, 1932; Fye *et al.*, 1969; Bacheler *et al.*, 1975; Cole and Adkisson, 1981). The larvae are white, legless grubs, while the pupae are similar to the adult since the external features of snout, legs and wings are visible through the pupal cuticula (Hunter and Hinds, 1905; Parrott *et al.*, 1970; Roach, 1973).

Host Plants—In the United States, the southeastern boll weevil is primarily restricted to cotton for feeding and oviposition (egg laying), while the thurberia weevil is primarily restricted to a wild cotton, *Gossypium thurberi* Tod., in parts of Arizona (Cross *et al.*, 1975; Burke *et al.*, 1986). Also, in Arizona the boll weevil may feed and survive on globe mallow, *Sphaeralcea* spp., but cannot reproduce (Palumbo, 1985). The boll weevil originated in Meso-America (i.e. Central America and Southern Mexico) therefore, many native host plants have been reported from Central and South America but most do not occur in the United States (Burke *et al.*, 1986). The number of seasonal generations ranges from two to eight, depending on length of the growing season (Fenton and Dunnam, 1929; Hopkins *et al.*, 1969; Sterling and Adkisson, 1971); however, the generations overlap and the average is closer to three per year in most areas.

Damage Symptoms—When boll weevils enter cotton, either from overwintering sites or through migration, the number necessary to cause economic damage depends on factors such as physiological condition of the cotton plant, phenological stage of plant development and weather patterns. Fecundity (egg laying ability) is higher in first brood females than in later females primarily due to plant maturity and the

[1]All color plates can be found in the Appendix of this chapter.

decreasing number of squares available for oviposition by the later broods (Fenton and Dunnam, 1929; Fye and Bonham, 1970). Rates of population increase per generation have been estimated by several researchers, and range from 1- to 9.6-fold, depending on environmental conditions (Knipling, 1960; Walker and Hanna, 1963; Lloyd *et al.*, 1964). Numbers of adults necessary to cause economic losses are quite low. Lloyd and Merkl (1966) found that overwintered weevil populations of 14, 25, 50 and 100 weevils per acre damaged 0, 28, 46, 66 and 83 percent of the available squares, respectively, while second-generation weevils damaged from 84 to 96 percent of the squares. In another study, Roach *et al.* (1971) indicated that more than 50 percent of all squares were punctured when the F_1 population exceeded 1000 per acre and 80 percent were punctured when the population exceeded 2000 per acre. Boll weevils both feed on and oviposit in cotton fruit, therefore their damage is easily discerned. Both sexes chew small holes into the fruit and yellowish frass (solid insect excrement) is usually present around the feeding area. The female oviposits (lays eggs) within the holes, then seals them with frass solidified with fluid from her excretory tract (Plate 2-2) (Cushman, 1911). Most squares with oviposition punctures will flare open and abscise from the plant within eight days, whereas older bolls may remain on the plant and result in damaged locks where the eggs were oviposited and the larvae developed.

Phenology[2] and Population Dynamics—Boll weevils overwinter as diapausing adults in woods litter and similar cover adjacent to the previous season's cotton fields (Brazzel and Newsom, 1959; Hinds and Yothers, 1909; Hunter and Hinds, 1905). Diapause in boll weevils is an induced dormancy. Diapause is the result of a complex interaction of photoperiod, temperature, physiological condition of the cotton plant, low night temperatures in the adult stage and boll feeding in the larval stage (Lloyd *et al.*, 1967; Earle and Newsom, 1964; Carter and Phillips, 1973; Cobb and Bass, 1968). Mortality of diapausing boll weevils during the winter is generally high, particularly in the more northern cotton growing regions, and is primarily dependent on the condition of weevils and the severity of winter weather conditions (Bondy and Rainwater, 1942; Fenton and Dunnam, 1929; Rummel and Carroll, 1983; Sterling, 1971; Taft *et al.*, 1973).

Spring emergence of boll weevils from overwintering quarters appears to be dependent on an accumulation of hours above a temperature threshold of 52F (10.85C), and possibly the time they entered overwintering quarters in the fall (Jones and Sterling, 1979; Rummel and Carroll, 1983; Mitchell *et al.*, 1973). In most areas of the Cotton Belt, spring emergence occurs from April through June, although diapausing weevils have been found in woods trash in all months of the year except July and August (Beckham, 1963).

The life span of emerging overwintered weevils is dependent on the availability of cotton for food in the spring. Fenton and Dunnam (1929) indicated the average longevity of weevils emerging prior to cotton emergence was 5.65 days (range 1 to

[2]Phenology is a branch of science that deals with the relationship of climate and periodic biological phenomena or behavior of insects.

52), and 8.13 days (range 1 to 40) on cotton prior to fruiting. On fruiting cotton, longevity was 19.39 (range 2 to 69) for males and 16.05 days (range 2 to 48) for females. This contrasts with the 70- to 80-day average indicated by Hunter and Hinds (1905), but agrees with data given by Fye *et al.* (1959). Mating occurs prior to entering diapause and females deposit fertile eggs in the spring without remating (Fenton and Dunnam, 1929; Walker and Pickens, 1962). However, overall reproductive potential of females increases significantly with spring remating (Taft *et al.*, 1963; Roach, 1979). The oviposition behavior of the boll weevil has been investigated by several workers and, in general, the females prefer half-grown cotton squares, but will lay multiple eggs in most sizes of squares and bolls when field populations are high (Hunter and Hinds, 1905; Cushman, 1911; Jenkins *et al.*, 1975; Lloyd *et al.*, 1961).

Mortality of developing immature weevils in squares can be quite high due to predation, parasitism and high temperatures, but more than 50 percent will usually emerge as adults (Fenton and Dunnam, 1929; Smith, 1936; Bacheler *et al.*, 1975; Chesnut and Cross, 1971). These newly emerged weevils will mate and begin ovipositing after five to eight days, unless they are subjected to cool temperatures or diapause-inducing conditions (Fenton and Dunnam, 1929; Roach, 1979; Cole and Adkisson, 1981).

Interfield movement and long range migration can occur in any summer brood of weevils (Isely, 1926; Roach *et al.*, 1971; Roach and Ray, 1972). Most mass movements of weevils apparently occur when fields become heavily infested and few oviposition sites remain (Fenton and Dunnam, 1929; Fye and Bonham, 1970). The direction of movement seems to be random and possibly wind-aided. Migrating individuals are known to move up to 45 miles (Davich *et al.*, 1970; Beckham and Morgan, 1960).

After feeding on cotton, male boll weevils produce a chemical pheromone that attracts both male and female weevils to the food source (Bradley *et al.*, 1968; Hardee *et al.*, 1969). Thus, it serves as both an aggregation and sex pheromone in this species, and is extremely important in the ability of migrating weevils to find and infest cotton fields.

BOLLWORMS AND TOBACCO BUDWORMS

Bollworm, *Helicoverpa zea* (Boddie)
Tobacco budworm, *Heliothis virescens* (Fabricius)

Identification and Development of the Stages—Eggs are laid singly, generally on new terminal growth. Newly-laid eggs are pearly-white, becoming darker with age. Prior to hatching, a brownish ring characterizes the upper portion of the egg (Plate 2-3). There are consistent differences between the eggs of the two species that can be seen with a stereoscopic microscope (Neunzig, 1964; Werner *et al.*, 1979). Tobacco budworm eggs have fewer ridges from bottom to top and the ridges terminate before they reach the tiny micropyle (minute opening in insect egg through which sperm enter) at the middle of the top. At least part of the ridges reach the micropyle on eggs of the bollworm. There are usually 10-12 of these ridges on tobacco budworm eggs and 12-15 on eggs of the bollworm.

Young caterpillars (larvae) are yellowish or reddish, with large black bumps (tubercles) on the body (Plate 2-4). Mature stages reach a length of 1-1 1/2 inch (26-38 mm) and vary in color from pale green to dark brown, often with a pattern of paler markings on the back and sometimes with a pronounced dark band on the sides. The dark bumps of the first instar are less conspicuous on later stages and the integument of the body contains many tiny spines, which are visible with a hand lens, especially on dark parts of the skin.

Third-instar or later caterpillars of the two species can be distinguished from each other with a hand lens. At this stage they are 3/8 inch (9 mm) long or greater. Tobacco budworm caterpillars have tiny spines, like those on the skin, extending onto the slightly enlarged dorsal bumps on the first, second, and eighth segments behind the true legs. Bollworm caterpillars lack spines on these bumps. Another positive character is the presence of a tooth-like structure on the inner face of the mandible of the tobacco budworm that is absent from the bollworm.

Adult moths, which may be found resting on leaves in the field, are very different in the two species. Tobacco budworm moths have three oblique dark bands on the front wings and are usually olive-green (Plate 2-5). Bollworm moths (Plate 2-6) are almost uniformly pale buff, with some small dark flecks on the front wings with a slightly paler crescent in the middle of the wing (Werner *et al.*, 1979)

Damage Symptoms—Damage to cotton by larvae of the bollworm and tobacco budworm cannot be distinguished. Upon hatching, the young larvae tunnel through young terminal leaf buds and tiny squares. The young squares turn brown and may be mistaken for plant bug injury. Larvae then move to larger squares, cutting a hole in the side of the square and feeding on the floral structures. Such squares will turn yellow, flare and drop from the plant (Brazzel *et al.*, 1953).

Larger larvae demonstrate a preference for squares, but will feed on bolls of all sizes, making an irregular-shaped entrance hole. In many instances the entire contents of the boll are consumed. Usually, a semi-solid, moist frass accumulates outside the entrance hole. Where fruit is in short supply with high population densities, larvae can be found feeding on older cotton leaves.

Distribution—The tobacco budworm is found throughout most of the Western Hemisphere. The species is apparently most abundant in the tropics and extends through the West Indies and South America as far south as Argentina (Neunzig, 1969). Neunzig (1969) reports that the range of the corn earworm (same as bollworm) is sympatric (occupying same geographic range) with that of the tobacco budworm.

The bollworms can cause damage to cotton in any area of the Cotton Belt. However, the tobacco budworm is not a pest of cotton in the San Joaquin Valley and only as late as 1972 became a serious pest of cotton in the lower desert areas of the Southwest (Watson, 1974).

Alternate Hosts and Outbreak Contributions—Bollworms/tobacco budworms are general feeders, having a wide variety of cultivated and wild host plants (Snow and

Brazzel, 1965). Tietz (1972) listed 31 host plants for the tobacco budworm and 106 hosts for the bollworm. Corn appears to be the preferred host of the bollworm and tobacco and cotton are major hosts of tobacco budworm (Lincoln, 1972).

The host ranges for both species dictate the relative importance of host-plant complexes in the widely-separated geographic regions and diverse agroecosystems. Barber (1937) and Neunzig (1963) cite hosts of bollworm/tobacco budworm in the Southeast, while Roach (1975) stated that bollworm/tobacco budworm populations in South Carolina, especially those in early spring and fall, depend on only a few major plant species. Harding (1976) indicates that in the Lower Rio Grande Valley both species build up to damaging numbers on cultivated hosts and use wild hosts to maintain the species when cultivated plants are not available.

Seasonal activity of bollworm/tobacco budworms extends over a longer period than does the growing season of any single species of host plant. A survey conducted by Rathman and Watson (1985) indicated that abundance of bollworm/tobacco budworms on desert annuals in the Southwest is difficult to measure since hosts are widely scattered and attractive to ovipositing moths for relatively short periods of time. Populations on wild hosts also appear to be extremely variable from year to year. Ornamentals and cultivated crops are more predictable food sources than desert annuals, whose abundance is dependent upon adequate winter rainfall. Nevertheless, several wild desert plants appear to be important early-season hosts and obviously help bridge the gap until cotton and other summer hosts are available.

Phenology and Population Dynamics—Many researchers have conducted life history studies on both the bollworm and tobacco budworm. In general, developmental time is quite similar. During summer conditions, the egg hatches in three to four days. Both species pass through five or six larval instars in as little as 12 days, and drop to the soil where the pupal stage lasts 9 to 10 days in a cell one to two inches (2.5-5 cm) below the soil surface. A complete life cycle may take as little as 25 days in midsummer and there may be six to eight generations in a season (Werner *et al.*, 1979).

Tollefson and Watson (1981) determined developmental times and damage to cotton during June, July and August near Phoenix, Arizona. In June, larvae that feed primarily on squares have significantly longer developmental times than July and August larvae that feed mostly on bolls. The average duration of prepupal and pupal stages in the soil is similar for all infestation periods. Constant temperature studies showed that greatest fecundity occurred at 77F (25C) and that longevity of both sexes declined as temperatures were increased. A moth usually expends most of its reproductive capacity within the first 7-10 days of its life.

Survival in much of the Cotton Belt is dependent upon individuals entering diapause in the fall. In Arizona, Potter and Watson (1980) found the tobacco budworm to exhibit a weak diapause that occurred during the last two weeks of October. Development can be continuous in Arizona, southern California, and some southern areas of cotton production in Texas, Louisiana (Brazzel *et al.*, 1953; Graham *et al.*, 1972) and Florida. Early-season legumes, e.g., crimson clover in the South (Roach, 1975) and alfalfa in the West (Rathman and Watson, 1985), are believed to be important hosts which support the first generation each year.

The ecological conditions favoring population increase of these pests are complex, therefore it is difficult to predict the exact circumstances that create an outbreak. Number of host plants and host sequence, as well as temperature and humidity, are important in permitting the full biotic potential of any bollworm/tobacco budworm population. However, these insects are vulnerable to effective biological control by parasites and predators and many bollworm and tobacco budworm outbreaks are insecticide-induced. Therefore, careful management of the total pest complex in cotton is of utmost importance to prevent destruction of the natural enemies at a critical time in the bollworm/tobacco budworm:cotton developmental cycles.

PINK BOLLWORM

Pink bollworm, *Pectinophora gossypiella* (Saunders)

Identification and Development of the Stages—The pink bollworm (PBW) is a small mottled, grayish-brown moth (Plate 2-7) belonging to the family Gelechiidae. It is slender and about 3/8 inch (9.5 mm) in length. The forewings are dark brown with irregular black areas; the hind wings are silvery-gray. The oval, white eggs, laid in "clusters," are about 1/25 inch (0.5 mm) by 1/50 inch (0.3 mm) in size. The first three larval instars are creamy white with dark brown heads and thoracic shields. At times the third larval instar will show transverse pinkish lines, changing into dark-pink bands in the fourth instar (Plate 2-8). Pupae are about 2/5 inch (8 mm) in length by 3/32 inch (2.5 mm) wide and exhibit a typical mahogany brown color (Werner *et al.*, 1979).

Damage Symptoms—Prior to the availability of bolls, pink bollworm infestations can be detected by the presence of "rosetted blooms," blossoms on which the petals are webbed together. Later, the first-instar larva may indicate its presence in bolls by conspicuous mines along the inner carpel wall, a result of not burrowing directly into the inner part of the boll. Other visible signs of damage include the small, round holes through which the larvae exit the bolls, and discolored lint and seed, where larvae have fed. Rotted bolls may also indicate the presence of the pink bollworms. The exit hole allows the entrance of boll rotting fungi (Watson, 1977).

Geographical Distribution—The pink bollworm was first reported from India in 1842. From there it has spread to all major cotton-producing countries of the world. Pink bollworm was first found in the United States near Hearne, Texas, in 1917. From there it spread both eastward and westward. Eastward spread of the pink bollworm apparently is limited by greater rainfall. It first was found in eastern Arizona in 1926. An eradication effort in the Salt River Valley of Arizona in the late 1950s virtually eliminated the pink bollworm from central Arizona where it had become established. However, in the early 1960s it again became established in Central Arizona, a "coincidence" with the growing of stub cotton and increased cotton production in Mexico to the South. By late 1965, it had completed its spread across Arizona and into the

Imperial Valley of California (Noble, 1969). The pink bollworm is not widely established east of Texas and Oklahoma or in the San Joaquin Valley of California. Adults are apparently carried into the San Joaquin Valley by winds from southern California. Small numbers of larvae are occasionally found in that Valley (Anonymous, 1984b).

Alternate Hosts and Outbreak Contributions—Although plants of worldwide distribution representing 7 families, 24 genera and 70 species have been recorded as alternate hosts, cotton is the preferred host of the pink bollworm. Most of the hosts belong to the Malvaceae family, of which, the genus *Hibiscus* ranks high in the insect's preference. The six cultivated plants which serve as alternate hosts are okra, *Hibiscus esculentus* L.; kenaf, *Hibiscus cannabinus* L.; roselle, *Hibiscus sabdariffa* L.; muskmallow, *Hibiscus abelmoschus* L.; castorbean, *Ricinus communis* L.; and jute, *Corchorus olitorius* L. (Noble 1969). None of these is considered to be important to the population dynamics of this pest in the arid Southwest. The severity of infestations is almost entirely associated with the way the cotton production system is managed. A long-growing season and short host-free period is conducive to pink bollworm outbreaks (Watson *et al.*, 1978).

Phenology and Population Dynamics—A generalized life cycle of the pink bollworm for a temperature of 86F (30C) is as follows: egg, 4-5 days; larval stage, 15-20 days; pupal stage, 7-9 days; and, the preoviposition period, 2 days. The total life cycle is 28-36 days. In arid, semi-tropical areas such as Arizona where the cotton-growing season may last 9-10 months, there may be six to eight generations per year (Slosser and Watson, 1972a). In more temperate regions having shorter growing seasons, four to six generations are more likely.

Short-cycle generations will continue until daylength falls to 13 hours, after which increasingly higher proportions of the population enter diapause. The long-cycle or diapausing larvae overwinter in cotton seed, lint, surface trash or in free cocoons in the soil (Watson *et al.*, 1976).

Temperature, moisture and photoperiod are important factors affecting the pink bollworm. Termination of diapause primarily is a function of temperature and moisture. Temperatures in excess of 59F (15C) are necessary for initiating pupation of overwintering larvae. Contact moisture or high relative humidity enhances survival and pupation, especially at higher temperatures. A temperature of about 72F (22C) and contact moisture appear to be most optimum for survival and the highest rate of pupation (Watson *et al.*, 1973). During the growing season moth activity is adversely affected by unusually high temperatures, and longevity and oviposition are reduced when temperatures exceed 95F to 104F (35 to 40C). Winter mortality of diapausing larvae generally is high and areas with cold, wet conditions are most detrimental to diapausing larvae (Slosser and Watson, 1972b).

Several species of parasitic and predaceous insects and predaceous mites have been reported to attack the pink bollworm. Spiders have also been observed feeding on adults. None of these, however, have been shown to effectively reduce field populations.

PLANT BUGS

Wesern lygus bug, *Lygus hesperus* Knight
Tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois)
Clouded plant bug, *Neurocolpus nubilis* (Say)
Cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter)

In addition to these four species, the pale legume bug, *Lygus elisus* (Van Duzee), *Lygus desertinus* Knight, ragweed plant bug, *Chlamydatus associatus* (Uhler), rapid plant bug, *Adelphocoris rapidus* (Say) and several other Miridae are reported as occasional pests.

Species Attacking Cotton and Distribution—The tarnished plant bug is common throughout the eastern and southwestern cotton growing areas. *Lygus desertinus* (no common name) is a pest of cotton in Arizona. A western lygus bug, *Lygus hesperus*, is the most common species throughout California and Arizona. The pale legume bug also invades cotton fields in the San Joaquin Valley; however, infestations do not normally persist. The cotton fleahopper occurs throughout much of the cotton producing areas of the United States. Each species appears to occupy a particular climate and host range. There is little evidence that expansion of their geographic ranges may occur.

Identification and Development of the Stages—Adult lygus bugs are 5/32 to 3/16 inch (4.5 to 5.5 mm) long, pale green, straw yellow or reddish brown in color and with a conspicuous triangle in the center of the back (Plate 2-9). This triangle is yellow or pale green on the western lygus bugs and yellow-brown on the tarnished plant bug. Lygus species have long slender and usually reddish-brown antennae. The first and second instar nymphs are pale green and may be mistaken for aphids, but differ in moving about more rapidly and having reddish tips on their antennae. Older nymphs have five characteristic black spots on their backs (Plate 2-10)—two spots on the first segment of the thorax just behind the head, two more on the next segment, and one spot in the center of the abdomen. Older nymphs of the western lygus bug and the tarnished plant bug may be pale to medium brown in color (Anonymous, 1984b; Kelton, 1975).

Cotton fleahoppers (Plate 2-11) are uniformly pale green in color with tiny black specks all over the body (Anonymous, 1984b). They are about one half the size of lygus bugs. They do not have the reddish antennae typical of lygus bugs and the nymphs do not have the pattern of dots found on lygus bugs. Other species of fleahoppers sometimes found in cotton fields have black markings on their bodies and are similar to the cotton fleahopper in size and shape.

The clouded plant bug appears somewhat larger than lygus bugs, at 9/32 inch (6.5-7 mm) long and 3/32 inch (2.5-2.6 mm) wide. Adults are yellowish tan to brown and the legs are tan with brownish markings. The body, legs and antennae have many black and pale hairs.

All species of mirids insert their eggs into the plant tissue. The elliptical egg cap is usually flush with the plant surface and is visible under magnification. Eggs may be deposited in leaf petioles, stems or fruiting structures of the plants.

Egg development of plant bugs requires about 5 to 7 days during the hot summer period but longer during cooler weather. Development of the immature stages is most rapid in hot weather, requiring as little as 9 days for cotton fleahoppers and 11 days for other species. Average total developmental time is about 11 to 14 days in summer and 21 or more days during cooler periods. Adult bugs have a preoviposition period of 4 to 7 days before egg deposition begins. Numbers of eggs produced are highly variable and influenced by hosts. Individual plant bugs may produce between 30 and 70 eggs (Little and Martin, 1942; Leigh, 1963).

Damage Symptoms—Plant bugs feed on developing squares, growing points and young bolls, particularly in the terminal portions of the plants (Strong, 1968; Wilson *et al.*, 1984; Leigh *et al.*, 1988). Smaller developing squares fed upon by plant bugs will abscise and dry (Plate 2-12), and are commonly seen in sampling for pests with the sweepnet or drop cloth. Bracts of larger squares may flare and will be shed from the plant. Squares that remain on the plant may have darkened anther filaments where the anther sacs have been destroyed. The petals and stigmatic areas of the blooms may be distorted. Bolls on which plant bugs have fed develop darkened areas where bugs have defecated. Internally, the boll wall will develop callous tissue to which the lint may cling when the bolls open. Developing seeds on which plant bugs have fed will be shriveled, lint will not develop normally and may rot in damaged locks.

Where plant damage by *Lygus* spp. and other plant bugs is limited to square loss, plants may grow tall and whip like with few or no bolls (commonly referred to in the past as "crazy" cotton). This condition is most common where some of the earliest squares are lost, stimulating the plant to greater vegetative growth followed by continued loss of squares to further lygus bug feeding. In response to destruction of growing points, squares and fruit, cotton plants will develop many new growing points at mainstem and branch nodes, take on a many branched appearance and produce additional squares. Mainstem apex destruction usually results in a candelabra appearing plant. Nodes of plants infested with plant bugs become swollen or enlarged and internodes may be shortened. Where plant bugs have been controlled, bolls may be set at later developed fruiting positions higher on the plant, providing a dispersed appearing boll set with many blank fruiting positions (Haney *et al.*, 1977).

Alternate Hosts and Outbreak Contributions—Most plant bug species that attack cotton have a wide range of native and crop hosts in a number of plant genera. The lygus bugs are major pests of alfalfa, carrot, beet, bean, crucifers and other crops, particularly when grown for seed. They may be found on many plant species in native situations (Young, 1986; Fleisher *et al.*, 1987; Fye, 1980; Womack and Schuster, 1987) and on weeds in cultivated crops. A host list for the western lygus bug, *Lygus hesperus* has been developed by Scott (1977) while Anderson and Schuster (1983) and Fleischer and Gaylor (1987) provide host lists of the tarnished plant bug in the Southwest and Southeast cotton production regions. Fleischer and Gaylor (1987) provide indications of seasonal abundance of the tarnished plant bug on the native plant hosts (Figure 1) in relation to outbreaks on cotton. Host plants appear to be particularly

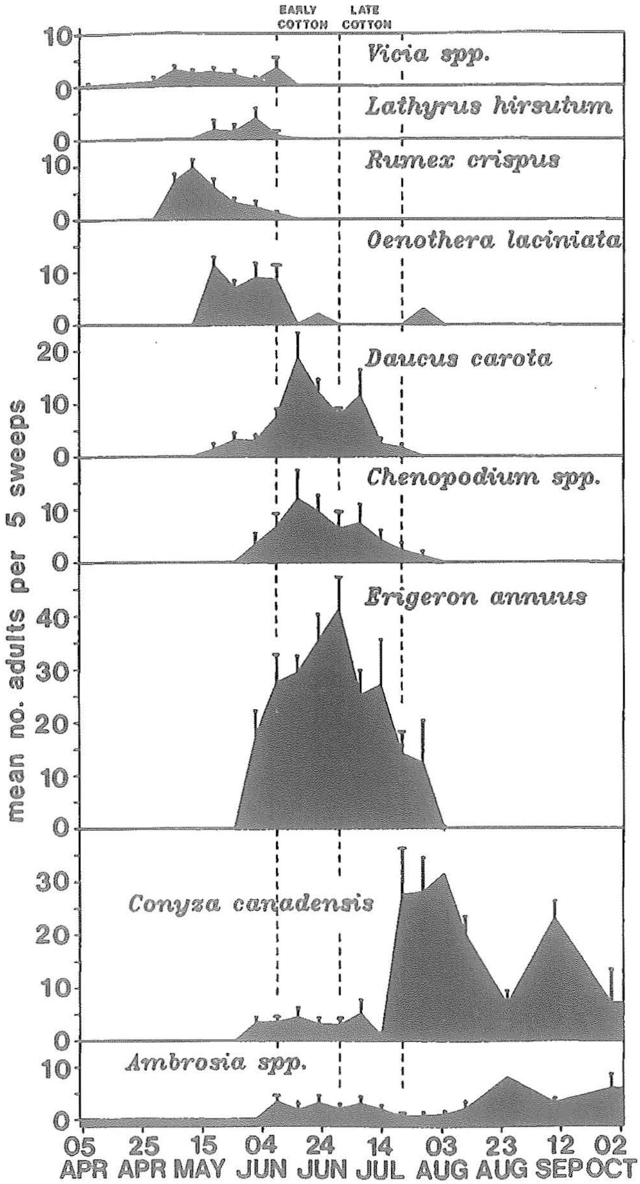

Figure 1. Seasonal abundance of adult tarnished plant bugs, *Lygus lineolaris* (Palisot de Beauvois) on hosts in the Coastal Plain Region of Alabama, providing an indication of host contribution to outbreaks of this pest on nearby cotton. (Source: Fleischer and Gaylor, 1987.)

attractive when in the flowering stage and plants in the Compositae may be preferred. *Erigeron annuus* Pers. (annual fleabane) is a common host of tarnished plant bugs, from which they may move to cotton. In the West, alfalfa (Stern *et al.*, 1967), safflower (Mueller and Stern, 1974) and weeds (redroot pigweed, *Amaranthus retroflexus* L., lambsquarter, *Chenopodium album* L. and several species of cruciferae) (Fye, 1980) in uncultivated areas and within several other crops (Leigh, unpublished data) are the principal sources of the western lygus bug. The cotton fleahopper has more than 40 reported crop, weed and native hosts, however, *Croton capitatus* Michx. (woolly croton) is the most important host of this pest (Reinhard, 1928). The clouded plant bug has more than 50 crop and wild plant hosts. Crop hosts include cotton, soybean and alfalfa. The most important wild native hosts appear to be button bush and black willow (Lipsey, 1970).

Plant bugs may migrate to cotton from their crop, native, and weed hosts at any time; however, major migrations usually occur when the spring and summer hosts mature, are harvested (Stern *et al.*, 1964, 1967), or are destroyed (Fleischer and Gaylor, 1987). For example, massive numbers of *Lygus hesperus* may appear in adjacent cotton when nearby alfalfa is harvested, as illustrated in Figure 2. Stern *et al.*

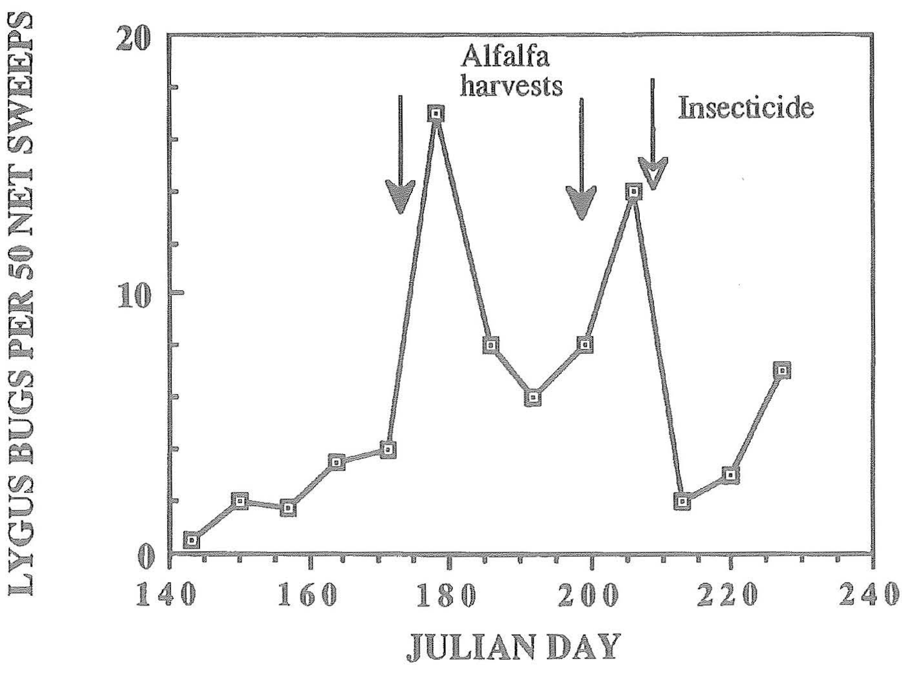

Figure 2. Western lygus bug, *Lygus hesperus* Knight, infestation level in cotton adjacent to an alfalfa field, indicating the contribution of the alfalfa crop (in relation to cutting) to infestations in cotton. (Developed from data of Stern *et al.*, 1964.)

(1967) recommend management strategies for harvest of alfalfa to attract lygus bugs from cotton and to reduce the threat of their movement from alfalfa to cotton. Fleischer and Gaylor (1987) provide suggestions for management of native and weed hosts to reduce the threat of these pests to nearby crops.

Phenology and Population Dynamics—The western lygus bugs overwinter as adults in a sexual diapause or arrested reproductive stage in suitable crop host areas (Leigh, 1966). Diapause is induced by reduced day length but is also ended in California when days become less than nine hours long (Beards and Strong, 1966). Adults become reproductive in December and on warm days will deposit eggs in available hosts from January through March. An average of 200 eggs may be deposited by an individual female over a 30-day period (Leigh, 1963). Five to seven continuous generations will develop on perennial crops such as alfalfa. One or two generations will develop on winter and spring annual hosts before movement to cotton. Three generations commonly occur on cotton. Except where large numbers of this pest migrate from crop or natural hosts, there is usually a gradual increase in bug numbers on cotton as the season progresses, without discrete generations being observed.

Tarnished plant bug phenology is very similar to that of the western species, with overwintering adults moving from groundcover to blooming plants in the spring (Crosby and Leonard, 1914). Initial infestations commonly relate to maturation of nearby weed hosts or their destruction by cultivation. In the southeastern United States, there may be at least three generations of tarnished plant bug on cotton.

The cotton fleahopper overwinters as diapausing eggs on *Croton* spp. plants (woolly croton, Texas croton, tropic croton, etc.), and hatching occurs in March and April (Sterling and Hartstack, 1979). There may be five to nine generations per year (Hartstack and Sterling, 1986) with successive generations developing on available hosts (Almand *et al.*, 1976).

As indicated in the preceding section, the magnitude of plant bug outbreaks is usually related to abundance of crop, native and weed hosts in the proximity of cotton fields. Mild winter weather, timely rainfall and cropping conditions that favor development of these alternate hosts may result in the development of high population numbers that migrate to cotton. Conditions that interfere with effective weed control in crops and timely rainfall may also result in populations of plant bugs that will move to cotton as the crops and weeds mature or are harvested. In contrast, severe winter weather, drouth and conditions that limit host growth and abundance will reduce the probability of outbreaks (Anonymous, 1984b; Fleischer and Gaylor, 1987; Fleischer *et al.*, 1988).

The magnitude of outbreaks on native or cultivated crop hosts is limited by a complex of predators and parasites provided they are not destroyed by insecticides. The most significant natural enemies are bigeyed, *Geocoris* spp., and damsel, *Nabis* spp., bugs. Wasp parasites of lygus bugs may also be locally abundant during some years (Clancy, 1968; Anonymous, 1984b; Graham *et al.*, 1986; Loan and Shaw, 1987; Dean *et al.*, 1987).

Plant bugs may occur in high numbers during the early fruiting stage of crop development. This is particularly likely in areas where there is an abundance of suitable hosts in favorable growing condition (i.e. in bloom). Frequent rainfall during winter, spring and early summer can favor buildup of most plant bug species. Later, as these hosts mature or dry as during a period of drought, plant bugs move to cotton fields (especially if irrigated) which may be the most attractive plants in an area.

Cotton plants are most vulnerable to plant bug attack in the pre-square and early-square formation period when the growing points and all small squares may be destroyed (Ewing, 1929; Wene and Sheets, 1964b; Haney *et al.*, 1977). As plants develop an abundance of squares they will tolerate low amounts of plant bug damage (Leigh *et al.*, 1988) although fruitset may be delayed somewhat. Severe infestations at any time during the fruiting period may remove all squares.

STINKBUGS

Green stink bug, *Acrosternum hilare* (Say)
Conchuela, *Chlorochroa ligata* Say
Say stink bug, *Chlorochroa sayi* Stål
Southern green stink bug, *Nezara viridula* (L.)
Brown stink bug, *Euschistus servus* (Say)
Euschistus conspersus (Uhler)
Onespotted stink bug, *Euschistus variolarius* (Palisot de Beauvois)
Dusky stink bug, *Euschistus tristigmus* (Say)
Euschistus impictiventris Stål
Redshouldered stink bug, *Thyanta accerra* McAtee

Numerous species of stink bugs, family Pentatomidae, have been found on cotton in the United States but many are predacious and only a few cause damage.

Identification and Development of the Stages—Adult stink bugs are usually oval or elliptical and somewhat flattened in shape (Plate 2–13). The antennae are five-segmented. The head appears tapered and it is much narrower than the maximum width of the pronotum (first body segment behind the head). The body length of species in this family ranges from 5/32 to 13/16 inch (4 to 20 mm), but most species present in field crops range from 1/4 to 1/2 inch (6 to 12 mm). Colors are usually shades of brown or green but some species such as the harlequin bug, *Murgantia histrionica* (Hahn), and several predacious species are brightly marked with red, orange, blue or black. Eggs of stink bugs are roughly barrel shaped (Plate 2–14) and are deposited in tight clusters, usually in multiples of seven. The eggs are usually white, light gray, green or cream, turning darker as the nymphs mature inside the egg chorion (shell). After hatching the first instar nymphs are gregarious, remain near the oviposition site and do not feed. There are five nymphal instars and the average length of time per instar is 4.5, 6.0, 8.0, 8.0 and 12.0 days for the first through fifth instars, respectively. Nymphs resemble adults with developing wing pads becoming visible in the fourth instar and approximate adult size being reached in the fifth instar (Esselbaugh, 1946; Decoursey and Esselbaugh, 1962; Slater and Baranowski, 1978; McPherson, 1982; Brewer and Jones, 1985).

Southern green and green stink bugs are bright green insects ranging in length from 1/2 to 5/8 inch (14 to 17 mm) and 1/2 to 3/4 inch (13 to 19 mm), respectively. However, the green stink bug can be easily identified by the presence of a forward projecting spine on the second abdominal sternite (between the last pair of legs) and the long, tapering scent-gland channels. The southern green stink bug has no spine and the scent-gland channels are tear shaped. *Chlorochroa* spp. are bright green, elongate-oval species with numerous white spots scattered over the dorsal surface. They are larger species (over 7/16 inch (11 mm) in length) and are mostly found in the western and southwestern states. The various species of *Euschistus* are brown dorsally, greenish-yellow ventrally, and are similar in shape and size at 3/8 to 9/16 inch (10-15 mm) in length. Species separation is often difficult without detailed descriptions or use of dimorphic keys. Species in the genus *Thyanta* are generally pale green and are smaller than *Nezara, Acrosternum*, and *Chlorochroa* (less than 4/16 inch (11 mm) in length). They also lack a spine on the second abdominal segment. Due to seasonal color variation (individuals may be brown or white spotted due to photoperiodic influences) and close similarity among species, confusion exists in the old literature concerning which species of *Thyanta* was observed or identified as occurring in a particular area. Several species of *Podisus*, which are predacious on other insects, also can be found in cotton and may be confused with the brown stink bugs, *Euschistus* spp. Coloration of *Podisus* spp. is very similar to *Euschistus* spp. but generally *Podisus* spp. are slightly smaller, have sharper lateral pronotal angles (upper surface of first segment behind the head), and have a thick rostrum or feeding tube that is not held against the underside of the head in a groove (Morrill, 1910; McPherson, 1982; Cassidy and Barber, 1939; Furth, 1974).

Damage Symptoms—Stink bugs feed by inserting their slender mouthparts into plant tissues or seeds and extracting enzymatically liquified material. Initial signs of feeding damage are often invisible to the naked eye but later, black spotting may appear on the surface of the plant. Secondary bacterial infection may cause browning. In cotton bolls, cell proliferation resulting in callous growth or a warty appearance on the inside of the carpel wall may be present. Blackened and shriveled seed also may occur and, when bolls open, one or more locks may be hardlocked or destroyed. Extensive feeding by adult and immature stink bugs on small cotton bolls causes shedding. However, older bolls are less often attacked and damage may be insignificant or limited to one or two locks (Morrill, 1910; Wene and Sheets, 1964a; Little and Martin, 1942; Jones, 1918).

Alternate Hosts—Most species of stink bugs affecting cotton have a wide range of hosts and cotton is attacked primarily when preferred hosts are senescent or unavailable. In early season, green stink bugs feed on developing terminals and fruits of a wide range of plants including black cherry, elderberry, dogwood, wheat, cowpea and coffee senna, *Cassia occidentalis* L. They usually produce one generation prior to entering fruiting cotton. Brown stink bugs feed on crucifers, alfalfa, clover, various weeds (such as white top fleabane and common mullein), peas, sorghum and berry plants as well as most vegetables. They may be present in cotton throughout most of the season, but do little damage until the cotton is fruiting (Schoene and Underhill, 1933; Jones and Sullivan, 1982; Morrill, 1910; Jones, 1918; Underhill, 1934; Rolston and Kendrick, 1961; Woodside, 1947).

Phenology and Population Dynamics—All species of stink bugs affecting cotton can produce one or two generations per season on cotton, depending upon latitude, available feeding site and temperature. In the more southern areas of the United States, as along the Gulf Coast and southern Texas, four generations may occur on a succession of host plants. In more northern areas one to one and one half generations may occur. Diapausing adults overwinter; few if any nymphs survive the winter. Spring emergence from overwintering sites occurs March through May, depending on latitude. Some adults may be active periodically during the winter in southern Texas and other subtropical areas but reproductive activity begins with increasing spring temperatures. Generation development takes from 38 to 60 days, depending on species and temperature. Normally, only the second generation is a problem on cotton throughout most of the Cotton Belt. In the West, the consperse and western brown stink bugs may move to cotton in massive numbers from maturing seed alfalfa and grain sorghum, respectively. Since cotton fruit set from June through August constitutes most of the lint that will be harvested, this is the period when cotton is most vulnerable to stink bug damage. The proximity to good overwintering sites and an abundance of wild host plants for the emerging overwintered adults contribute significantly to the chances for stink bug problems in cotton (Little and Martin, 1942; Jones and Sullivan, 1982; Morrill, 1910; Jones, 1918; Woodside, 1946).

ARMYWORMS

Beet armyworm, *Spodoptera exigua* (Hübner)
Fall armyworm, *Spodoptera frugiperda* (J. E. Smith)

The beet armyworm is an occasional pest of cotton and may become severe under certain environmental conditions, particularly in the San Joaquin Valley of California and the gulf coast states (Alabama, Louisiana, Mississippi and Texas) (Essig, 1926). The fall armyworm occurs in the tropical and subtropical Americas and is an occasional pest of cotton in the southeastern United States (Sparks, 1979). Fall armyworm is most common where grasses and corn are grown (Folsom, 1932).

Identification and Development of the Stages—The moth of the beet armyworm is mottled gray with light markings and a wing expanse of 1 to 1 1/2 inches (2.54–3.81 cm) (Todd and Poole, 1980). They deposit masses of eggs on the upper surface of leaves (Plate 2-15) that are beneath the uppermost canopy of leaves. These egg masses, which are revealed by pushing aside the upper leaves, are covered with the gray-white body scales of the moths. The tiny, newly hatched larvae have black head capsules and they feed gregariously (Plate 2-16). Later instars are usually pale olive green in color with a dark stripe down the back and pale stripes on the sides (Plate 2-17) and usually have a black spot on the sides of the second body segment (over the second thoracic leg). They may grow to 1 to 1 1/2 inches (2.54 - 3.81 cm) in length when fully developed. There is considerable color variation with some maturing larvae being nearly black-green while others may be pale green.

The fall armyworm adult is similar in appearance to the beet armyworm (Todd and Poole, 1980), but slightly larger 1 1/4 to 1 inches (3.18–3.81 cm) in length. It produces egg masses similar in appearance and location on plants to the beet armyworm. The large larvae have a prominent white inverted "Y" on the head capsule, three fine yellowish stripes down the back, with a dark band on either side, below which there is an ill-defined lighter colored band. They also have prominent tubercles (pimple-like structures) on the back in a pattern similar to that of the bollworm (Little and Martin, 1942).

Damage Symptoms—Early instar larvae of both species skeletonize leaves adjacent to and on which egg masses are laid. Fourth and fifth instar larvae may feed in and destroy the terminals of small cotton plants. Older larvae of infestations that develop in July will feed on bracts, large squares and young bolls and, in heavy infestations, can remove all fruiting forms in that stage of development. Square loss in early season can be replaced by new squares, but a major reduction in yield may occur since squares produced from late July on may not produce bolls that can mature before harvest (Eveleens *et al.*, 1973).

Feeding by early-stage fall armyworm larvae usually is restricted to grasses in weedy fields. Migration to cotton usually is by the larger larvae which can cut off branches and defoliate plants.

Alternate Hosts—The beet armyworm attacks a number of plants in several plant families. Lambsquarter, *Chenopodium* spp., appears to be a preferred late spring and summer weed host in California, and larvae can be collected from alfalfa and sugarbeet throughout the year.

The fall armyworm has a wide range of hosts including Coastal bermudagrass, corn, other grains and grasses, but they will feed on peanut and cotton in the absence of these preferred hosts (Sparks, 1979; Pitre *et al.*, 1983).

Phenology and Population Dynamics—The beet armyworm overwinters in most southern Cotton Belt states and the San Joaquin Valley in the larval stage on actively growing hosts such as alfalfa and sugarbeet, but larval growth is decreased by cool temperatures. Moth flights occur in May, mid- to late-June, mid- to late-July, and late-August through September.

The fall armyworm overwinters only in Florida, southern Texas and the tropical Americas (Sparks, 1979). Successive broods of moths migrate northward and can invade the entire Cotton Belt east of the Rocky Mountains. This habit of migration enables them to escape high levels of parasitism and predation during severe outbreak years (Little and Martin, 1942; Pair *et al.*, 1986).

Outbreaks of the beet armyworm may occur in the spring of the year and appear to relate to an abundance of suitable hosts and a prey:predator imbalance. Seedling stage outbreaks on cotton can occur when infested weed hosts are present in the cotton field and weed removal by cultivation leaves only cotton on which to feed. Outbreaks on fruiting stage cotton occur when beet armyworms build to high numbers on nearby alfalfa, sugarbeet or other crop hosts and the moths move to cotton to oviposit. These crops usually have insecticides applied that destroy natural enemies, particularly predators such as the minute pirate bug, bigeyed bugs and damsel bugs (Eveleens *et al.*, 1973) and the parasite *Hyposoter exiguae* (Vier.) (van den Bosch and Hagen, 1966). July and later outbreaks on cotton are common during years of drought and also can be traced to application of insecticides that have destroyed the natural enemies of this pest.

Climatic conditions that provide an abundance of host grasses appear to favor the fall armyworm. Outbreaks also appear to be favored by their ability to migrate ahead of their natural enemies. Outbreaks of fall armyworm that affect cotton are more likely to occur during late summer. However they can occur at any time of the year particularly when cotton fields contain grassy weeds.

LEAF FEEDING INSECTS AND MITES

SPIDER MITES

Carmine spider mite, *Tetranychus cinnabarinus* (Boisduval)
Desert spider mite, *Tetranychus desertorum* Banks
Fourspotted spider mite, *Tetranychus canadensis* McGregor
Pacific spider mite, *Tetranychus pacificus* McGregor
Schoene spider mite, *Tetranychus schoenei* McGregor
Strawberry spider mite, *Tetranychus turkestani* Ugarov and Nikolski
Tumid spider mite, *Tetranychus tumidus* Banks
Twospotted spider mite, *Tetranychus urticae* Koch
Tetranychus ludeni Zaker
Tetranychus yustis McGregor

Ten species of spider mites are reported to attack cotton in the United States (Anonymous, 1984b). At least 23 additional species attack cotton worldwide (Leigh, 1985).

The twospotted spider mite is recorded from cotton throughout the United States and much of the temperate and subtropical world and the strawberry spider mite from that region of the northern hemisphere. Similarly, the carmine spider mite occurs in most tropical and subtropical cotton producing areas. Other spider mite species are more restricted in distribution, perhaps as a result of host and climatic factors. While there may be potential for more widespread distribution of some spider mite species through future commerce, the majority of them may already occupy situations to which they are best adapted.

Identification and Development of the Stages—The spider mites that attack cotton are microscopic in size and ovate in shape (Plate 2-18). They may be observed with a 10X magnifying glass or hand lens. The mature females are less than 3/64 inch (0.13 mm) long. Adult male spider mites are smaller than the females, and have a tapered abdomen. Mature adult females usually are pale greenish with some variation in color and in distribution of the dark spots within their abdomen. Diapausing or recently molted spider mites may lack these dark spots and be ivory or pale orange to red in color.

The carmine and twospotted spider mites, which are most commonly cited as pests of cotton in the United States, are identical in their morphology. However, the carmine spider mite is light carmine in color and has been separated from the twospotted spider mite by differences in host plant preference, biology and color, as well as through cross mating studies (Jepson *et al.*, 1975). The body of adult females of the desert spider mite is reddish in color. Adult females of the twospotted, strawberry and other spider mite species usually tend to be greenish in color with dark interior abdominal spots that have typical distribution in some species; however, distribution of the spots is variable and not a reliable identification factor.

Immature stages of the several spider mite species appear similar to the adults, although the young carmine and desert spider mites lack the distinctive coloring of the adults. Newly hatched mite larvae possess only six legs while later stages have eight legs.

Spider mite eggs are found on leaf surfaces or on webbing within colonies. They are spherical and translucent when first laid and become opaque, ivory or faintly brownish before hatching.

Detailed identification of the several spider mite species is provided by Baker and Pritchard (1953) and by Jeppson *et al.* (1975). Positive identification usually requires males of the species mounted on a microscope slide and under high magnification. They are identified by the shape of the male aedeagus or copulatory organ. Field identification of some species, based on plant injury, is possible by workers who are very experienced.

Spider mites develop through an egg and three immature stages before becoming adults (Jepson *et al.*, 1975). At higher favorable temperatures, the egg stage may require as little as two days, and each immature stage a little more than one to two days. Between each stage there is a quiescent or immobile phase of a few hours. A complete generation may require only 8 to 12 days. At cooler temperatures this may be extended to nearly one month (Figure 3).

Damage Symptoms—Spider mites can colonize all foliar and fruiting portions of the cotton plant. They most commonly are located in colonies on the under surface of cotyledons and leaves. There may be significant species differences in appearance of these colonies, ranging from compact colonies near the base of the leaf or in leaf folds

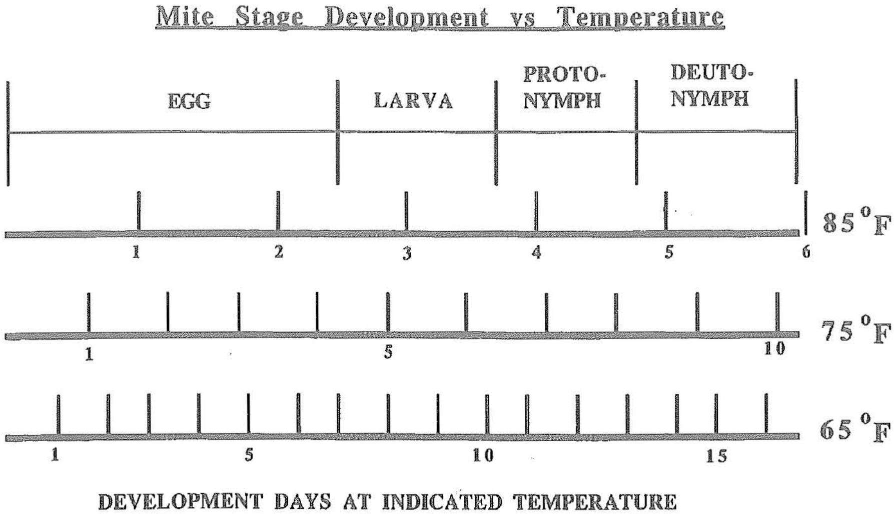

Figure 3. Developmental time in days for growth stages of twospotted spider mites, *Tetranychus urticae* Koch, in response to three temperature regimens. (Developed from Carey and Bradley, 1962.)

to wide dispersion over both leaf surfaces (Jepson *et al.*, 1975; Leigh and Burton, 1976). The strawberry spider mite appears to be unique in causing abscision of infested leaves (Leigh and Burton, 1976), square and boll shed and death of severely infested plants. There are reports of similar defoliation by the carmine and twospotted spider mites in some regions of the world. Areas may develop in cotton fields where there are few or no leaves present and very few bolls. The other spider mite species cause various degrees of leaf-scarring and leaves exposed to the sun may turn red (Smith, 1942). As a result there will be large areas of reddened leaves (Plate 2-19). Apparently, damaged tissue is not as photosynthetically active as undamaged leaves, and there is general debilitation of infested plants, shedding of squares and small bolls and incomplete fiber and seed development.

Alternate Hosts—The several spider mite species that attack cotton have a wide range of hosts in numerous plant families, with some species recorded as having between 100 and 150 hosts. Leigh (1985) provides a generalized host and distribution summary for the species that attack cotton throughout the world. There are major differences in host preference among spider mite species. In addition to cotton, common crop hosts are alfalfa, bean, carrot, corn, cucurbitaceous plants, eggplant, peanut, safflower, soybean, many compositae and landscape plants. In the natural environment, there are many broadleafed weed plant hosts including nightshades, mallows, morningglories, daisies, etc. (Jepson *et al.*, 1975).

Phenology and Population Dynamics—In warmer climates several spider mite species continue to reproduce throughout the winter if there are suitable hosts, but most species will enter diapause if there is an absence of growing plants. In colder climates adult mites seek shelter and enter diapause, usually in cracks of bark on perennial hosts, in the crowns of other plants (Jepson *et al.*, 1975) and in the soil near the base of hosts. Diapausing forms may appear in most populations under adverse conditions such as declining host quality. High numbers of spider mites may develop on spring and early summer hosts and result in continuous reproduction through spring and summer with no distinct generations.

Spider mite numbers may be greatly reduced by winter conditions. They increase rapidly on spring and early summer hosts, particularly where they are able to escape their natural enemies or in crops where natural enemies have been suppressed by pesticide applications. Spider mites may appear in cotton fields when plants first emerge from the ground or at any time during the growing season. Infestations may develop slowly during cool spring weather and then seemingly explode with onset of hot summer weather. Infestation buildup is strongly enhanced by hot dry weather and conditions that suppress the presence and numbers of several predators (Figure 4).

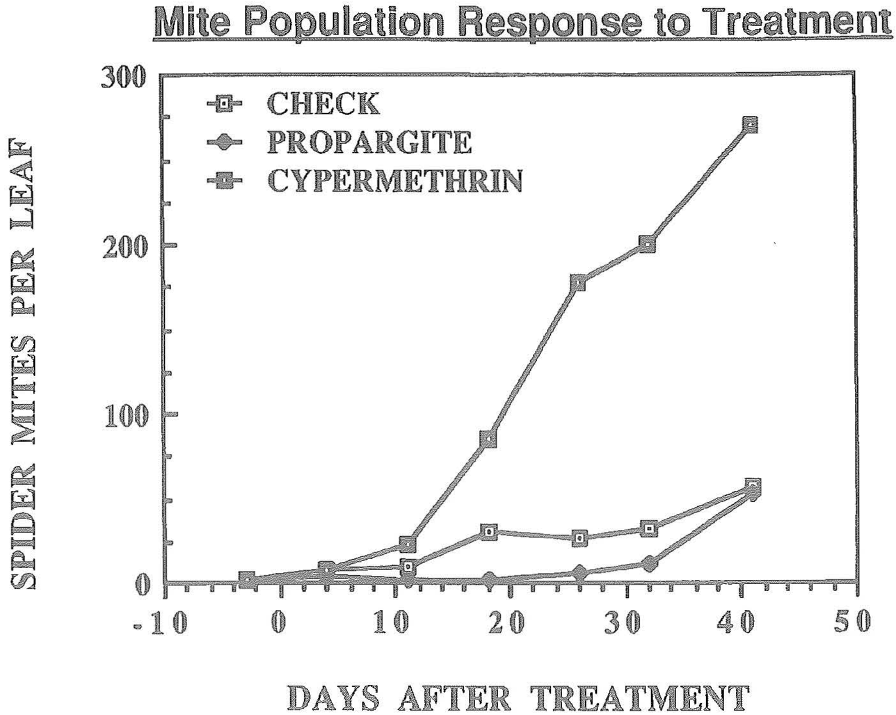

Figure 4. Pacific mite, *Tetranychus pacificus* McGregor: population response to natural conditions (absence of insecticide use), treatment with a selective acaricide or treatment with a broad spectrum insecticide, California San Joaquin Valley.

In undisturbed situations, i.e. where broad spectrum insecticides are not used, gradual maturation of the plants during August and buildup of predator numbers will cause a general decline in spider mite numbers.

Spider mites are generally favored by hot dry conditions (Cannerday and Arant, 1964). A number of species demonstrate their greatest potential for increase at temperatures near 86-90F (30-32C). The carmine and desert spider mites can not survive temperatures at or near 50F (10C). Longevity and reproduction in most species declines greatly above 100F (38C). Moderate humidities appear to be most favorable to most spider mite species although there are wide differences in humidity tolerance (Andres, 1957; Nickel, 1960). Extreme low humidities may result in reduced reproduction (Jepson *et al.*, 1975)

High relative humidity interferes with molting of the developing stages and several species will enter a quiescent stage at extremely high humidity. In areas where humidity is commonly high, viral and fungal diseases may decimate spider mite infestations (Muma, 1955; Carner and Cannerday, 1968, 1970; Jepson *et al.*, 1975). The favorability of molting conditions and absence of conditions favoring disease organisms may account for the perennial severity of spider mites in arid climates.Spider mites may be abundant in the soil in arid climates and on alternate hosts when cotton seedlings emerge from the ground. Frequent spring winds may blow spider mites into cotton fields at any time. Early infestations on cotyledons and first leaves may be evident but can be masked by the flush of vegetative growth that occurs with the onset of hot weather. Mites will move into the upper foliage under increasing population pressure and as vegetative growth is slowed by nutrient requirements of developing bolls (Leigh, 1984).

FOLIAGE FEEDING CATERPILLARS

Alfalfa looper, *Autographa californica* (Speyer),
Cabbage looper, *Trichoplusia ni* (Hübner)
Cotton leafworm, *Alabama argillacea* (Hübner)

Species Attacking Cotton and Distribution—The larvae of more than a dozen species of moths feed on leaves of cotton plants and may cause severe defoliation. The beet armyworm, southern armyworm and cotton leafperforator are discussed elsewhere in this chapter. The alfalfa looper is not a significant pest and is mentioned only because the moths and larvae are very similar in appearance to the cabbage looper and are often confused with it.

The cabbage looper is native to North America and occurs throughout the United States and in Canada and Mexico. The alfalfa looper occurs throughout the western United States, but is reported on cotton only in California. The cotton leafworm is native to the tropical Americas and frequently invades gulf coast cotton fields. Occasionally the cotton leafworm will invade cotton in the low desert regions of California and Arizona.

Identification and Development Stages—Moths of the cabbage looper are grayish-brown in color, about an inch long with a wingspread of nearly 1½ inches (38 mm). The mottled brownish front wing has a distinctive small silvery spot near the middle resembling the "figure 8" or a "question mark". The alfalfa looper is slightly larger than the cabbage looper. They are very similar in color and appearance but the silvery spot of the alfalfa looper is more in the shape of a "gamma" (Y) mark. The cotton leafworm moths (Plate 2-20) are olive-tan color with three wavy transverse bars on the forewings; they are 1 1/4 inches (32 mm) from wingtip to wingtip.

The larvae of these three "worm" pests can be distinguished from other "worms" by their looping action as they crawl (Anonymous, 1984b). Larvae of both the alfalfa and cabbage loopers are very similar in appearance—long, slender, and green with faint whitish longitudinal lines, with true legs on the first three segments and prolegs on the fifth and sixth abdominal segments (Plate 2-21). The cabbage looper has nipple like vestigial prolegs on the third and fourth abdominal segments; they are lacking on the alfalfa looper (Okumura, 1961). The cotton leafworm, which is a semilooper (Plate 2-22), is very distinctive from the other two loopers in being yellowish green to dark green in color with three narrow white stripes down the back and a white line along each side (Little and Martin, 1942). Distinctive spots on the dorsum are paired white rings surrounding a dark spine on each segment. Fully grown larvae of each species are about 1 1/2 inches (38 mm) long.

The pale yellowish, ribbed eggs of the alfalfa and cabbage (Plate 2-23) loopers are hemispherical, while the eggs of the cotton leafworm are ribbed and somewhat flattened. The eggs of all three species usually are laid singly on the lower surface of fully developed leaves.

Damage symptoms—Newly hatched larvae feed on the lower leaf surface, producing semi-transparent windows. Larger worms consume the interveinal tissue, leaving only the veinal skeletons of leaves. Older leaves are usually consumed first, but the plants may be completely defoliated.

Alternate Hosts—Larvae of alfalfa and cabbage loopers are very general feeders with a wide range of crop and weed hosts (Essig, 1926). The cabbage looper generally demonstrates preference for cruciferous plants. The cotton leafworm is capable of reproducing only on cotton, although larvae may occasionally feed on other hosts (Little and Martin, 1942). Adults of the three species will feed on nectar of many plants.

Phenology and Population Dynamics—The alfalfa looper overwinters in the pupal and adult stages (Essig, 1926). There are two generations per year, occurring in late May to early June and in July. This insect usually is controlled on its many hosts by parasites and predators although considerable leaf-ragging may occur on cotton during the early squaring stage. Economic infestations of alfalfa looper have not been encountered although it is sometimes the target of pesticide use.

The cabbage looper is not known to overwinter in the California San Joaquin Valley where it occurs annually as a pest. It may reinvade that valley each season. It usually is under excellent control by naturally occurring parasites and predators. There are usually three generations per year occurring in July through September. Potentially severe infestations are often controlled by a naturally occurring polyhedrosis virus. This disease is common in late-season populations. Outbreaks of cabbage looper are most likely to occur where vegetable hosts are grown and where the biological control agents on cotton or other hosts have been destroyed through use of insecticides.The cotton leafworm is a tropical insect that does not overwinter in the United States and must reinvade this country each year. During outbreak years it usually first appears along the gulf coast in Texas, Louisiana and Alabama. Cotton leafworm outbreaks usually occur following a rain in years of above average summer rainfall. This suggests that the moths are carried into the United States on tropical storm fronts. There can be three generations in the United States. There are many natural enemies of the cotton leafworm in its native habitat, and both generalist parasites or predators and some specialist natural enemies may increase in numbers to decimate the third generation. Birds can be effective predators of this pest.

COTTON LEAFPERFORATOR

Cotton leafperforator, *Bucculatrix thurberiella* Busck

The cotton leafperforator occurs in the southern United States, in Tropical Central America and in Australia (Schmutterer, 1977). In the United States it is a pest only in Arizona and southern California (Anonymous, 1984b).

Identification and Development of the Stages—The cotton leafperforator is a small, elongate, whitish moth (Plate 2-24). The wings are narrow, lanceolate, and the margins are fringed with very long hairs. The antennae are long and the head is concealed by a tuft of short white hairs on the upper surface. Wing span is only about 1/4 to 1/3 inch (6.3-8.4 mm) (Metcalf *et al.*, 1962). Female moths lay minute, bullet-shaped eggs, upright, usually on the lower leaf surface. The caterpillar cuts directly through the egg base and into the inner part of the leaf where it starts its mine (Werner *et al.*, 1979). Development continues as a leaf miner (Plate 2-25) for the first three instars at which time the fourth instar moves to the leaf surface. The fourth and fifth instars (Plate 2-26) are surface feeders, interrupted only by a resting stage (referred to as the horseshoe stage) between instars. During this resting period, it is protected by a loosely-spun web surrounding the U- or horseshoe-shaped larva. After completing the fifth instar it spins a slender, ribbed, whitish cocoon in which it pupates on the leaves, stems or sometimes on the soil (Watson and Johnson, 1972).

Damage Symptoms—At first, damage appears only as small mines in the leaves, increasing in size with each subsequent instar. After the fourth instar emerges to the surface of the leaf, the larva eats only to the opposite epidermis. Feeding occurs on both upper and lower surfaces. During daylight hours the larvae generally feed on the lower surface of the leaf. When disturbed, both fourth and fifth instars wriggle vigorously, usually dropping from the leaf on a silken thread and returning when the disturbance is over (Watson and Johnson, 1972). Severely damaged leaves take on a scorched appearance due to the windows of necrotic tissue.

Alternate Hosts and Outbreak Contributions —This insect is native on wild cotton, *Gossyspium thurberi* Tod., but thrives on planted cotton, usually first attacking field edges. Overwintering and subsequent build-up is favored in areas where cotton is grown as a perennial (stubbed or ratoon) plant. Populations are generally low and held in check by a complex of tiny parasites and predators. Outbreaks usually follow applications of insecticides for control of other pest species (Werner *et al.*, 1979).

Phenology and Population Dynamics—The adult overwinters on abandoned cotton. A long, host-free overwintering period is very detrimental to survival. Seasonal development begins as soon as cotton is available. A detailed study on the biology of this pest indicates that a complete life cycle may take as little as 16 days under summer conditions to as much as 40 days under conditions similar to those in early or late season (Watson and Johnson, 1972). For example, in a constant 68F (19.8C) environment, the egg hatches in slightly over three days, followed by a three-day mining period. The exposed fourth and fifth instars require only approximately one and 2.5 days, respectively. Following a pupal period of 4.5 days and a pre-oviposition period of almost two days, the cycle begins anew (Watson and Johnson, 1972). Thus, many generations are possible each season, depending upon the length of the growing season and management practices.

The cotton leafperforator is a secondary pest; outbreaks are usually human-induced. Because it overwinters on wild or abandoned cotton, survival is directly related to the abundance of overwintering sites and the length of the host-free period. Therefore, a shorter growing season is detrimental to this pest. Additionally, any practice which reduces the use of insecticides lessens the chance of a perforator outbreak since it is usually held under excellent biological control unless its natural enemies are destroyed. This pest is resistant to most of the currently registered insecticides and has the capacity to quickly develop resistance to others, therefore; it is extremely important to manage cotton leafperforator through biological and cultural control measures.

LEAFHOPPERS

Potato leafhopper, *Empoasca fabae* (Harris)
Southern garden leafhopper, *Empoasca solana* DeLong

Species Attacking Cotton—Both the potato leafhopper and southern garden leafhopper occur throughout the Cotton Belt. They are pests of cotton primarily in the West. The southern garden leafhopper is most common in the desert valleys. It migrates to cotton when fields of its main host, sugarbeet, are dried down for harvest. Potato leafhopper damage to cotton occurs in areas of Texas and on the east side of the San Joaquin Valley. In California it migrates to cotton, citrus and other crops from California buckeye (*Aesculus californica* (Spach), its winter and spring host (Smith, 1942; Anonymous, 1984b).

Identification and Development of the Stages - The adults are about 1/8 inch (3 mm) long, by 1/4 as broad, of a general greenish color and somewhat wedge-shaped (Plate 2-27). They are broadest at the head end, which is rounded in outline, and tapered evenly to the tips of the wings. There are several faint white spots on the head and thorax. One of the characteristic marks of the potato leafhopper is a row of six white spots along the anterior margin of the prothorax. The hind legs are long, enabling the insect to jump considerable distances (Metcalf *et al.*, 1962).

Beginning from 3 to 10 days after mating, the small, whitish, elongate eggs, about 1/24 inch long, are inserted into the main veins or petioles on the underside of the leaves. An average of two to three eggs are laid daily, and the females live for about a month. The eggs hatch in about 10 days and nymphal development is completed in about 14 days. The nymphs resemble the adults but lack wings and are pale green (Metcalf *et al.*, 1962).

Damage Symptoms—Adults and nymphs of both species feed by sucking sap from veins on the underside of mature leaves, mostly in the lower half of the plant. Affected leaves may become distorted and leathery and may develop yellow or red blotches (Plate 2-28), a condition know as hopperburn. The most reliable symptom of leafhopper injury is that the veins are swollen and lumpy (Anonymous, 1984b). Other leafhoppers on cotton feed between leaf veins. They may cause a light-colored stippling of leaves, but they do not cause swollen veins and their injury does not result in yield loss.

Alternate Hosts and Outbreak Contributions —Adults overwinter on native plants and in plant debris. Each spring they migrate into various cultivated crops, including cotton (Werner *et al.*, 1979). As mentioned earlier, in the West sugarbeet is the main host of the southern garden leafhopper, and California buckeye, *Aesculus californica* (Spach), provides the spring source of the potato leafhopper that moves into cotton, citrus and other crops (Anonymous, 1984b).

In the eastern half of the United States, the potato leafhopper is the most injurious pest of potatoes (Metcalf *et al.*, 1962). It also feeds on other plants such as eggplant, rhubarb, dahlias and horsebean, producing hopperburn as well. On bean and apple, stunting, dwarfing, crinkling and tight curling of leaves are characteristic symptoms. Alfalfa leaves become yellowed and clover leaves reddened when attacked. The southern garden leafhopper is common on potato, cotton, lettuce and beans. Both species have a wide host range, feeding on more than 100 cultivated and wild plants (Metcalf *et al.*, 1962).

Phenology and Population Dynamics—These two leafhoppers occur throughout the year in the southernmost parts of the Cotton Belt. With their extensive host range, they may move from one crop that is drying to another more succulent host and continue reproducing in the seasonal sequence. Natural enemies usually keep leafhoppers from building up large populations on cotton. However, when large numbers migrate to cotton from other hosts, severe injury may cause plants to shed squares and small bolls. Generally, large populations develop after insecticide has been applied for control of other cotton pests.

APHIDS

Cotton aphid (also called melon aphid), *Aphis gossypii* Glover
Cowpea aphid, *Aphis craccivora* Koch
Green peach aphid, *Myzus persicae* (Sulzer)
Potato aphid, *Macrosiphum euphorbiae* (Thomas)

Species Attacking Cotton and Distribution—These aphids are nearly worldwide in distribution and are pests of seedling stage cotton throughout the Cotton Belt. The cotton aphid may persist throughout the season and is a particular threat to the crop when cotton bolls open (Anonymous, 1984b).

Identification and Development of the Stages—Adult and immature stages of the aphid species are similar in shape, but differ in size, color, and in relative size of the cornicles, cauda and last antennal segment. The cotton aphid (Plate 2-29), which is the most common pest species on cotton, is smallest at 3/64-1/16 inch (1.1-1.7 mm) long. Most commonly it is yellow or greenish-yellow in color, but may be brownish to almost dull greenish-black. The cowpea aphid is 2/32-5/64 inch (1.6-1.9 mm) long and shiny black. The green peach aphid is 1/16-5/64 in (1.8-2.1 mm) long, and green, pink or yellow in color. Cornicles (prominent tubules on top of the insect terminal end) of the cotton aphid are shortest and scarcely extend to or beyond the edge of the body, while on the cowpea and green peach aphids they are long and at least one half of their length extends beyond their body. The last antennal segment and the cauda (the tail) are shortest on the cotton aphid, and proportionately longer on the cowpea and green peach aphids. While winged forms occur, they usually are not common and their wing patterns are similar for the three species described. Color of the immature stages may be less intense than that of the adults, but is usually quite similar.

Invading winged and wingless adult aphids give birth to between two and three living nymphs each day. These nymphs appear very much like the adults. Nymphs can complete their development to the adult stage and begin reproduction in as little as four to six days and will produce about 50 offspring during their lifetime. Winged forms are produced when hosts become unfavorable.

Damage Symptoms—Aphids commonly infest the lower surfaces of developing terminal leaves of the mainstem and branches, causing them to become crinkled and to cup downward. When infestations are heavy, they also may colonize the tender stem tissue and the bracts of squares. Infestations are recognized best by the appearance of developing leaves and the shiny honeydew that they excrete onto the leaves below the infestation. In late season, when bolls begin to open, aphids excrete honeydew onto the fiber (Plate 2-30). This honeydew may stick to picker spindles, ginning equipment and spinning equipment at the mills, making harvest and processing of the fibers difficult or impossible. This greatly jeopardizes sale of the crop. Sooty molds may grow on the honeydew, causing discoloration of the fiber and reduced grade.

Infestations of aphids on seedling and small cotton plants may permanently stunt the growth and cause death of plants (Smith, 1942). The most significant reductions in yield occur when young plants are infested, but yield reductions can result from later infestations (Smith, 1942; Isely, 1946)

Alternate Hosts—The cotton aphid has a wide range of hosts (Paddock, 1919). It is most commonly reported as a pest of cotton, hibiscus, melon, okra and squash and is also reported from citrus. While all of these hosts may develop large numbers of aphids, there is a degree of inter-host incompatibility (Isely, 1946; Swift, 1958). There is no clear verification of alternate host source contribution to outbreaks in cotton although this pest overwinters on citrus and a number of weed or wild non-cotton hosts.

Phenology and Population Dynamics—While winter eggs of the cotton aphid have been recorded in areas of its more northern distribution, it is capable of year-round reproduction on suitable hosts (Paddock, 1919) including dock, *Rumex* spp., and other winter weeds (Swift, 1958). Its rapid rate of development, high reproductive rate and low reproductive temperature threshold make infestation development highly volatile. While infestations of aphids may occur throughout the season, the three dominant aphid pests are most abundant in early spring and outbreaks of the cotton aphid frequently occur in late summer and fall.

Periodic outbreaks of aphids occur at periods of several years. At the present time, entomologists have not been able to develop a clear cause-and-effect relationship for these outbreaks. However, they occur over wide geographic areas on many crops and involve several aphid species.

Spring outbreaks of aphids, particularly the cotton aphid, appear to be a result of the capacity for this insect group to reproduce at temperature thresholds that are lower than the reproductive thresholds of their natural enemies (Isely, 1946). These and later season infestations are usually controlled by parasitic wasps and predators. During some years infestations will develop during September and October. This apparently is due to low population levels of several of their natural enemies which may result from the use of insecticides against other pests or the detrimental impact of a hyperparasite on numbers of the major aphid parasite, *Lysiphlebus testaceipes* Cresson. Fall outbreaks may also be due to onset of cooler weather.

Reproduction by the cotton aphid in the Cotton Belt is continuous throughout the year and there are no distinctive generations on cotton. The potential for invasion of and development on cotton appears to be regulated largely by temperature, since reproductive potential is greatest at about 68F (20C) and is reduced by hot summer weather. The threat of infestation development is then conditioned by numbers of natural enemies that may be present.

WHITEFLIES

Sweetpotato whitefly, *Bemisia tabaci* (Gennadius)
Silverleaf whitefly, *Bemisia argentifolii* Perring and Bellows
Bandedwinged whitefly, *Trialeurodes abutilonea* (Haldeman)
Greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood)
Aleyrodes spiraeoides (Quaintance)

Species Attacking Cotton and Distribution—The sweetpotato whitefly occurs worldwide. It was described from tobacco in Greece in 1889 (Mound and Halsey, 1978). Russell (1957) reported it as a serious pest of cultivated crops in Central America, South America, the West Indies, Africa and Asia. In the United States, sweetpotato whitefly became a serious pest of cotton in the low desert areas of Arizona and California where it cycled from cotton to fall and winter vegetables and back to melons and cotton again in spring and summer. In 1990 a more virulent whitefly, now referred to as the silverleaf whitefly (Plate 2-31) (Perring *et al.*,1993), appeared in the low desert regions of Arizona and California (Brown *et al.*, 1991; Costa and Brown, 1991) and appears to have displaced the sweetpotato whitefly. This new species (which is morphologically indistinguishable from the sweetpotato whitefly but genetically distinctive and with different biological characteristics), devastated several crops in the low desert and Lower Rio Grande Valley of Texas during 1991-92 and spread into the San Joaquin Valley of California.

The bandedwinged whitefly (Plate 2-32) occurs across the Cotton Belt of the United States and is most frequently reported as a pest of cotton in Louisiana and locally in the San Joaquin Valley of California. The greenhouse whitefly is a frequent pest and *Aleyrodes spiraeoides* is a localized pest of cotton in the San Joaquin Valley of California.

Identification and Development Stages—The sweetpotato and silverleaf whiteflies are tiny, 1/16 inch (1.6 mm), white, mothlike insects. The nymphs are entirely different from the adults. They are tiny and scale-like, flat and fringed with white waxy filaments. Gill (undated) has provided a key and color guide to identification of the pupal stage of these whitefly. The first stage is known as the crawler and moves about until settling down to feed. The immature stages are opaque with pale yellow spots within their body.They develop red eye spots in the pupal stage. They have piercing-sucking mouth parts, are confined to the underside of leaves, and secrete sticky honeydew (Plate 2-31). Whitefly eggs have a short subterminal stalk which the female inserts into the leaf tissue of the host plant, usually on the lower surface of a leaf (Mound and Halsey, 1978). Under high populations, hundreds of eggs can be found per square centimeter of leaf surface. Eggs are opaque when deposited and turn black within three days.

Adults begin feeding soon after emergence and mate within one to two days. Reproduction is arrhenotokous, i.e., unmated females produce male progeny. Under typical summer-time conditions the pre-oviposition period is one to two days. Eggs are laid singly on both the underside and top of the leaf, but usually on the underside unless populations are extremely high. Developmental rates vary, depending upon temperature (Butler and Henneberry, 1986) and host plant (Coudriet *et al.*, 1985). Gameel (1978) reported the incubation period on cotton to be 20.5 and 5.2 days at 60 and 104F (15 and 40C), respectively. Development from egg to adult at 80F (26.7C) ranged from 16 days on sweetpotato to the maximum time of 38 days on carrots (Coudriet *et al.*, 1985). Butler and Henneberry (1986) reported that adult longevity was highly variable, depending upon temperature, ranging from 2 to 34 days in the male and 8 to 60 days in the female.

Damage Symptoms—Damage symptoms on cotton are two-fold. First, honeydew secretions by both the immature and adult stages cause a glossy, shiny appearance to the contaminated foliage. Foliage and lint in open bolls become sticky to the touch. Later, a blackening of foliage and lint may occur due to the growth of a sooty-mold fungus on the honeydew. The sweetpotato and silverleaf whiteflies are also vectors of a virus-like disease of cotton called cotton leafcrumple. This causes distorted and stunted growth of the terminal areas of the plant and, if infection occurs early in the life of the plant, will cause severe yield losses. The distortion of the terminal foliage is in the form of severely crumpled and discolored leaves (Allen *et al.*, 1960). In addition to removing plant nutrients, whiteflies produce numerous chlorotic spots on infested leaves, by the action of the saliva of feeding adults as well as by the removal of cell contents by the immature stages. Under heavy feeding, the chlorotic areas coalesce and cause an irregular yellowing of the leaf tissue which extends from the veins to the outer edge of the leaf. The silverleaf whitefly is capable of killing cotton and other crop plants.

The honeydew excreted by all immature stages covers the leaves and may affect the metabolic processes. It can contaminate the seed cotton in open bolls (Plate 2-30) and create problems in harvesting, ginning and spinning (Gameel, 1977).

Alternate Hosts—Greenhouse, sweetpotato and silverleaf whiteflies have a wide range of crop, native plant and weed hosts in numerous plant families. While the host lists for the bandedwinged whitefly and *Aleyrodes spiraeoides* are much shorter than for the other species, host types are still numerous and varied.

Butler and Henneberry (1986) reported sweetpotato whitefly adults overwintering in the Phoenix, Arizona area on cheeseweed, *Malva parviflora* L., and prickly lettuce, *Lactuca serriola* L., during January and February 1982. Natwick and Zalom (1984) stated that although the sweetpotato whitefly has been reported in the desert southwest since the late 1920s, it first became a significant pest in both southern California and Arizona during 1981, when it inflicted serious damage to cotton, melon, squash, lettuce and sugarbeets. The potential for sweetpotato whitefly to overwinter on 17 cultivated crops grown in the southern California desert valleys was reported by Coudriet *et al.* (1985). In addition to the crops given above, these included: carrots, broccoli, tomato, flax, guar, pepper, guayule, bean, alfalfa, eggplant, cucumber and sweetpotato. Coudriet *et al.* (1986) reported 9 weed hosts on which sweetpotato whitefly development could be completed. These were: wild sunflower, *Helianthus annuus* L.; mesquite, *Prosopis* spp.; malva, *Malva parviflora* L.; horseweed, *Conyza canadensis* (L.) Cronq.); field bindweed, *Convolvulus arvensis* (L.); Wrights' ground cherry, *Physalis acutifolia* (Miers) Sandwith.; common sowthistle, *Sonchus oleraceus* (L.); spring sowthistle, *Sonchus asper* (L.) Hill; and wild lettuce, *Lactuca serriola* L. Mound and Halsey (1978) reported 315 plant species as hosts of sweetpotato whitefly.

These reports indicate the extensive host range of the sweetpotato and silverleaf whitefly and thus the difficulty in achieving control culturally by breaking the cycle through host-free periods. It is fortunate that many of these hosts are relatively scarce and untreated and thus, help maintain the reservoir of parasites which can be so effective in the control of the whitefly.

Phenology and Population Dynamics—Whiteflies are tropical and subtropical insects that must reproduce throughout the year. Their numbers drop to very low levels during winter when hosts may be scarce and weather is adverse. The sweetpotato whitefly is trapped throughout the year in the Imperial Valley of California and the Yuma area of Arizona (Watson *et al.*, 1992). Infestations on cotton develop slowly during spring although whiteflies may be found on cotton by April. Highest densities are attained during August through October. This coincides with cotton boll opening. Bandedwinged whitefly is often detected by mid-July in Louisiana and reaches maximum infestation levels when cotton bolls are opening in late-August through September. In western Arizona the bandedwinged whitefly predominated during the earlier part of the season, with nearly total displacement by the sweetpotato whitefly by late-June to early-July (Watson *et al.*, 1992). While this species may be trapped throughout the year in the California San Joaquin Valley, it is usually detected locally in cotton fields during mid- and late-summer. The greenhouse whitefly is also trapped throughout the year in the San Joaquin Valley where population numbers increase rapidly with onset of hot summer weather. Like the other species, infestation levels usually become highest during August through October.

The extensive host range, effect of both temperature and plant host on developmental rate, biological control agents and grower management practices, particularly chemical control, contribute to the complex ecology of the sweetpotato whitefly. Under certain conditions in Arizona and California cotton fields, Butler *et al.* (1985) found that populations doubled every six to ten days. These factors should similarly affect the other species.

Whitefly populations are characterized by rapid increase and intercrop movement in multicrop agricultural systems (Horowitz *et al.*, 1982). This occurs in spite of high natural mortality during the crawler stage and first larval instar. The distribution of whitefly within the plant canopy on the underside of leaves, as well as their high reproductive potential, contribute to the difficulty in controlling the insect with conventional spray application methods (Butler and Henneberry, 1986). Fullerton (1982) found nymphal reductions of 83.1, 33.2 and 22.5 percent respectively, from terminal, mid-plant and bottom leaves, 24 hours after treatment.

The role of natural enemies in regulating sweetpotato whitefly populations is unknown. However, outbreaks appear to intensify with the use of synthetic organic insecticides, suggesting that natural enemies play a significant role in population regulation (Anonymous, 1981). Gerling (1967) reported that whiteflies in southern California seldom reached economic levels except when insecticide applications were applied to cotton. He suggested that natural regulating factors were important in maintaining low population levels.

In regions of the San Joaquin Valley during many years, the parasitic wasp, *Eretmocerous haldemani* Howard and a complex of predacious insects appear to provide effective control of the greenhouse and bandedwinged whitefly.

THRIPS

Flower thrips, *Frankliniella tritici* (Fitch)
Western flower thrips, *Frankliniella occidentalis* (Pergande)
Frankliniella exigua Hood
Frankliniella gossypiana Hood
Tobacco thrips, *Frankliniella fusca* (Hinds)
Onion thrips, *Thrips tabaci* Lindeman
Soybean thrips, *Sericothrips variabilis* (Beach)
Bean thrips, *Caliothrips fasciatus* (Pergande)
Caliothrips phaseoli (Hood)
Kurtomathrips morrilli Moulton

Species Attacking Cotton and Distribution (Anonymous, 1984a)—The flower, western flower and onion thrips occur throughout the Cotton Belt as well as elsewhere in the United states. The onion thrips apparently occurs worldwide wherever onions are grown. The western flower thrips is reported in greenhouses in Europe and on outdoor plants in many other countries. Locally, either of these two species may predominate in a particular year, although the western flower thrips appears to be the most general pest. Other species appear to be localized in their distribution. The bean thrips is reported to occur in the western and southeastern United States as well as in Mexico and South America.

Identification and Development of the Stages—Adult females of the flower, western flower (Plate 2-33) and onion thrips are predominantly straw colored although intermediate to dark brown color forms occur (Metcalf *et al.*, 1962; Bryan and Smith, 1956). The same color forms may occur in the other species. Adult females are about 1/12th inch (1.5-2 mm) long, and have four wings that fold over their backs and are fringed with long hairs. Males are wingless and very rare. First instar nymphs usually are pale to ivory and second instar nymphs golden yellow in color and resemble the adults in shape. Eggs, which usually are deposited within the leaf tissue, are reniform and usually can be located by staining the plant tissue and examining it with the aid of strong magnification (Bryan and Smith, 1956).

Adult bean thrips are about 1/25th inch (5 mm) long, slender and black with white bands across the wings which fold on the dorsum of the abdomen. The first instar nymphs are slender, pale to dark orange in color, and resemble the adults in shape. Older nymphs have deep pink to orange spots on the abdomen (Smith, 1942).

Thrips develop through the egg, two nymphal stages and the propupal and pupal stage before becoming adults. The egg stage lasts from three to four days during hot summer weather to two weeks or more in colder winter and spring weather. First and second instar nymphs complete their development in 2 to 10 and 3.5 to 12 days, respectively, depending on temperature. Fully developed nymphs drop to the soil to pupate. The pupal stage may be as short as four days. Total development time is as little as two weeks. Adult females live about a month and deposit 40 to 50 eggs during their lifetime. While males are rare, their development is very similar to that of females and they are smaller (Bryan and Smith, 1956).

Damage Symptoms—The flower thrips, western flower thrips and onion thrips are most frequently reported as pests of seedling cotton, particularly where cotton is grown at higher elevations and cool temperatures persist. The western flower thrips is reported to be a mid-season pest of cotton in Arkansas, Louisiana, Georgia and Mississippi. The bean thrips is an infrequent mid-season pest in the San Joaquin Valley of California.

Thrips feed on the surface of the plant tissue. They pierce the epidermal cells with needle-like stylets and suck the plant liquids. Their very small size permits them to crawl into the folded terminal leaves. With the exception of the bean thrips, most species demonstrate a preference for feeding within the folded developing leaves in the plant growing points, in folds of leaves or at the base of leaf veins and in spider mite colonies. Spotted silvering on the lower surfaces of cotyledons and leaves is a typical result of their feeding. During severe outbreaks thrips feeding in the growing points will cause severe deformation and stunting of the developing leaves. The growing point may be completely destroyed in some instances. Death of plants is uncommon but can occur with continued severe attack. When plant terminals are destroyed, new buds must be initiated and bloom may be delayed for about two weeks (Smith, 1942).Thrips will continue to feed on cotton plants throughout the growing season. Immature stages are commonly found on lower leaf surfaces, particularly within spider mite colonies, while adults are found within blooms feeding on pollen.

With the onset of hot weather, cotton plants injured during the seedling stage outgrow thrips injury and develop normal leaves. Severely injured plants that loose apical terminals develop vegetative branches from mainstem nodes and become candelabra shaped with three to five terminals (Race, 1965).

The bean thrips typically attacks more mature leaves of cotton plants, feeding on the lower leaf surfaces where they cause the typical spotted silvering. Their excrement spots will also be very evident in feeding areas. These leaves will attain a copperish color, turn brown and fall from the plants. Squares and small bolls will also abscise. The tendency for leaf abscission suggests injection of a plant toxin during their feeding process (Smith, 1942).

Alternate Hosts—Flower, western flower and onion thrips have many hosts in the areas where they occur. These include grasses, cereal grains, alfalfa and other leguminous crops, numerous broad leafed plants in several plant families and a number of field and vegetable crops. Large populations often develop on these hosts, particularly on alfalfa, and migrate into cotton during the early seedling stage of crop development (Bailey, 1938; Newsom *et al.*, 1953; Race, 1965). In the Mid-South, large numbers of the western flower thrips apparently develop on grain crops and migrate to cotton during the early flowering stage, where they feed on the blooms.

Phenology and Population Dynamics—In colder regions of the Cotton Belt adult thrips overwinter in fine-textured plant litter (Race, 1965) while, in the warmer areas such as Louisiana and California, they may reproduce on suitable hosts throughout the year (Smith, 1942; Newsom *et al.*, 1953). Large numbers develop on uncultivated hosts as well as on winter and spring grown cereal grains, alfalfa or clover crops. Greatest numbers may occur on cotton in late spring and early summer as the native vegetation matures and dries. However, they may be abundant in blossoms throughout the spring and summer. While the most evident damage to cotton occurs in the seedling stage, greatest numbers of thrips are present when the plants are in bloom. However, blooming plants can usually tolerate these numbers without obvious damage. In portions of Arkansas, Mississippi and Louisiana, the western flower thrips may reach greatest numbers on cotton in early July when maturation of grain crops occurs.Weather conditions that provide an abundance of natural annual vegetation during late winter and spring and extensive plantings of cereal grains can lead to high populations of thrips. Continued rainfall during the cotton growing season and sprinkler irrigation may seal the soil where the thrips pupate and can prevent their emergence as adults. Cool weather that slows plant growth during the seedling stage enhances the severity of thrips injury. However, cotton plants usually outgrow thrips damage when they are about 32 days old (Race, 1965).

SUMMARY

The most frequently encountered insect and spider mite pests of cotton are reviewed. While the several species in each group are cited, only the most common pest species and their damage are described. Geographic distribution, phenology, population dynamics, population regulation by natural enemies and host contributions to outbreaks are reviewed. References cited in the text will provide details of the cited information and will serve as a guide to extensive literature on the the various topics.

ACKNOWLEDGMENTS

We are grateful to the University of California Statewide IPM Project and photographer Jack Kelly Clark for approval to use 31 photographs of cotton insects and their damage. These pictures are taken from Integrated Pest Management for Cotton in the Western Region of the United States, University of California Division of Agriculture and Natural Sciences Publication 3305. Winfield L. Sterling, Texas A&M University has kindly provided photographs of the cotton leafworm moth and larvae, and Michael J. Gaylor of Auburn University has provided a graph of tarnished plant bug host contributions to outbreaks of that pest. Other graphs are by the senior author of this chapter, Thomas F. Leigh.

Chapter 2

APPENDIX

IDENTIFICATION AND DAMAGE GUIDE TO PEST INSECTS AND MITES

The information and color plates that follow are intended to aid readers in identification of insect injury observed in cotton fields and in identification of insects and spider mites they see and examine. Color plates of the most common pests are included. The user of this identification guide is also referred to Chapter 3 for descriptions of the beneficial natural enemies of cotton pests.

More than 100 insect and spider mite species may be found in cotton fields. While a few of these species appear in damaging numbers annually, many are rare in their occurrence and others are predators or parasites of the pests.

Effective control, environmental concerns associated with insecticide use, disruption of natural biological control systems and costs of insecticides and their application dictate that the cotton grower or his crop advisors carefully ascertain which pest(s) must be controlled. Few insecticides are effective against a wide range of these pests and use of the wrong material may result in control failure in addition to outbreaks of other pests against which they are not effective. Management of insect and mite pests depends very much on their proper identification, an understanding of their interrelationships, and knowledge of the threat they pose to the crop.

Particular pests will usually dominate in the type of management strategy selected for a particular region of the Cotton Belt. Need for control of thrips, boll weevils and lygus bugs frequently will dominate pest management decisions in states east of Texas and Oklahoma. In Texas and Oklahoma, fleahoppers, boll weevils and thrips may be the most frequent pests. In the far west, lygus bugs, pink bollworms and whiteflies are often the earliest seasonal targets. Aphids and the threat of sticky cotton have become increasingly significant across the Cotton Belt.

Both a cotton insect/mite pest species (types) identification guide and an insect/mite damage symptoms guide are included in this chapter appendix. Pest types are grouped according to physical characteristics that are most apparent. Damage symptoms are grouped by stage of growth and development of the cotton plant.

INSECT AND MITE DAMAGE IN COTTON

(Major Pests in Bold Type)

Many insects are referenced to the color plates that follow.

	DAMAGE SYMPTOMS	PEST	PLATE
PLANTED SEEDS			
Seeds	eaten. Stand poor.	seedcorn maggot wireworms	not incl.
SEEDLINGS			
Stems	cut off just above or just below ground level.	cutworms	not incl.
	gouged at or above ground level.	darkling beetles field crickets	not incl.
Stems, Cotyledons, Leaves	dried and shriveled.	false chinch bugs	not incl.
Cotyledons, Leaves	covered with honeydew.	aphids	not incl.
	silvery, without honeydew.	thrips	not incl.
	ragged, eaten.	**beet armyworm** alfalfa looper field cricket	not incl.

ESTABLISHED PLANTS

Stems	with rows of deep gouges.	cicada egg punctures (rare).	not incl.
	bored into or cut off near terminal.	**beet armyworm**	not incl.
Leaves	covered with honeydew, deformed.	aphid	not incl.
	not deformed.	whitefly	not incl.
	discolored above, usually webbed beneath.	spider mites	Plate 2-19
	not webbed, veins distorted	potato leafhopper	Plate 2-28
	with twisting mines and windows or holes	cotton leafperforator	Plate 2-25
	and no holes.	leafminer	not incl.
	skeletonized, with twisting mines.	cotton leafperforator	Plate 2-25
	by small caterpillars	**beet armyworm**	Plate 2-16
	feeding in a group.	fall armyworm	
		yellowstriped armyworm	
		saltmarsh caterpillar	
		cotton leafworm	
	ragged, eaten; caterpillars present.	**beet armyworm**	not incl.
		cabbage looper	Plate 2–21
		soybean looper	
		yellowstriped armyworm	
		saltmarsh caterpillar	
		cotton leafworm	Plate 2–22

INSECT AND MITE DAMAGE IN COTTON (Continued)

	DAMAGE SYMPTOMS	PEST	PLATE
Leaves	ragged, eaten; insects present (not caterpillars)	cucumber beetles field crickets grasshoppers	not incl.
	rolled and webbed, terminal leaves eaten.	omnivorous leafroller	not incl.
	older leaves rolled and webbed.	celery leaftier	not incl.
Squares	small hole eaten in side, may be plugged with excrement, flared, dropped.	**boll weevil**	Plate 2-2
	punctured, flared, dropped, shiny spots of excrement. Also, very small squares dried in plant terminal.	**lygus bugs** fleahoppers superb plant bug clouded plant bug	Plate 2-12
	without excrement spots.	**stink bugs**	not incl.
	eaten into, dropped.	**beet armyworm** **bollworm** **tobacco budworm** fall armyworm yellowstriped armyworm cotton square borer **boll weevil**	not incl.

	with bracts chewed, and webbed.	omnivorous leafroller	not incl.
Blooms	with rosetted petals.	**pink bollworm**	not incl.
	with hole eaten out of base.	**beet armyworm** **bollworm** **tobacco budworm** fall armyworm yellowstriped armyworm cotton square borer	not incl.
	disfigured, warty.	**lygus bug** superb plant bug clouded plant bug	not incl.
Bolls	with slightly depressed reddish brown spots, shiny excrement spots, small bolls drop.	**lygus bug** clouded plant bug superb plant bug	not incl.
	without excrement spots, may crack and show internal rot.	**stink bug**	not incl.
	with hole in side, eaten out, small bolls may drop.	**beet armyworm** **bollworm** **tobacco budworm** fall armyworm yellowstriped armyworm	not incl. Plate 2-4

INSECT AND MITE DAMAGE IN COTTON (Continued)

	DAMAGE SYMPTOMS	PEST	PLATE
Bolls	bored at tip, chewed.	cotton leafperforator omnivorous leafroller	not incl.
	with holes through wet lint and walls separating locs.		
	pink larvae in seeds of large bolls.	**pink bollworm**	Plate 2-8
	white larvae in holes in lint.	**boll weevil**	not incl.
	open and normal but honeydew and mold on lint.	aphids whitefly	Plate 2-30 Plate 2-30

FIELD GUIDE TO COMMON INSECT AND MITE PESTS OF COTTON

(Major Pests in Bold Type)

	DESCRIPTION	PEST	PLATE
INSECT EGGS			
Laid in groups or clusters.	Pale green, usually on upper leaf surface beneath top canopy. Covered with velvety moth scales.	**beet armyworm** fall armyworm yellowstriped armyworm	Plate 2-15
	Pale bluegreen, flat, overlapping on upper leaf surfaces.	omnivorous leafroller leaf tiers	not incl.
	Pearl-like, spherical, not covered. Usually on upper leaf surface near top of plant.	saltmarsh caterpillar	not incl.
	White to gray, like closely stacked barrels, in clusters of 7, 14 or 28.	**stink bugs**	Plate 2-14
Laid singly.	White, with brownish band in upper third soon after deposition. On terminals & squares. As tall as wide at base.	**bollworm** **tobacco budworm**	Plate 2-3
	White, without brownish band, shorter than wide at base. Laid on under side of leaves below terminal.	**cabbage looper** alfalfa looper	Plate 2-23
	Blue-green to dirty white. Dish shaped. Circular, flattened, ribbed. On lower leaf surface middle third of plant.	cotton leafworm	not incl.

FIELD GUIDE TO COMMON INSECT AND MITE PESTS OF COTTON (Continued)

	DESCRIPTION			PEST	PLATE
Laid singly	Greenish to red, oval, laid at bases of bolls and on inside of bracts.			**pink bollworm**	not incl.

CATERPILLARS
(Larvae of moths and butterflies. Have false legs on abdomen in addition to the three pairs of legs on the thorax.)

	DESCRIPTION			PEST	PLATE
Exposed on foliage	Body almost concealed by long yellow to black hair. To 1 1/4 inches.			saltmarsh caterpillar	
	Body naked	Only two pairs of false legs, behind middle of abdomen. Pale green, walk as "loopers". Length to 1 1/4 inch.		**cabbage looper** alfalfa looper	Plate 2-21
		3 pairs of hind legs, yellowish green with narrow white strips, distinctive spots on dorsum. Semiloopers. Length to 1 1/2 inch.		cotton leafworm	Plate 2-22
		Skin smooth.	Dull green with black spots and white bumps. Length to 3/8 inch; slender.	cotton leafperforator	Plate 2-26

			Greenish with dusky stripe down side, tiny black spot above middle true leg. Length to 1 inch.	**beet armyworm**	Plate 2-17
			Black with yellow and and brown stripes. Length to 1 1/4 inch.	yellowstriped armyworm	not incl.
			Brown with darker bumps on back, pale inverted "Y" on head. Length to 1 1/4 inch.	fall armyworm	not incl.
On or in boll (sometimes blossom or square)	No visible entrance hole in boll, but sometimes frass-free exit hole. Tiny white to 1/2-inch pink caterpillar in lint or seed, often mines or warts in inner carpel walls & holes in lock separators.			**pink bollworm**	Plate 2-8
	Slight feeding at tip of boll. Dull green caterpillar with black spots & white bumps, 3/8 inch.			cotton leafperforator (rare)	not incl.
	Hole in side of boll	Skin of body with tiny spines.		**bollworm**	Plate 2-4
			Greenish to rose brown with irregular black stripes. Length to 1 1/4 inch.	**tobacco budworm**	

FIELD GUIDE TO COMMON INSECT AND MITE PESTS OF COTTON (Continued)

DESCRIPTION			PEST	PLATE
	Skin without spines.	Smooth, greenish with dusky stripe down side and tiny spot above middle true leg. Length to 1 inch.	**beet armyworm**	Plate 2-17
		Smooth, black with yellow and brown stripes. Length to 1 1/4 inch	yellowstriped armyworm	not incl.
		Brown with darker bumps on back, pale inverted "Y" on head. Length to 1 1/4 inch.	fall armyworm	not incl.
		Velvety green, with dense coat of short, erect hairs. Head small. Length to 3/8 inch.	cotton square borer (rare)	not incl.
Within webbed or rolled leaves or bracts. Olive green, with white spots or spines on each segment. Crawl forward or backward rapidly. Length to ½ inch.			omnivorous leafroller leaftiers	not incl.

Within leaf mines. Tiny, to 1/16 inch, white.		**cotton leafperforator**	Plate 2-25
In soil near severed seedlings. Mottled gray to brown, greasy, shiny. Curl up when disturbed. Length to 1 inch.		cutworms	not incl.
OTHER LARVAE			
With distinct head	In wet lint in boll. C-shaped, cream with tan head, legless. Length to 3/8 inch.	**boll weevil**	not incl.
Maggots (head end tapering)	White to cream, length to 3/8 inch. In soil, in seed, or on underground parts of damaged seedlings.	seedcorn maggot	not incl.
	Tiny, white, with black mouth hooks at front end. In leaf mines. Length to 1/8 inch.	leaf miner	not incl.
COCOONS AND PUPAE			
Loose or flimsy white cocoon	3/4 inch long, enveloping a green caterpillar or brown pupae.	**cabbage looper**	not incl.
	Brown to near black pupae to near 13/16 inch. In fold of leaf.	cotton leafworm	not incl.
	1/4 inch long, enveloping a U-shaped larva. Horseshoe stage of...	**cotton leafperforator**	not incl.

FIELD GUIDE TO COMMON INSECT AND MITE PESTS OF COTTON (Continued)

		DESCRIPTION	PEST	PLATE
		Found in leaf trash or near base of plant, pink larvae or brown velvety pupae to 2/5 inch long.	**pink bollworm**	not incl.
Tight tapered white cocoon		1/4 inch long with fine ridges. Cocoon of...	**cotton leafperforator**	not incl.

TRUE BUGS

Mouth parts a sucking beak.

		DESCRIPTION	PEST	PLATE
Triangular shaped, wings membranous, held roof like over abdomen. 1/8 inch long.			leafhoppers	Plate 2-27
Wings held flat on back, leathery at base, membranous beyond middle, wings and the triangular scutellum forming an "X" on the back.				
1/4 inch long or longer.	Shield shaped	1/4 to 1/2 inch long, green to brown. Some species with pointed shoulders.	**stink bug**	Plate 2-13
	Oval in outline	1/4 inch, greenish with yellow heart-shaped mark on scutellum, wings often reddish to brown near middle.	**lygus bug**	Plate 2-9

		3/8 inch, mostly black, margined with orange or red.	superb plant bug	not incl.
		9/32 inch long, yellowish tan to brown.	clouded plant bug	not incl.
	1/8 inch long or less	Pale green with black specks on body.	cotton fleahopper	Plate 2-11
		Black with base of leathery part of front wing brownish. Last two antennal segments white.	western plant bug	not incl.
		Black with white marking on leathery part of front wings. Antennae entirely black.	whitemarked fleahopper	not incl.
		Aggregate in large numbers. Feed early morning, late evening. Hide beneath clods of dirt in daytime.	false chinch bug	not incl.
BEETLES				
	Wing covers with dark markings	1/4 inch, soft bodied: green to yellowish; wing covers with black spots or stripes.	cucumber beetles	not incl.
		3/16 inch. Tan with yellow stripe down each wing cover. Hind legs thickened for jumping.	flea beetle	not incl.

FIELD GUIDE TO COMMON INSECT AND MITE PESTS OF COTTON (Continued)

	DESCRIPTION	PEST	PLATE
Wing covers one-colored	Front of head drawn out into a curved snout. 1/4 inch, tan to brown. Femur of front leg with large double tooth.	**boll weevil**	Plate 2-1
	1/4 inch. Dull brown to black. In soil near seedlings with gouged stems.	darkling beetle	not incl.
	3/16 inch, black, slender, tapered. Wing covers very short. In blossoms.	fruit bud beetle	not incl.

MOTHS

(Only distinctive species that are likely to be seen in cotton fields are included.)

3/4 inch long or longer	1 1/4 inch long. Wings white with black spots, male hind wings rich yellow. Top of abdomen orange & black.	saltmarsh caterpillar	not incl.
	3/4 inch long, variegated black & brown, front wing with a silver "Y" or gamma mark in middle. Thorax with tuft of long scales.	**cabbage looper** **soybean looper** alfalfa looper	not incl.
	3/4 inch long. Greenish tan, front wings with 3 diagonal darker bands, hind wings paler with outer third all black.	**tobacco budworm**	Plate 2-5

	3/4 inch long. Front wings rich tan with some browner pattern, hind wings paler with outer third black but enclosing pale spots.	**bollworm**	Plate 2-6
	3/4 inch long. Olive-tan color with three wavy transverse bars on front wings.	cotton leafworm	Plate 2-20
Less than 1/2 inch long	1/4 inch long, Very slender, all white.	**cotton leafperforator**	Plate 2-24
	3/8 inch long. Dark, triangular, with long snout.	omnivorous leafroller	not incl.
	Mottled grayish-brown moth.	**pink bollworm**	Plate 2-7
	Slender, variously yellowish to buff or reddish, with snout.	webworms	not incl.

OTHER INSECTS WITH OBVIOUS WINGS

Front and hind wings unequal.	Large, over 1 inch long, brown to black. Hind legs thickened for jumping. Antennae very long & slender.	field cricket	not incl.

FIELD GUIDE TO COMMON INSECT AND MITE PESTS OF COTTON (Continued)

	DESCRIPTION	PEST	PLATE
	Small, 1/8-1/4 inch, green to brown. Hind legs used in jumping.	leafhopper	Plate 2-27
	Small, to 1/8 inch, green to black, in colony with wingless individuals. Abdomen with 2 tubes (cornicle) at back.	**aphid**	Plate 2-29
	Tiny mothlike, 1/16 inch. Wings and body covered with white powder. Cloud of adults will fly. Adult...	**whitefly**	Plate 2-31 Plate 2-32
Only front wings present	1/16 inch long. Body black with yellow markings. Adult...	leafminer	not incl.
APPARENTLY WINGLESS INSECTS AND MITES			
1/8 to 1/4 inch long	Length to 1/8 inch, yellow to green to black. Abdomen with 2 tubes. Live in colonies. Produce honeydew.	**aphids**	Plate 2-29
	Length to 3/16 inch. Red antennae, green with black spot on abdomen, 4 black spots on older nymphs, varying to brownish, Active. Nymphs...	**lygus bug**	Plate 2-10

	Length to 1/4 inch, some larger, nearly circular. Green to brown with scent gland at middle of abdomen. Nymph...	**stink bug**	not incl.
Tiny 1/16 inch smaller	Flat, almost transparent, not obviously motile, usually with fringe of white waxy filaments. Produce honeydew. Nymphs...	**whitefly**	Plate 2-31 Plate 2-32
	Globular, in webbing on under side of leaves. Body not segmented, with four pairs of legs.	**spider mites**	Plate 2-18
	Slender, tapered at both ends. Active. Opaque to tan to dark.	larval thrips	Plate 2-33

ACKNOWLEDGEMENTS

The authors of this chapter gratefully acknowledge and deeply appreciate the generosity and contribution of Jack K. Clark, principal photographer of the IPM Manual Group, University of California, Division of Agriculture and Natural Resources, for supplying the color transparencies used for Plates 2-1 through 2-19, Plate 2-21 and Plates 2-23 through 2-33 and of Winfield Sterling of Texas A&M University for Plates 2-20 and 2-22.

The authors acknowledge that the damage symptoms guide is adopted from "Arizona Cotton Insects", Cooperative Extension Service, University of Arizona, Bulletin A23 (Revised 1979). The authors of this bulletin are Floyd G. Werner, Leon Moore and Theo F. Watson.

Plate 2-1. Adult boll weevil, *Anthonomus grandis grandis* Boheman. (Adult commonly found beneath the bracts of squares or feeding in flowers during the day.)

Plate 2-2. Cotton square with a boll weevil, *Anthonomus grandis grandis* Boheman, egg puncture. (After ovipositing, adult weevil seals the feeding puncture with a frass plug.)

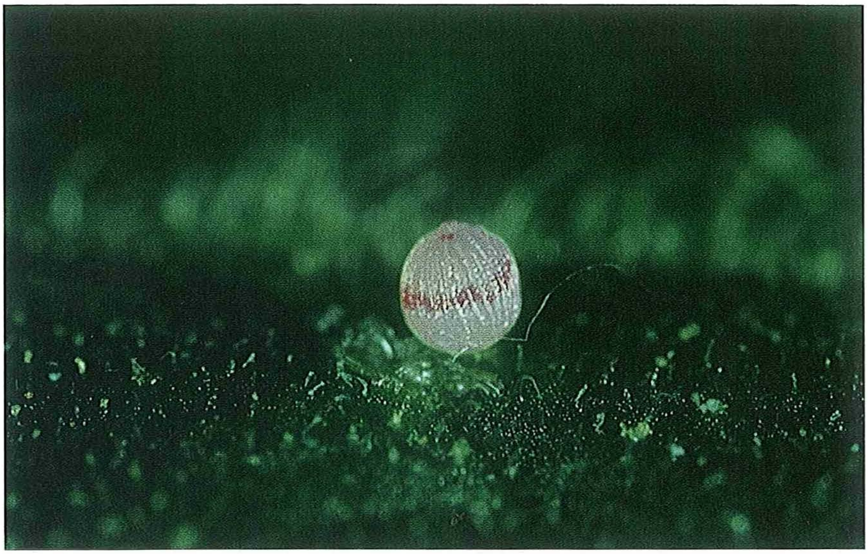

Plate 2-3. Bollworm, *Helicoverpa zea* (Boddie), egg on cotton leaf. (Egg develops a reddish brown ring a day after it is laid.)

Plate 2-4. Larvae of bollworm *Helicoverpa zea* (Boddie). (Under magnification, larva has tiny spines on most parts of the body and prominent tubercles.)

Plate 2-5. A mating pair of tobacco budworm, *Heliothis virescens* (F.), adults. (Illustrates the three oblique dark bands on the forewings and typical olivegreen color.)

Plate 2-6. Mating pair of pale buff colored bollworm, *Helicoverpa zea* (Boddie), moths.

Plate 2-7. Moth of the pink bollworm, *Pectinophora gossypiella* (Saunders).

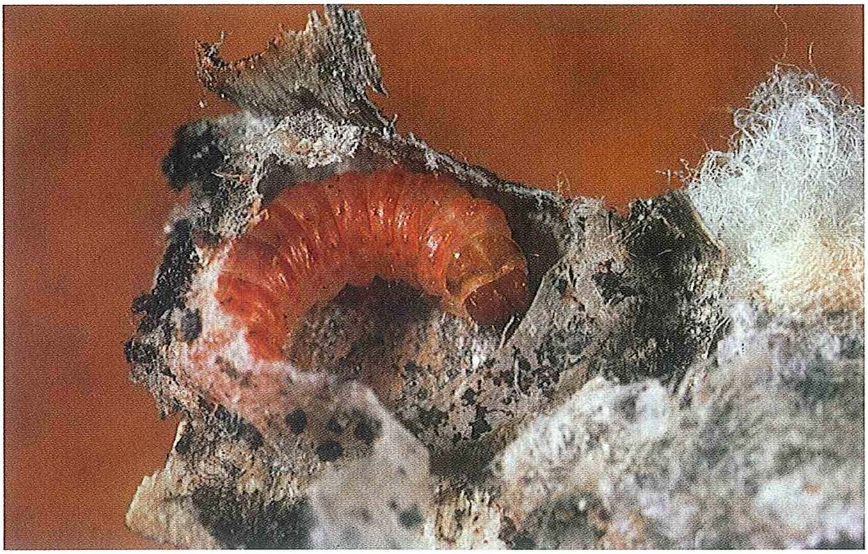

Plate 2-8. Mature larva of the pink bollworm, *Pectinophora gossypiella* (Saunders), and associated cotton boll damage. (The first three larval stages are white, with a dark head capsule; the fourth stage shows pink coloring.)

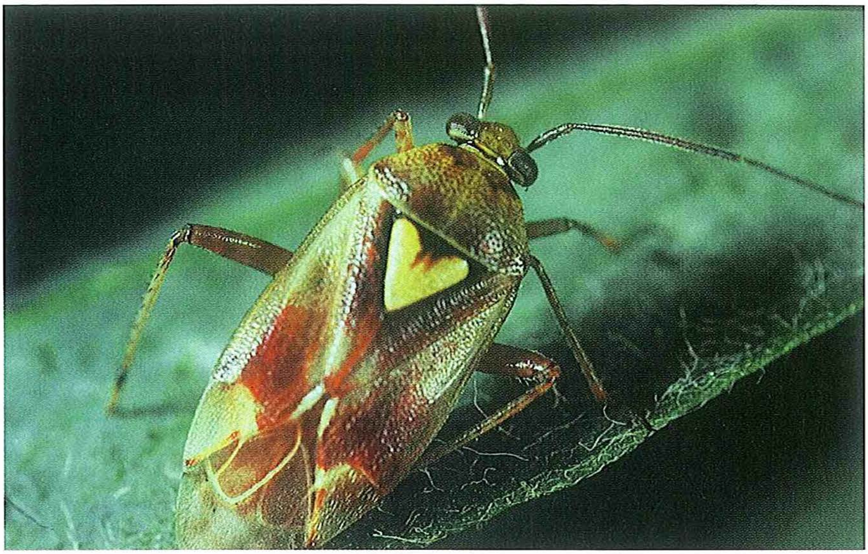

Plate 2-9. Adult western lygus bug, *Lygus hesperus* Knight. (Illustrates the prominent heart-shaped scutellum, which is commonly yellow in this species.)

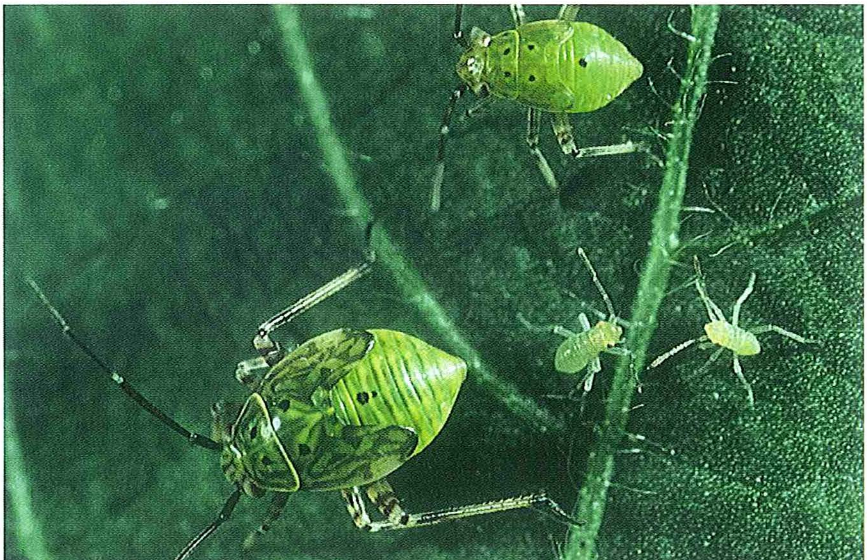

Plate 2-10. Nymphal western lygus bugs, *Lygus hesperus* Knight. (Nymphs are commonly green, with red antennal tips. Older nymphs have five black dots on the back and may be brownish in color.)

Plate 2-11. Nymphal and adult cotton fleahoppers, *Pseudatomoscelis seriatus* (Reuter). (Light green in color, speckled with small brown spots and numerous short spines, and have bristle-like antennae that are not reddish as in lygus bugs.)

Plate 2-12. Shriveled dried squares injured by western lygus bugs, *Lygus hesperus* Knight. (Often found in the plant terminals, or in the sweep net when sampling for this pest.)

Plate 2-13. Adult Say stink bug, *Chlorochroa sayi Stål.*

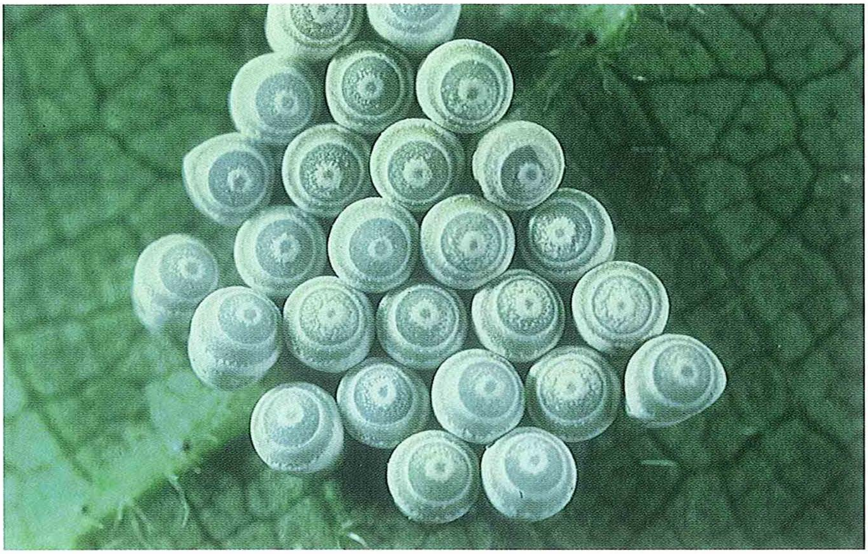

Plate 2-14. Egg mass of the consperse stink bug, *Euschistus conspersus* (Uhler).

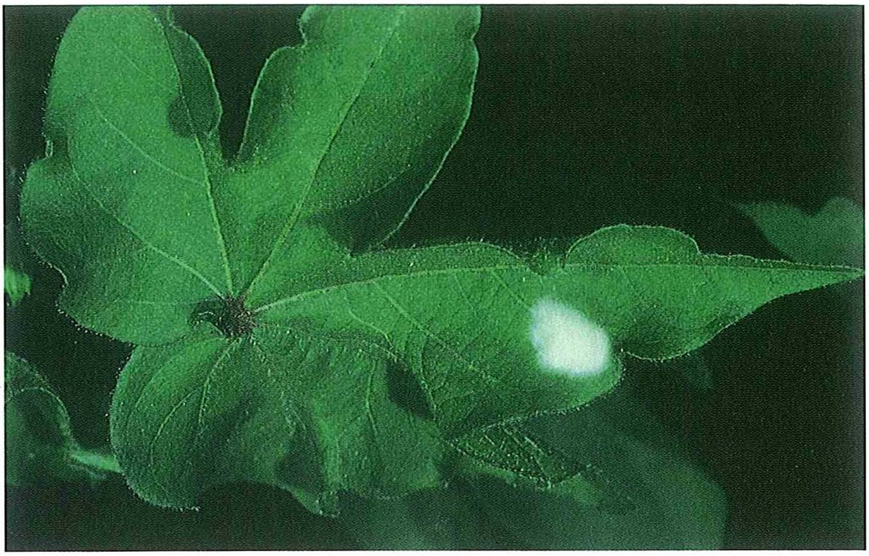

Plate 2-15. Egg mass of the beet armyworm, *Spodoptera exigua* (Hübner) (Eggs usually laid on the upper leaf surface beneath the uppermost plant canopy and covered with white hair-like scales from the female moth's body.)

Plate 2-16. Young beet armyworm, *Spodoptera exigua* (Hübner), larvae (Usually feed in a group near where the eggs were laid, skeletonizing the leaf; often spin silk over the feeding site.)

Plate 2-17. Beet armyworm, *Spodoptera exigua* (Hübner) (Usually have a black spot on the side of the body above the second true leg. Color may vary from green to very dark green or black with lighter stripes on the sides of the body.)

Plate 2-18. Female strawberry spider mite, *Tetranychus turkestani* Ugarov and Nikolski: immature stage and an egg. (The large dark body spots are typical of several spider mite species, although the adult carmine, *Tetranychus cinnabarinus* (Boisduval), and desert spider mites, *Tetranychus desertorum* Banks, are carmine and red in color, respectively.)

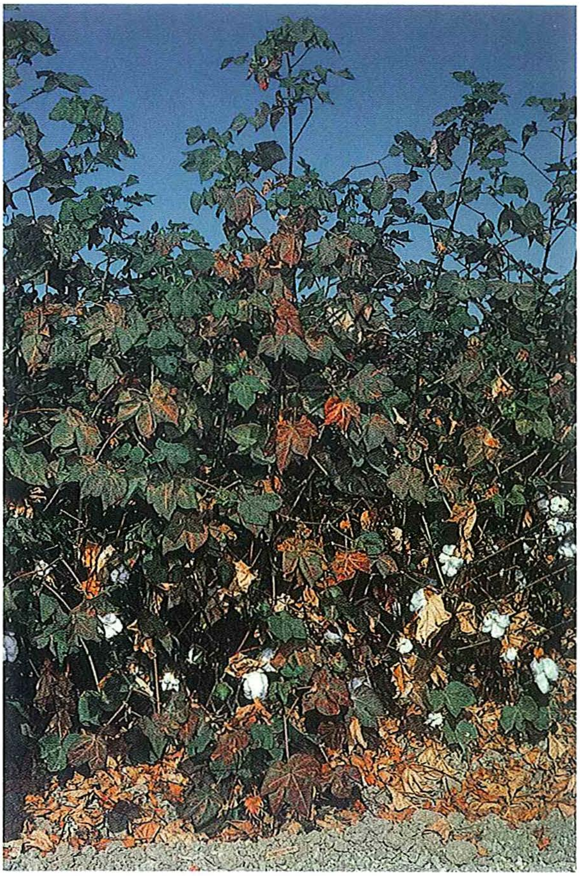

Plate 2-19. Spider mite damage symptoms. (Reddening of the leaves in small to large areas of fields and defoliation.)

Plate 2-20. Moth of the cotton leafworm, *Alabama argillacea* (Hübner). (Shows typical olive-tan color and three wavy transverse bars on the forewings.)

Plate 2-21. Larva of the cabbage looper, *Trichoplusia ni* (Hübner). (Alfalfa looper is similar in appearance.)

Plate 2-22. Cotton leafworm, *Alabama argillacea* (Hübner). (Illustrates distinctive white rings on the dorsum.)

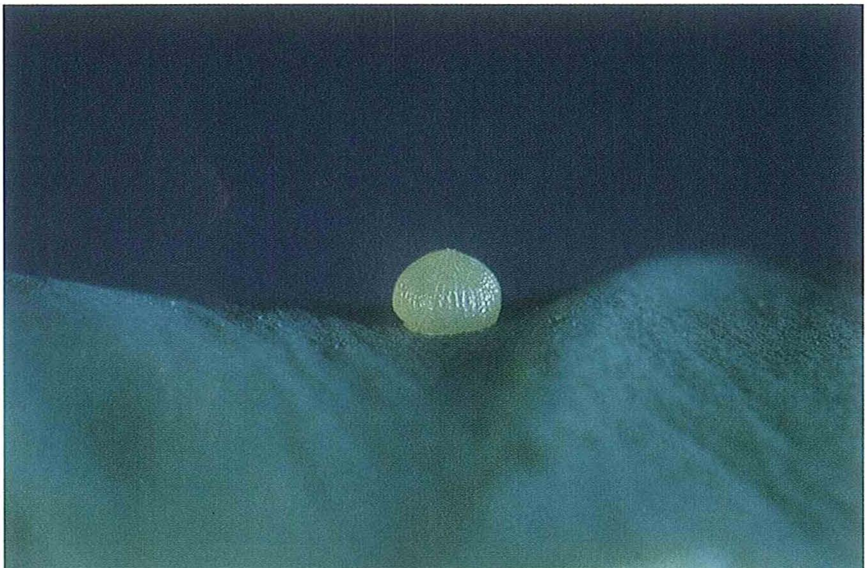

Plate 2-23. Egg of the cabbage looper, *Trichoplusia ni* (Hübner). (Usually laid on the more mature leaves and is more flattened than bollworm eggs.)

Plate 2-24. Adult cotton leafperforator, *Bucculatrix thurberiella* Busck.

Plate 2-25. Cotton leafperforator, *Bucculatrix thurberiella* Busck, damage symptoms (mines) made by young larvae.

Plate 2-26. Fifth-instar cotton leafperforator, *Bucculatrix thurberiella* Busck, larva. (Fourth- and fifth-instar larvae skeletonize leaves.)

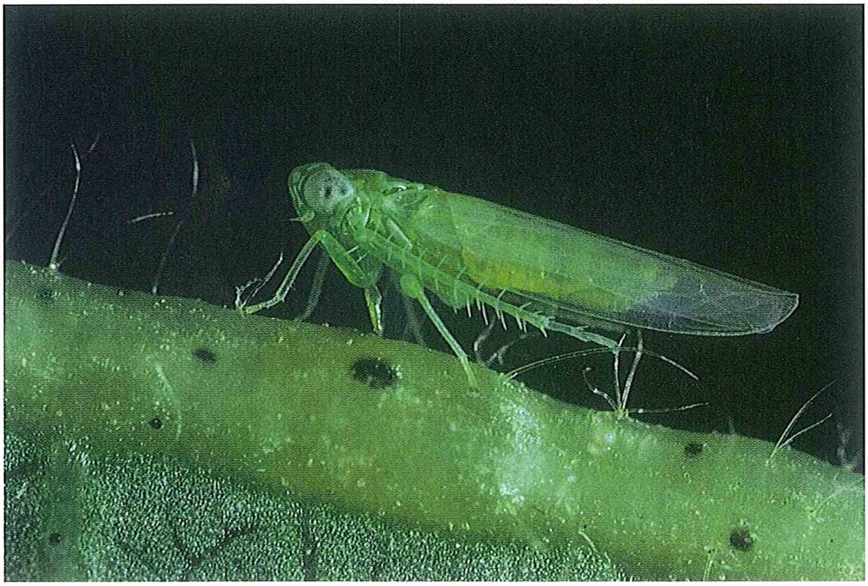

Plate 2-27. Potato leafhopper, *Empoasca fabae* (Harris), feeding on a leaf vein. (Feeding by this species and the southern garden leafhopper, *Empoasca solana* DeLong, causes veins to become swollen and rough.)

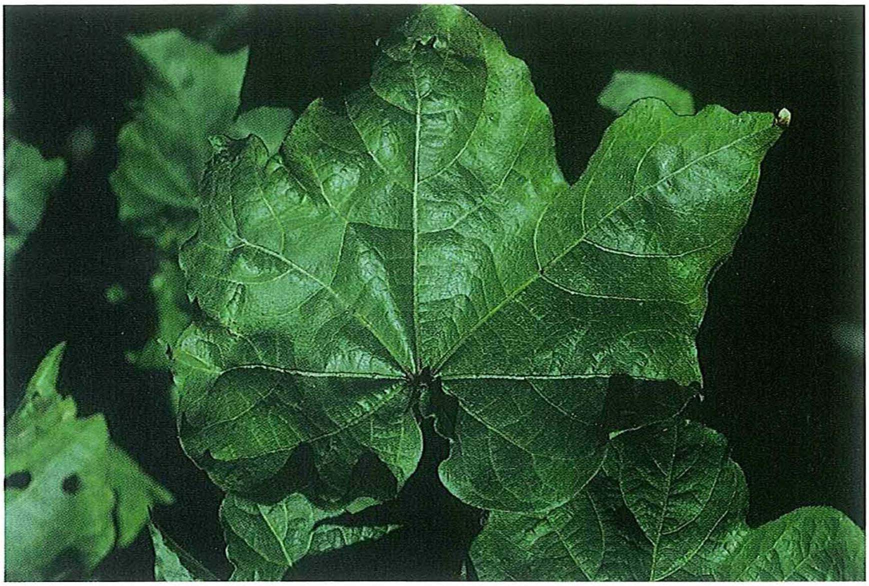

Plate 2-28. Potato leafhopper, *Empoasca fabae* (Harris), damage symptoms. (Cotton leaf illustrating cupped crumpling and discoloration.)

Plate 2-29. Colony of cotton aphid, *Aphis gossypii* Glover, on a lower leaf surface. (Shows light and dark forms of the aphid as well as winged and wingless types.)

Plate 2-30. Honeydew contaminated lint. (Honeydew excreted by aphids and whiteflies supports growth of sooty mold.)

Plate 2-31. Silverleaf whitefly, *Bemisia argentifolii* Perring and Bellows. [This species cannot be distinguished from the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), or the iris whitefly, *Aleyrodes spiraeoides* (Quaintance) except in the pupal stage.]

Plate 2-32. Bandedwing whitefly, *Trialeurodes abutilonea* (Haldeman). (Illustrates dark bands on the wings of adults. Immature stages of this pest are also evident.)

Plate 2-33. Adult of the western flower thrips, *Frankliniella occidentalis* (Pergande).