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ENY-830

UF UNIVERSITY of FLORIDA IFAS Extension

Cotton Pest Monitoring Manual for Florida[1]

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Sampling for Insect Pests of Cotton

Of all the different types of sampling and monitoring that may be carried out on cotton, insect sampling requires the most time during the growing season. One of the main reasons for this is that new insect problems which may occur weekly can be corrected with appropriate management procedures. Despite the fact that insect sampling consists of simple procedures--determining square retention, estimating damage, and counting insects and stages present--it is a very powerful tool that is necessary for successful crop management.

Sampling is generally done weekly prior to the pinhead square stage (5 to 6 true leaves). Thereafter for approximately the next 12 weeks insect monitoring should be carried out twice weekly at intervals of 3 to 4 days (Table 1).

Because relatively few plants are checked in the sampling process, it is extremely important for a scout to take representative samples in a field. That is to say, plants in a sample should be selected because they are typical of the plants in the general area and not because they are easy to sample (small, isolated, etc.) or because they differ from all of the other surrounding plants. In addition, samples should be taken from all areas of the field--front to back, side to side, as well as the middle. To create variability in the sampling pattern, scouts should develop the habit of entering the field at a different point each time it is sampled and walk varied routes in the field.

When it comes to the number of samples to take a good rule is the more the better. On uniform fields, five samples of ten plants each (a total of 50 plants per field) is the absolute minimum to have confidence in the scouting report. It is easy to justify additional samples for the following reasons: 1) your samples show that a pest is near threshold. Additional samples will help clarify the number of the pest present. This could save a treatment if the population is just under threshold or justify a treatment and avoid losses if the population is just over the threshold. 2) It is necessary to determine the extent of an infestation. For example, if four samples fail to pick up a particular pest while the fifth sample shows a moderate to high level of the pest, additional samples should be taken in the vicinity of the fifth sample to determine how widespread the "hotspot" is. 3) The field has developed uneven spots which may differ in their attractiveness to insect pests.

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Finally, regardless of how well a field is scouted it is impossible to determine if one or more pests have reached threshold if the numbers obtained are not properly summarized. For this reason, it is important for a scout to be familiar with the calculations involved and the thresholds on which the need to treat are based.

Although there are other insects that are capable of causing economic damage in cotton those discussed below are the ones most likely to be encountered in Florida (Table 2). A summary of the generally-accepted thresholds used for the pests discussed below is presented in (Table 3).

Cutworms

Description

Several species of cutworms are capable of causing stand loss to cotton in Florida although the most common appears to be the granulate cutworm, *Feltia subterranea*, (Fabricius). The adult stage of the granulate cutworm is seldom seen by cotton scouts. It is a night-flying moth with a wingspan of approximately 1 1/4 inches and mottled gray coloration. Eggs are pale yellow about the size of a bollworm egg and laid on plant stems near the soil surface. Larvae are smooth, and plump-looking with indistinct dark markings on a gray to dark brown background. Larvae are usually not readily evident during the daytime. However, if found they will invariably curl up into a tight "C" shape.

When fully grown, larvae are nearly 1 1/2 inches in length. Pupation occurs several inches below the soil surface. Pupae are approximately 3/4 inch in length and a shiny, mahogany color.

Life Cycle

Depending on temperature, the egg stage may last up to two weeks although 5 to 7 days is more common. The length of the larval stage is also very variable. In Florida, the granulate cutworm is able to overwinter as larvae meaning that this stage may last 4 to 5 months. Under optimum conditions the larval stage requires only two weeks to complete. After digging several inches into the soil, the larvae make cells in which they pupate for 1 to 2 weeks. Under optimum conditions the entire life cycle requires 30 to 35 days to complete.

Figure 1. Cutworm in soil.

During the day, the larvae remain on the soil surface or in cracks in the soil and move up on the cotton plant to feed only at night or during very cloudy weather. Because of the habit of resting in the soil and because they pupate in the soil, soaking rainfall will, on occasion, greatly reduce cutworm populations. This occurs not only due to physical damage (drowning) but also because water logged soils cause the cutworms to move onto the plants during the day where they are exposed to parasites and predators.

Although cotton is a suitable host for the granulate cutworm, the larval population which reduces the cotton stand at emergence is frequently not the result of the moth laying eggs on cotton. Rather, these larvae develop from eggs which were laid on weed hosts growing in the field prior to planting cotton. After these weeds were destroyed through the use of herbicides or tillage, the remaining cutworm larvae move to cotton when it emerges. Therefore, it is possible to have half-grown or larger larvae doing considerable damage to seedling cotton.

Damage

Cutworm larvae may cut off cotton plants from the time they emerge up to the time they have reached the 2 to 3 true leaf stages. Cotton this age or older is usually free from clipping damage however damage to individual leaves may still occur. After cutting off seedling cotton, cutworms may either leave the entire

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plant on the ground or may eat all or part of the stem. Frequently, several consecutive plants in a row may be cut off during a single night by one cutworm larva. The end result of cutworm feeding damage is stand reduction in scattered areas across a field.

Sampling

Routine field sampling for larvae of the granulate cutworm is not practical. As soon as cotton emerges (4 to 7 days after planting), fields should be checked weekly for cutworm damage (cut plants or missing plants). If damage is found, the soil around the bases of cut plants should be checked to confirm the presence of cutworm larvae. Usually the larvae are no more than 1/4 to 1/2 inch below the soil surface within 6 to 8 inches of the row. After confirming the presence of cutworm and noting their size, it is necessary to estimate the extent of damage (% of field affected and location of damage).

Threshold

Determining a course of action after confirming the presence of a cutworm problem in seedling cotton requires that several factors be taken into consideration. For example, despite an infestation, a field may not require treatment if the remaining plant population is at least 25,000 to 27,000 plants per acre (Table 5). Unfortunately, cutworm damage across a field is usually not uniform. For example, some areas may be destroyed completely while others are unaffected.

In some cases, replanting may be justified but only after taking into consideration the availability of soil moisture for replanting, adequate time for replanted cotton to mature before cold weather, etc. Needless to say each cutworm problem must be evaluated individually and specific thresholds cannot be given.

Thrips

Description

There are several species of thrips (*Frankliniella* spp.) which feed on cotton. All are small (1/15 to 1/20 inch in length) slender and highly mobile. Depending on species, stage, environment and other factors their color may be black, tan, yellowish-brown, or pale orange. The adults have wings that are long, slender and fringed with hairs. The wings and other features of the thrips are best observed using a 10X hand lens. The immature stages are wingless and generally pale-colored.

Figure 2. Closeup of thrips adult (left) and nymph (right).

Life Cycle

Adult thrips migrate to seedling cotton from wild and cultivated hosts in the vicinity of the cotton field. On cotton, the adult female thrips inserts her eggs individually into leaf tissue. The eggs hatch in about six days after which the larvae undergo two molts over a period of 6 days before pupating. The prepupal and pupal stages require an additional four days resulting in a life cycle from egg to adult of approximately 16 days. The adults may live for 35 days during which the female may lay 500 or more eggs.

Damage

Thrips feed on plant juices using modified sucking mouthparts. They prefer to feed on tissues that are in the process of expanding or developing. This feeding behavior results in stunted plants and distorted, crinkled leaves. Heavy infestations may destroy terminal buds causing excessive branching and delayed maturity. Thrips damage is generally more severe during dry weather when plant growth is reduced, at-plant granular insecticides are poorly taken up by the plant, and the number of thrips migrating from senescing hosts is high. Generally, by the time cotton reaches the five true leaf stage, it is beyond the point at which thrips can cause damage.

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Figure 3. Typical thrips damage on cotton.

Sampling

Because the thrips prefer to feed and rest in folds in plant tissue and because they move quickly when disturbed, accurate sampling may be difficult. However, by pulling seedling cotton plants and shaking the terminals into a 16 oz. plastic drink cup or a small white box, dislodged thrips (larvae and adults) may be counted relatively easily. On average-sized fields, five to ten plants in ten different areas should be sampled in this way. Calculate the average number of thrips per plant. Also note the presence of thrips feeding injury to the plants and if larvae, adults, or both stages are present.

Threshold

If plants show evidence of thrips feeding damage and there are 2-3 or more thrips per plant, treatment with a foliar insecticide is usually justified. If the population is made up of larvae as well as adults, the at-planting granular insecticide is probably not being taken up by the plants. If the population is made up almost entirely of adults, it is reasonable to assume that the granular insecticide is being taken up controlling the larvae but high levels of migration by adults are maintaining the adult population on the cotton.

Plant Bugs

Description

Adult tarnished plant bugs, *Lygus lineolaris* Palisot de Beauvois, are approximately 1/4 inch in length and flattened on top when viewed from the side. They are predominately dark with white, yellowish-brown, and reddish-brown markings. There is a cream-colored y-shaped mark on the scutellum (the triangular-shaped area located between the bases of the front wings.

The nymphs of the tarnished plant bug are wingless and pale green frequently with four conspicuous black spots on the thorax (the body section between the head and abdomen). Older nymphs have small wing pads.

Figure 4. Adult tarnished plant bug on cotton square.

Life Cycle

The tarnished plant bug overwinters as an adult. Adults migrate to cotton in the spring and begin to feed and lay eggs. The white, curved, eggs are inserted into the cotton plant. After an incubation period of 7 to 10 days, the eggs hatch into first stage nymphs. There are five nymphal stages requiring a total of approximately two weeks to complete. The last stage nymph develops into an adult. The entire life cycle requires from 20 to 30 days.

Damage

Both the nymphs and adults feed by inserting their mouthparts into cotton plants and sucking plant juices. Although all above ground portions of the

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cotton plant may be fed upon, the fruiting forms are preferred and, of these, pinhead squares sustain the most damage. Soon after being fed on by a tarnished plant bug the pinhead square begins to change color, first pale yellow, then brown and finally dark brown to grey. The off-color, dead squares are referred to as "blasted" and show no external signs of feeding injury. However if an off color square is carefully sliced in half using a single edge razor blade or sharp pocket knife the feeding damage may be readily seen with a good hand lens. Inside the square, the damaged anthers are brown, and frequently shrunken. As the time from feeding to examination increases, the contents of a square take on a dark, jelly-like consistency. In contrast, physiological stress which occasionally causes square loss appears as uniform color changes and shrinkage leading to "mummified" contents.

Older squares may not be shed but rather develop to form misshaped bolls due to poor pollination. On bolls, feeding sites appear as small, dark, shrunken areas. Under extreme feeding pressure, a condition referred to as "crazy cotton" develops. Symptoms include split lesions on the stems and leaf petioles, aborted terminals, fruitless, spindly lateral branches, and swollen nodes.

Sampling

There is no single sampling method that is adequate to assess tarnished plant bug populations under all situations. Nymphs are probably best sampled using a shake cloth (ground cloth). However, because of the flighty nature of the adults, a shake cloth will frequently not detect economic adult populations. A sweep net is occasionally an effective method to sample adults. Hoewver, under some conditions that are not fully understood, a sweep net will seriously underestimate the adult population. Also, a sweep net generally captures only a small portion of the nymphs. In addition, estimates may be low for all stages if sweeps are taken during the heat of the day as plant bugs tend to move lower on the plant in search of more shade. At this time, the best strategy appears to be a combination of sampling methods which include a sweep net for the adults and an estimate of square retention to measure the total impact of feeding by nymphs and adults.

To estimate the percent square retention on 6-leaf or older cotton, examine 50 to 100 plants, at random, across the field. To simplify sampling and recording, ten plants in each of five areas in the field may be checked. On each plant, look for the first position square that is at the base of the main stem leaf that is approximately the size of a half dollar. This square will be about 1/8 inch in diameter. Note whether the square is healthy or whether the square is off-color showing signs of tarnished plant bug feeding. If the square is missing, it should be recorded as tarnished plant bug injury. When all samples have been taken determine the percent healthy squares (percent square retention) by dividing the total number of squares checked into the number of healthy squares found and multiplying that number by 100.

Thresholds for tarnished plant bugs in cotton are based on the use of a 15 inch sweep net. Make 20 sweeps (one sample) at each of five representative areas of an field. During the heat of the day, tarnished plant bugs tend to move lower in cotton canopy. To obtain the best estimate of the population, samples should be taken in the morning as soon as the dew has dried. To use a sweep net swing the net through the foliage on one row of cotton. As plant height permits, the entire diameter of the net (15 inches) should hit the foliage. The rim of the net should strike the foliage perpendicular to the main stem. One way to get the correct rhythm is to take a sweep (one pass of the net through the foliage) on one row each time your foot strikes the ground when walking at a fairly fast pace between rows. As a gauge to determine if you are striking the foliage hard enough to catch tarnished plant bugs, check the contents of the net after 20 sweeps. If there are no cotton leaves present you are probably not striking the foliage hard enough. On the other hand, if there are more than 3-4 leaves present, you are probably striking the plants harder than is necessary.

After making 20 sweeps examine the contents of the bag carefully for adults and nymphs of the tarnished plant bug. Be aware that adults will fly readily and may leave the bag as soon as it is unfolded.

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Threshold

In cotton that is in the first four weeks of squaring, treatment for tarnished plant bug is justified if there are 6-7 tarnished plant bugs per 100 sweeps or if square retention is less than 80-85% and tarnished plant bugs are present in the field.

Cotton Aphid

Description

The cotton aphid, *Aphis gossypii* Glover, is a small soft-bodied insect that may vary in color from yellow to dark green to nearly black. Adult cotton aphids are approximately 1/12 inch in length, although considerable size variation is not uncommon. In addition to variations in color and size, the cotton aphid may be either winged or wingless.

One of the most characteristic features of the cotton aphid, as well as other aphids, is the presence of a pair of tubes called cornicles near the tail end of the insect. With a hand lens these are easily seen on the cotton aphid.

Figure 5. Cotton aphids on underside of cotton leaf.

Life Cycle

All adult cotton aphids are females. They reproduce parthenogenetically and give birth to living young. The immature aphids called nymphs develop to the adult stage in as few as five days under ideal conditions. A single female cotton aphid can give birth to as many as 10 young aphids per day. With the rapid life cycle and high rate of reproduction, the cotton aphid has a potential to develop large populations in a short period of time. However, the cotton aphid is a favored prey of a number of common predators in cotton. In addition, parasites and a fungal pathogen usually prevent the cotton aphid from maintaining large populations.

Damage

Cotton aphids may move into seedling cotton although typically populations do not reach high levels until July. Cotton aphids feed by sucking plant juices. On tender terminals and young leaves feeding may result in distorted growth which may include stunted plants and rolled or downward cupped leaves. Excessive feeding may cause wilting, chlorotic leaves and premature leaf loss. When feeding, cotton aphids secrete a sticky substance known as honeydew which drops onto leaves, bolls, and more importantly, lint. A fungus, using the sugars in the honeydew as an energy source, grows on the leaves, bolls, and lint resulting in a black growth called sooty mold. Sticky lint and black-stained lint reduce the quality of the cotton.

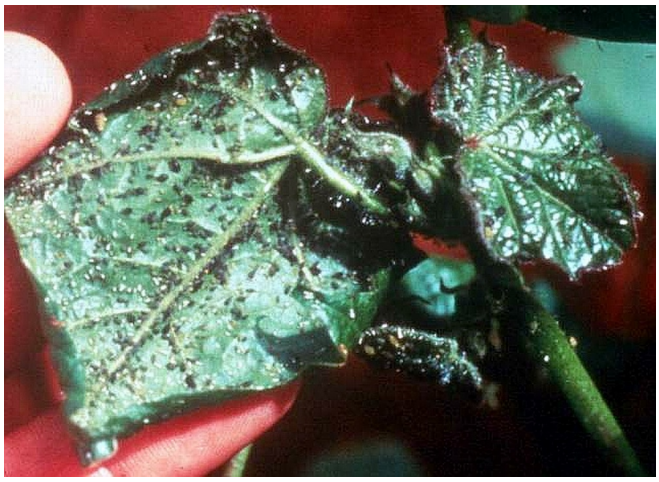

Figure 6. Typical cotton aphid feeding damage.

Sampling

At each sampling site, examine the terminals and undersides of the uppermost 3-4 leaves on 10 plants for the presence of aphid colonies. A colony is a group of 20 or more aphids. Record the number of plants out of the 10 examined that have colonies present. Also note whether leaf cupping and plant stunting are evident. If high numbers of cotton aphids are present, look for tan or gray "fuzzy-looking" dead aphids. This indicates that the fungal pathogen of the

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cotton aphid is present in the field and will probably control the population. In Florida, the fungus typically shows up in July.

Threshold

At the present time, the threshold for cotton aphids in Florida is 50% of the plants with colonies (20 or more individuals). However, ineffectiveness of existing chemical controls and a highly effective fungal pathogen support the elimination of a treatment threshold in most situations.

Budworm/Bollworm

Description

The tobacco budworm, *Heliothis virescens* (Fabricius) , and the cotton bollworm, *Helicoverpa zea* (Boddie), are closely related species which cause similar damage on cotton. They are nearly indistinguishable in the egg, larval, and pupal stages and both species are frequently referred to as "bollworms".

Eggs are nearly spherical, about the size of a pin head, and pearly-white when first laid. Later they begin to darken which first shows up as a reddish-maroon crescent in the egg. Just prior to hatch the eggs take on a grayish-brown color. With a hand lens, surface ridges extending from bottom to the top of the egg may be observed.

Newly-emerged larvae are approximately 1/16 inch in length with a dark brown body and black head. As the larvae grow the head color becomes lighter and the body develops a color that varies from yellow to brown to pink to green. The larvae have three pairs of true legs located just behind the head and five pairs of prolegs (four pairs of abdominal prolegs and one pair of anal prolegs). When full grown, larvae are approximately 1 1/2 inch in length. Larvae burrow into the soil and turn into reddish-brown pupae.

Unlike the immature life stages, the adult stage of the bollworm and budworm are easily distinguishable. The cotton bollworm moth has a wingspan of approximately 1 inch. On newly emerged moths, a dark spot is evident near the center of each forewing. A dark band crosses each wing

Figure 7. Cotton bollworm and feeding damage under bloom tag.

behind the spot. The hind wing is somewhat lighter in color with a dark border on the trailing edge. On older moths, the markings described above may be harder to see because wing scales are lost with age. Front wings of the tobacco budworm are cream-colored with four olive-green bands crossing each wing. Hind wings are cream-colored with few markings evident. On average, wingspan is slightly less than that of the cotton bollworm.

Figure 8. Adult cotton bollworm resting on cotton leaf.

Life Cycle

Both species overwinter as pupae in the soil. Soon after emergence, the female mates and begins to lay eggs on cotton. Each female is capable of laying 1000 or more eggs over a 7-10 day period. Eggs are laid singly on the terminal bud, either leaf surface, bracts, stems, petioles, blooms or bloom tags (dried

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flowers). Under drought conditions or late in the season, a greater proportion of eggs may be laid on the lower part of the plant. After an incubation period of about 3 days, eggs hatch. Larvae undergo six instars and pupate after feeding for approximately 14 days. After 10-14 days in the pupal stage the adults emerge. The entire life cycle requires 30 days.

Damage

On conventional cotton cultivars, damage is mainly evident on squares and terminals. Newly-hatched larvae feed on squares and terminals. This latter feeding activity gives rise to ragged terminals as the leaves unfold. On squares, larval feeding may be subtle where only the edges of the sepals (the leaf-like parts surrounding the developing petals) show feeding damage or severe with a hole chewed through the square. As larvae grow, they move down the plant feeding on progressively older fruiting forms (medium-sized squares, large squares, small bolls, and medium-sized bolls). Generally, bolls 14 days or older are not attacked by bollworms.

On Bt transgenic cotton cultivars, damage to terminals and squares is minimal. This is because the transgenic plants carry the gene from the bacterium *Bacillus thuringiensis*. As a result of this gene, a protein that is toxic to the tobacco budworm and the cotton bollworm is produced in the plant. The concentration of this toxin in the plant is sufficient to provide complete control of the tobacco budworm and 90-95% control of the cotton bollworm. Experience suggests that cotton bollworms hatching from eggs which were oviposited on blooms or bloom tags feed for a period of time on pollen. Data suggest that the concentration of Bt toxin in the pollen is low enabling these larvae to survive. For this reason, damage on the transgenic cotton cultivars has tended to be lower on the terminal and squares and concentrated on blooms and small bolls.

Other situations which could lead to the development of bollworm larvae on Bt transgenic cotton cultivars include larvae which migrated to cotton from a weed host in the field and larvae which are feeding on the 1-2% of the plants in a field which do not have the gene.

Sampling

For conventional cotton cultivars, use the standard 10 plant sample and check the top 10-12 inches of each plant for eggs, small larvae (up to 3/8 inch in length) and large larvae (over 3/8 inch in length). All plant surfaces including the squares and inside surface of the bracts need to be checked. Noting the average age of the eggs (pearly-white = 1 day old, crescent shaped mark = 2 days old, or dark gray-brown = 3 days old) will allow treatments to be more precisely timed. A minimum of 50 plants (5 samples) need to be checked in each field with more samples being taken in larger fields (>50 acres). The average number of eggs, small larvae, and large larvae are expressed per 100 plants. Most entomologists refer to number per 100 plants as percent eggs and percent larvae.

Scouting procedures will vary somewhat with the transgenic cotton cultivars containing the Bollgard gene. Because of the pattern of survival of cotton bollworm larvae on the transgenic cotton cultivars, a modified whole-plant inspection is necessary to adequately estimate the size of the population and the need for a chemical treatment. To conduct a modified whole-plant inspection, examine the terminal as for conventional cotton cultivars. In addition, also examine a white bloom, red bloom, bloom tag and a small boll on each plant in the sample for eggs and small larvae. For the blooms and bloom tags, examine all plant surfaces.

Threshold

For the conventional cotton cultivars in fields that have not previously been treated for the bollworm, the threshold is 30% eggs or 10% small larvae. On fields that have been previously treated, the threshold is 25-30% eggs or 5% small larvae.

For the Bt transgenic cotton cultivars there is insufficient data to establish an economic threshold at this time. However, experience suggests that 8-9 larvae 1/4 or more inch in length per 100 plants justifies treatment.

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Beet Armyworm

Description

Beet armyworm, *Spodoptera exigua* (Hubner), lays its eggs in masses containing from 40-60 eggs. The masses are covered with grayish scales from the female moth's body. Newly-hatched larvae are dark green with black heads.

As they grow the body color generally becomes lighter beneath while retaining a somewhat darker green color above. A fairly reliable characteristic for identifying the beet armyworm is the presence of a dark spot on each side of the body just above the middle pair of true legs (those located just behind the head). Other armyworms that may be found on cotton have dark spots located behind the third pair of true legs. In addition to the true legs, the beet armyworm also has four pairs of abdominal prolegs and one pair of anal prolegs. When fully-grown, larvae are approximately one inch in length and smooth in appearance.

Figure 9. Beet armyworm larvae feeding in cotton bloom.

The larvae pupate in the soil. The pupae are approximately 5/8 inch in length and are mahogany-colored with dark-green markings. The sexes of beet armyworm are similar in appearance. They have a wing span of approximately one inch. he front wings are grayish-brown with two yellow spots near the center. Perhaps the best characteristic for field identification of the adults is the translucent white hind wings with a brown border on each wing.

Life Cycle

The eggs are laid in masses generally containing from 40 to 60 eggs. Over her 10 to 14 day life span, a female may lay up to 600 eggs. The eggs hatch in 3 to 5 days. The larvae feed for approximately three weeks and pass through five instars before pupating. Generally, the first instars feed in a group or groups on the lower leaf surface near the egg mass. During the later instars the larvae tend to scatter and begin feeding on squares, blooms, and bolls.

The beet armyworm remains in the pupal stage for 10 to 14 days before emerging as an adult. Adults can go to cotton at any time of the year. Generally, hot, dry weather favors survival and/or development on cotton. There may be several generations on cotton each year in Florida. Although early literature suggests that the beet armyworm overwinters only in central and south Florida and occasionally on the gulf coast in the panhandle, recent observations indicate that it is able to routinely overwinter not only in north Florida but well up into Alabama and Georgia.

Unchecked, the beet armyworm has the potential to cause serious economic damage to cotton despite extensive use of registered chemical controls. However, the beet armyworm has a number of naturally-occurring parasites and predators. Although individually none has the ability to keep the beet armyworm under control together these biological control agents frequently keep this pest at sub-economic levels. One of the most commonly-encountered biological control agents is a parasite, *Cotesia marginiventris*. The adult females of the parasite search out small beet armyworm larvae and insert individual eggs into the larvae. The parasite larva hatching from the egg consumes the contents beet armyworm larva causing it to be stunted and ultimately killing it. The full grown *Cotesia* larva leaves the dying beet armyworm larva and pupates in a small, off-white cocoon attached to the leaf. It is this cocoon which is the stage of *Cotesia* that is most conspicuous and frequently seen by scouts. The life cycle of *Cotesia* (egg to adult) requires only 12 to 14 days.

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Damage

The first three instars of beet armyworm larvae are generally leaf feeders beginning first on the lower leaf surface in the vicinity of the egg mass. This damage is readily evident even when examining the leaf from above. These beet armyworm "hits" as they are commonly called appear on the top of the leaf as brown, irregularly-shaped dead areas.

Damage due to beet armyworm would be tolerable if feeding were confined to leaves. However, large larvae and occasionally medium-sized larvae also feed on squares, blooms, and small bolls. It is this feeding behavior coupled with its tolerance to most registered insecticides which make the beet armyworm a serious economic pest on cotton.

Sampling

Ideally, a population of beet armyworm on cotton would need to be identified in the egg stage to time chemical controls for maximum effectiveness. However, egg masses being placed in the lower portion of the plant on the bottom sides of leaves are difficult to locate which makes an accurate estimate of the population nearly impossible to obtain. For this reason, counting the number of hits (feeding damage done by small beet armyworm larvae) has become the accepted method for population estimate.

To sample hits, examine 20 to 40 feet of row at each of five locations in a field. At each location push the top of the cotton plant out of the way and examine the top surface of leaves in the lower part of the canopy for the characteristic dead, brown areas. If a hit is found, determine whether it is old or new (larvae still present) and if the *Cotesia* parasite is active (cocoons present on leaf). From the total number of new hits found on the 100 to 200 feet of row examined, calculate the number of hits per 100 feet of row. Also note the success of the beet armyworm at establishing (eg. sometimes only one larva survives from the egg mass) and the activity of *Cotesia* when making a scouting report or when considering the need for chemical control.

Although the above sampling method is appropriate after the beet armyworm has generally infested a field, an easier, more specialized sampling procedure will frequently detect low population levels in a field. This method is based on the ovipositional preference of the female moth. These locations include isolated plants in a field similar to those around a planter skip, weak plants similar to those found on poor soils in a field and, perhaps of most use, isolated plants on the edges of a field. By routinely checking these areas for hits, it is possible to identify when the beet armyworm is first trying to colonize a field. When hits are found in these areas, the more structured, intensive, field sampling described above should be initiated.

Threshold

Treatment for the beet armyworm is justified if infield sampling shows three or more active hits per 100 feet of row. If active hits contain only a few healthy larvae and/or *Cotesia* cocoons are numerous, a higher threshold is probably justified.

Fall Armyworm

Description

The adult fall armyworm, *Spodoptera frugiperda* (J.E. Smith), has dark gray forewings with light gray mottled areas. The hind wings are light gray with a dark border. The wingspan is approximately 1 1/4 inches. Eggs are laid in masses which are covered by scales from the females body. The fuzzy-looking gray masses may contain up to 150 eggs. Newly-hatched larvae are dark-colored and slightly over 1/16" in length. Older larvae vary from tan to greenish-brown to nearly black with light-colored strips running the length of the body.

An inverted light-colored Y on the dark-brown head is a good characteristic for field identification of larger fall armyworm larvae. Another fairly reliable characteristic is the presence of four round dark spots on top of the last body segment. These are arranged to mark the corners of a square and they are visibly larger than the dark spots found on the side of the body. Many fall armyworm larvae have a conspicuous mark on each side of the body just behind the third pair of true legs (those present just behind the head). Larvae burrow into the soil and develop into a reddish-brown shiny pupae.

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Figure 10. Fall armyworm lava and typical bract etching damage on cotton boll.

Life Cycle

The ability to diapause has not been demonstrated in the fall armyworm and its overwintering success is apparently largely determined by the severity of the winter. Although a severe winter may eliminate the fall armyworm from an area, the strong flying capability of the adult moths allow for rapid colonization of hosts in north Florida in early spring. Generally the fall armyworm does not move into cotton in Florida before mid to late July. In cotton, the female moth lays its eggs on the bottom sides of older leaves. After an incubation period of 3-6 days, the larvae hatch. After first consuming most of the eggshells leaving little trace of the egg mass, the larvae begin to move to squares, open blooms and small bolls. In rank cotton, first instar fall armyworm larvae begn feeding on the inside of boll bracts on the lower portion of the plant. Larvae develop through six stages (instars) requiring, on average, 48, 35, 31, 32, 51, and 93 hours for instars 1-6, respectively. Pupation occurs in the soil and adults emerge after approximately two weeks.

Damage

The first damage on cotton plants by small fall armyworm larvae is frequently feeding on bracts of small bolls and squares. This feeding on the inner surface of the bracts is commonly referred to as etching or window paning and appears as brown areas on the bracts. As larvae grow, they begin to feed on small bolls and squares. Larger larvae are able to damage full-sized immature bolls by chewing a hole into the base of the boll where the bracts are attached. Because of the extended period of time spent in instars 5 and 6 (approximately 6 days) this damage can be quite severe. Although, it probably does not result in significant damage, all stages of larvae may be found in white blooms feeding on anthers, pollen, and petals. Characteristically, fall armyworm larvae do very little leaf feeding on cotton.

Sampling

Sampling for fall armyworms on cotton is difficult. Best results are generally obtained by concentrating sampling efforts on lower half of the cotton plant beginning early to mid July. Cotton plants should be pushed back and the small boll and square bracts along a 2-3 foot section of row scanned for etching. On a 10 plant sample, the bracts on all squares, blooms, and bolls on the lower half of each plant should be opened and examined for the presence of larvae. White blooms in the sample should be inspected for larvae in the bloom. A minimum of 50 plants (5 samples) should be examined per field.

Threshold

Currently, fifteen to twenty fall armyworm larvae 1/2 inch or less in length per 100 plants is regarded as a treatment threshold. However, there is considerable data which show that each fall armyworm larva causes considerable less damage than a bollworm larva. Therefore, with support of additional data the treatment threshold will probably be raised to 15-20 small larvae/100 plants. Because of problems with coverage and general tolerance to registered insecticides, larger larvae are rarely controlled with chemical treatments.

Whiteflies

Description

There are two principle species of whiteflies on cotton in Florida.

One, the banded-winged whitefly, *Trialeurodes abutilonea* (Halderman), is generally distributed throughout the cotton growing areas of state while the second, the sweetpotato whitefly, *Bemesia tabaci*

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(Gennadius), is largely confined to the eastern part of north Florida. The sweetpotato whitefly is also known as the poinsettia whitefly and the cotton whitefly.

Figure 11. Banded-winged whitefly on underside of cotton leaf.

Figure 12. Adult sweetpotato whiteflies and eggs on underside of leaf.

Eggs of the whitefly are white when first laid and are oval in shape with a slightly pointed end. They are small (less than 1/100 inch in length) and, in the case of the sweetpotato whitefly, laid with the blunt end touching the leaf on the lower leaf surface. Prior to hatch the eggs turn light brown. Eggs of the banded-winged whitefly are laid on their sides on the bottom of the leaf. The first nymphal instar, also called the crawler, is oval in outline and is able to move about the leaf presumably allowing it to find a suitable feeding site. In cross section, the crawler is convex. The color is whitish-green and on each side of the body there is a yellow spot.

The second through fourth nymphal instars are immobile feeding stages found on the lower leaf surface. These instars are all greenish-white to greenish-yellow in color and become progressively larger (fourth instar 1/30 inch in length). Unlike other insects with a pupal stage there is no molt between the fourth nymphal instar and the pupal stage in whiteflies. The pupa is approximately 1/30 inch long and elliptical in outline. In cross section, the pupa of the sweetpotato whitefly is greatly flattened often appearing as a slightly raised area on the leaf. Probably the most conspicuous feature of the pupa is a pair of red spots near the front end. These are the eyes of the adult stage seen through the integument of the pupa. The background color of the pupa is yellowish-green. The pupa of the banded-winged whitefly is gray to nearly black in color. Unlike the flattened pupa of the sweetpotato whitefly, the pupa of the banded-winged whitefly has parallel sides appearing columnar in vertical cross section. No eye spots are evident. The adult stage is approximately 1/25 inch in length and is probably the stage most frequently seen. In flight, the adult appears as a small, white gnat. Although the whitefly has the appearance of a fly in flight, it has piercing/sucking mouthparts and is more closely related to aphids and scales.

Adults of the two species of whitefly may be easily distinguished with a 10X hand lens when they are at rest on a leaf. As the name suggests, the banded-winged whitefly has two light gray, irregular bands going across its wings. The sweetpotato whitefly lacks the bands but has snow-white wings folded over a lemon-colored body.

Life Cycle

The length of the life cycle of the sweetpotato whitefly varies greatly not only with temperature but also with host. For example, at a constant temperature of 80°F the time to develop from egg to adult is as short as 19 days on sweetpotato to as long as 30 days on carrot. Cotton is intermediate at 22 days from egg to adult. For the egg, first through fourth instar nymphs, and pupa stages, the development times are 8, 3, 3, 4, 2, and 2 days, respectively. Adults live between 8 and 12 days and the females have a preovipositional period of approximately 5 days.

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During her reproductive period, the female lays from 50 to 75 eggs. The banded-winged whitefly has a slightly longer life cycle and lower rate of fecundity.

The sweetpotato whitefly has an extensive host range which includes more than 500 species of plants representing 74 families. It is probable that few annual broadleaves or grasses found in north Florida are unsuitable as hosts for the sweetpotato whitefly.

Damage

Both the adult and nymphal stages of whitefly damage cotton by piercing plant tissues and withdrawing sap. Under extreme populations, feeding causes reduced plant growth, some leaf shedding, decreased number of bolls, and smaller bolls. Also, as a by-product of feeding activity, the whitefly secretes honeydew. This results in sticky cotton and gives rise to sooty molds which may reduce photosynthesis and stain lint, lowering quality. In addition, the sweetpotato whitefly is known to transmit at least 19 viruses or virus-like agents. In cotton the only virus known to be transmitted by the sweetpotato whitefly is the cotton leaf crumple virus. At this time, this virus is not known to occur in the southeast.

Sampling

Sampling procedures consist of a two step process that will 1) detect the presence of whiteflies and 2) identify the species composition of the population and give an estimate of the number of whiteflies present. Sampling for the first part consists merely of observing for the presence of whiteflies in flight as plants are handled when sampling for bollworm eggs and larvae. If whiteflies are seen under these circumstances, the fifth mainstem leaf from the terminal should be turned over and examined for the presence of adults. If three or more adults are present, count the leaf as infested. Turn over 30 to 50 leaves per field and note whether they are infested. On several leaves, carefully inspect the adults or pupae and record the percent banded-winged and sweetpotato whitefly present.

Threshold

If 50 to 60% of the leaves turned over have at least three adult whiteflies present, treatment is usually justified. If cotton is beginning to open and sooty mold is already present immediate action is warranted.

Loopers

Description

Two species of loopers may be found in Florida cotton. Of the two, the soybean looper, *Pseudoplusia includens* (Walker), is the most common. The other, the cabbage looper, *Trichoplusia ni* (Hubner) only occasionally infests cotton. The adult soybean looper is a mottled gray to black moth with a wing span of approximately 1 1/4 inches. On each front wing there is a bright white mark that resembles two connected circles.

Eggs are about the same size as those of the bollworm but are somewhat flattened. Eggs hatch into greenish, nearly-transparent larvae that are slightly over 1/16 inch in length. As the larvae grow they take on a green color similar to that of cotton leaves. The looper has several thin white stripes down both sides and a pair of stripes down its back. The most characteristic feature of the looper that distinguishes it from other worms on cotton is the presence of only three pairs of prolegs (the fleshy legs toward the rear end of the body). In addition to one pair of anal prolegs there are two pairs of abdominal prolegs.

Large soybean looper larvae are occasionally marked with black spots on the body and black true legs (the three pairs of legs just behind the head). This characteristic is not consistent and individuals in a field may be marked with black while others lack the coloration. Larvae also have a characteristic crawling movement from which their name is derived. Larvae crawl by looping which is reaching out with the front part of the body and grasping the leaf with their true legs.

Pupae are green with dark, nearly black markings. They are located on the undersides of cotton leaves and are held in place with numerous strands of webbing

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Figure 13. Soybean looper larva on cotton leaf.

Figure 14. Typical soybean looper feeding damage on cotton.

Life Cycle

Like the bollworm, looper eggs are laid singly on cotton leaves but unlike the bollworm, looper eggs are placed on the older leaves in the middle of the canopy. Eggs hatch in approximately four days and larvae feed 14 to 21 days before pupation. The pupal stage lasts for 12 to 14 days and a generation requires approximately 35 days to complete. Generally, there is only one generation per year on cotton in Florida.

Damage

Soybean loopers feed only on cotton leaves and do not damage fruiting forms. However, high populations are able to defoliate plants completely causing losses.

Damage by small to mid-sized larvae appears as shot holes in cotton leaves located in the lower part of the canopy. As larvae grow they eat more of the area between the leaf veins giving the leaves a net-like appearance. Full grown larvae may consume all of the leaf tissue except the largest veins.

Sampling

Because of their coloration and location within the cotton canopy, looper larvae cannot be accurately sampled using the direct observation method like that used for bollworm larvae. If in sampling a field, looper larvae or their characteristic leaf feeding damage is seen, the population needs to be estimated using a shake cloth or ground cloth. To take a sample, place the shake cloth on the ground so that it completely covers the row middle between adjacent cotton rows. Bend the plants along three feet of row along one edge of the shake cloth over the cloth and shake or beat the plants to dislodge any larvae present. Push back the plants and count the looper larvae on the cloth. Note the size distribution of the larvae. On most fields, five to ten samples should be taken to get an accurate estimate of the looper population. After sampling a field, calculate the average number of looper larvae per foot of row keeping in mind that each sample represents three row feet.

Threshold

Treatment is usually justified if there are an average of 4 to 6 small to medium-sized larvae per foot of row. Late in the season after the cotton crop has been made chemical control is generally not considered to be necessary.

Stink Bugs

Description

Several species of stink bugs have been observed causing economic damage to cotton in Florida. The two species most commonly encountered are the southern green stink bug, *Nezara viridula* (Linnaeus), and the brown stink bug, *Euschistus servus* (Say).

Eggs of both species are barrel-shaped, cream-colored, and laid in orderly clusters on the undersides of leaves. Close examination of the eggs with a hand lens will reveal a ring of short spines around the top of each egg. There may be 10 to 50 or more eggs per batch.

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First stage nymphs are slightly more than 1/16 inch in diameter and resemble the adults except they are darker in color, tend to be more round in shape and lack wings. Small nymphs tend to remain clustered around the egg mass. Stink bugs undergo a series of molts (total 5 nymphal stages) growing larger with each one. In the last stage before molting into an adult, the stink bug nymph has small wing pads.

Figure 15. Adult southern green stink bug on a boll.

Life Cycle

Stink bugs have a very wide host range that includes virtually all of the cultivated row crops and many of the weeds found in north Florida. Generally, stink bugs do not move to cotton before late August although in some years July populations have been observed. The drying down or harvesting of their host appears to be the main factor causing movement to cotton.

The eggs require an incubation period of 5 to 10 days. The nymphal feeding period requires 35 to 37 days. Unlike many other insects which mate and begin to lay eggs soon after reaching the adult stage, stink bugs have a pre-ovipositional period (the time from adult emergence to first eggs) of 17 to 20 days. The life cycle of the stink bug requires nearly 60 days to complete.

Damage

Stink bugs can damage large squares although undoubtably more damage is done to small to medium-sized bolls. In all cases, damage is the result of feeding where the stink bug inserts its mouth parts into the fruiting forms and takes up plant juices. Perhaps more importantly, while feeding the stink bug introduces digestive enzymes to liquify the carbohydrates and proteins in the cotton plant. The plant reaction to feeding and the enzymes in particular results in squares and small bolls turning yellow and falling from the plant. Larger bolls may either form hard acorn-like mummies on the plant or develop hard lock when the bolls begin to open.

Sampling

Obtaining an accurate population estimate of stink bugs on cotton presents a difficult sampling challenge. Because of their tendency to readily drop from the plant when disturbed, conventional single plant samples are inadequate. Likewise, a shake cloth may give erratic results particularly for the adults. However, if care is taken when placing the cloth under the plants to avoid dislodging the adult stink bugs, a shake cloth can provide useful information on the size of teh nymph population and in many cases the adult population as well. Ten to 20 three-foot shake cloth samples need to be taken per field to obtain an accurate estimate of population size. Adults and nymphs larger than 1/4 inch in diameter are included in the counts. Small nymphs are not able to penetrate the boll wall with their mouthparts and are unable to cause damage.

Sampling for damage to assess the impact of stink bug feeding has been adopted by a number of states. To obtain a damage sample, fifty bolls having the diameter of a quarter are selected per field. The bolls are opened and the seeds are examined for evidence of stink bug feeding. Seeds will be slightly off-color to brown where stink bugs have fed. Frequently the inside of the boll wall will be discolored or have an unusual growth as well.

Although samples need to be taken from all parts of the field particular attention should be given to the edges of the field bordoring on hosts of the stink bug that could give rise to the population moving into

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cotton. For example, peanuts that have been inverted or corn that is drying down both become unsuitable stink bugs hosts causing the adults to migrate to adjacent cotton fields.

Threshold

A population of 1stink bug per 6 feet of row using a shake cloth or 15-20% boll damage usually justifies a chemical treatment.

Spider Mites

Description

Several species of spider mites can cause damage to cotton but the most common and important in Florida is the *two-spotted spider mite, Tetranychus urticae,* Koch. Adult spider mites have four pairs of legs and are approximately 1/60 inch in length. Viewed from above they are oval and vary from yellow to pale green. The two-spotted spider mite gets its name from the presence of a dark area on each side of the body near the rear end. Eggs are spherical, smooth, shiny-white, and very small (less than 1/120 inch in diameter). The stage after the egg is called a larvae and has three pairs of legs. The larva molts into a nymph which has four pairs of legs. Both the larvae and the nymphs are straw-colored.

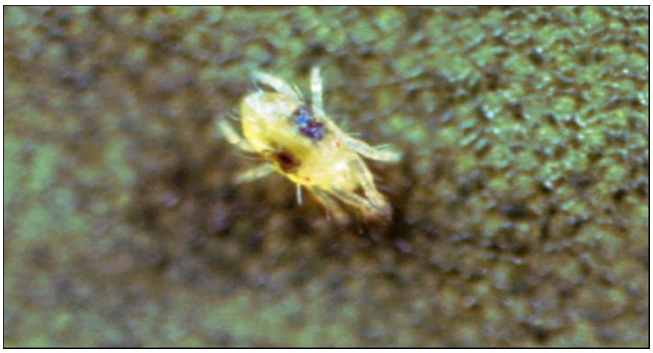

Figure 16. Twospotted spider mite, *Tetranychus urticae*, on leaf.

Life Cycle

All stages of spider mites may be found on the undersides of infested cotton leaves. Eggs require 1 to 3 days to hatch. The six-legged larvae feed for 2 to 3 days before molting into the eight-legged nymphs. Nymphs feed for 5 to 6 days before molting into the adult stage. The life cycle may be completed in as few as seven days but more commonly requires 10 to 11 days for a generation.

Since spider mites do not fly and are able to crawl very slowly, colonization of a field is usually assisted by mechanical means. These include farm machinery, people moving through fields or in some cases by spider mites riding the wind on a silken strand that they spin. However, they can also spread from wild hosts located near field margins, weeds around power poles in fields , etc. When moving from these areas or from a site of mechanical introduction in a field, the rate of spread is generally slow and inconspicuous. However, during periods of hot, dry weather the damage becomes more evident due to plant stress and the rate of spread more rapid because of conditions highly favorable for the spider mite.

Damage

Spider mite infestations usually first become evident as cotton leaves turn pale green and then yellow. On close examination, the yellow areas of the leaf appear stippled particularly at the base of the leaf where the veins join. These stippled areas are the feeding sites of the mites on the lower leaf surface. As damage progresses, more of the leaf takes on a white speckled look culminating in the leaf turning reddish or rusty brown while curling. Defoliation of these leaves generally follows.

Sampling

Because of the spotty nature of spider mite infestations, conventional sampling techniques frequently fail to detect economic populations. Rather than individual plant samples, spider mites should be monitored by looking for signs of off color dusty-looking irregular patches of cotton when you walk through a field. Because infestations frequently begin around trees, fence posts, poles, etc., these sites should be given particular attention. When off-color patches are found the presence of spider mites should be confirmed by turning the leaf over and examining the surface using a 10X hand lens. Pull several leaves from the infested area and estimate the number of spider mites according to the following scale: light 1-10, medium 11-25, and heavy more than 25 spider mites per leaf.

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Threshold

A population in an area that is rated as medium (average of 11-25 spider mites per leaf) is probably causing economic damage. However, if this area only occupies 50-100 square feet in a 50 acre field, treatment of the whole field is not justified. If at all possible, only the infested areas should be treated (spot treatment). Many times this will mean only one or two passes by a sprayer next to a fence row, one loop around a tree in a field or treatment of only one side of the field.

Minor Pests

There are several insects that are infrequent pests of cotton in Florida. Although the following are generally regarded as minor pests, some situations may allow the pest to develop to high levels and cause economic damage. For this reason, scouts should become familiar with the type of damage caused and the description of the pest to allow for correct identification.

Garden Webworm

The garden webworm, *Loxostege similalis* Guenee, shows up every year in a few cotton fields in Florida. It has a wide host range and is generally distributed throughout north Florida. The larva of the garden webworm is small (maximum length is 1 inch), has a black head, and a greenish body with a light stripe extending down its back. On the side of each segment, there are three conspicuous black spots. The adult stage is a moth with a wing span of approximately 3/4 inch. The wings are buff-colored with irregular markings in various shades of gray. The eggs are laid in masses of 2 to 20 eggs. Larvae hatch from eggs after an incubation period of about three days. After feeding for approximately three weeks, the larvae burrow into the soil and pupate. The pupal stage lasts from 7 to 10 days during the summer.

The garden webworm begins feeding in the terminals of cotton plants where they web the small leaves together. This shows up as "ragged" terminals as the leaves unfold. As the garden webworm larvae grow, they begin to feed on larger leaves under a fine web. Feeding damage rarely develops to this stage in Florida cotton. One of the best diagnostic characters for identification of the garden webworm in the field is that if the larva is disturbed it retreats into its web nest. If outside its web, it rapidly crawls backward or drops to the ground.

European Corn Borer

The European corn borer, *Pyrausta nubilalis* (Hubner), are only occasionally a serious pest of cotton in Florida. Generally, cotton fields located in the vicinity of extensive acreage of field corn are those most likely to be infested. Larvae of the European corn borer damage cotton by tunneling into the main stem of the upper portion of the plant. They may also tunnel into leaf petioles and more importantly into the bases of bolls. Tunneling into the terminal or leaf petiole results in flagging or wilting of the affected plant part. At the point of entry into the plant, there is usually a characteristic pile of sawdust-like material.

The female European corn borer moth lays it eggs in masses on the undersides of a cotton leaf. Typically, 5 to 40 eggs are laid in each mass. Eggs are off-white in color and flattened similar to fish scales. Eggs hatch in 3 to 5 days and on hatching the larvae proceed directly to a suitable site for tunneling. Larvae feed for 3-4 weeks before pupating either in the plant or in the soil. Larvae are flesh-colored with numerous dark spots. When full grown they are nearly one inch in length. The adult female moth is a pale yellowish-brown with irregular dark, wavy bands across the wings. The male moth is darker with the wings heavily marked with olive-brown. Both sexes have a wing span of about one inch.

Yellowstriped Armyworm

The yellowstriped armyworm, *Spodoptera ornithogalli* (Guenee), is a day-feeding species that generally causes only minor damage to cotton in Florida. The larva has a typical armyworm shape, that is, a plump-looking smooth body. The larva has a broad dark brown to velvety black stripe down the center of its back. On both sides of the stripe are a row of triangular-shaped spots bordered by a yellow to orange stripe. After feeding for approximately three weeks, the larvae pupate in the soil. The adult has a wing span of nearly 1 3/4 inches. The fore wing is blackish-brown with oblique yellow markings near

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the center. The wing veins are usually lighter in color. Eggs are laid in masses on the undersides of leaves and, like other armyworms, are covered with scales from the females' body.

The yellowstriped armyworm larvae are usually found in young cotton where they do little economic damage. Occasionally, they may be present in older cotton where they feed on squares and bolls. Under these circumstances, they can cause economic damage to cotton.

Cotton Leafworm

The cotton leafworm, *Alabama argillacea* (Hubner), is a very infrequent pest of cotton in Florida as it is a tropical species that does not overwinter in the United States. For an infestation to occur, the adult moth must fly or be carried by winds from the tropics of central and South America. The female lays its greenish-blue eggs singly on the bottom sides of cotton leaves. The adult has a wing span of approximately 1 1/2 inches. The front wings have wavy reddish lines and an oval dark spot near the center of each fore wing. The larvae are smooth, light to dark yellowish-green with three narrow white stripes down the back and one along each side. On each segment there are four black dots that form a square. Each black spot is surrounded by a white ring. The head capsule of the larvae also has a numerous spots. When fully-grown, larvae are approximately 1 1/2 inches in length. The larval stage lasts for approximately 15 days. The larvae pupate in flimsy cocoons on leaves. The pupal stage lasts for 6 to 10 days.

Larvae feed between the veins on the undersides of leaves skeletonizing them. The cotton leafworm is a voracious feeder and can rapidly defoliate a cotton field. Although, primarily a foliage feeder, the cotton leafworm can damage squares and small bolls.

Cotton Stainer

The cotton stainer, *Dysdercus suterellus* (Herrick-Schaffer) is a pest of cotton only in the southern part of the state. The cotton stainer is a true bug with piercing-sucking mouthparts. The adult is approximately 1/2 inch in length with a bright red head and pronotum (the "collar" behind the head). The remainder of the body is dark brown with crossed pale yellow lines on the back. The immature stages resemble the adults but are smaller and lack wings. Eggs are pale yellow and are laid individually on the cotton plant. Eggs hatch in about one week. The five nymphal stages require 21 to 35 days to complete. Medium to large-sized nymphs and adults feed on seeds in developing bolls. This feeding causes plant juices to ooze onto the lint staining it a yellow color.

Beneficial Insects on Cotton

Cotton fields that have not been treated with insecticides generally have a rich diversity of beneficial insects. In many cases, these insects are able to keep pest species at sub threshold levels eliminating one or more chemical treatments. Some of the more common beneficial insects found in Florida cotton are discussed below.

Assassin Bug

Assassin bugs (Hemiptera, Reduviidae) vary from one-half to more than one inch in length. Because of their size, they can easily subdue and kill medium to large-sized larvae their major prey in cotton. Occasionally when checking a field for insect pests, an assassin bug may be found with its long, sucking mouthparts stuck into a dead larva. The different species of assassin bugs vary in colors ranging from brown to black. In general the assassin bug is flattened and oval in shape with a narrow head and neck.

Bigeyed Bugs

As the name suggests, bigeyed bugs (Hemiptera, Lygaeidae) have large eyes which curve around the sides of the thorax. They can be very abundant in cotton but are difficult to find because of their small size (<1/8 inch in length) and their rapid movement. Adults are dark gray to black with clear wings. Nymphs are silver with small black spots. The oval eggs are cream-colored and are laid singly on the cotton plant. Occasionally when checking plants for bollworm eggs, bigeyed bug eggs are found. Adults and nymphs feed on a wide range of insect pests on cotton including aphids, thrips, immature plant bugs, small worm larvae and worm eggs.

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Hooded Flower Beetles

Hooded flower beetles (Coleoptera, Anthicidae) are small (approximately 1/8 inch in length) tan-colored insects with black markings. On close examination, a conspicuous forward extension of the thorax over the head is evident. This extension partially covers the head and is the basis for the common name. Although hooded flower beetles are known to feed on soft-bodied insects, their importance as predators has not been thoroughly studied.

Hover Flies

Larvae of hover flies (Diptera, Syrphidae) are common and important predators of aphids on cotton. The adults have yellow and black-striped abdomens and resemble small bees or wasps. They are usually seen hovering over flowers where they feed on pollen. The larvae are slug-like in appearance and range in color from creamy-white to green or brown. In large colonies of aphids it is not uncommon to see one or more hover fly larvae feeding on the aphids.

Lacewings

The green lacewing (Neuroptera, Chrysopidae) and occasionally the brown lacewing (Neuroptera, Hemerobiidae) may be common on cotton when aphids are abundant. The adults are 1/2 to 1/4 inch in length and are either green or brown (depending on the species). Their wings are held roof-like over their backs and each wing has many veins. The female lacewing lays her eggs in small groups, each egg held off of the plant surface on the end of a slender stalk. The larva is alligator-shaped and has long, sharply-pointed jaws ex-tending forward from the head. The larva uses its jaws to catch and hold its prey. In addition to aphids, the lacewing will also feed on insect eggs, thrips, immature whiteflies and small worms.

Lady Beetles

Several species of lady beetles (Coleoptera, Coccinellidae) are commonly found in cotton. Among the more common species are the twicestabbed lady beetle, *Chilocorus stigma*, a shiny, black beetle with a single orange spot on each front wing and the multicolored Asian lady beetle, *Harmonia axyridis*. This beetle was introduced from Japan several years ago and is now established over all of Florida's cotton production areas. It is a large beetle (slightly more than 1/4 inch in diameter) and variable in the number of spots and background color.

Nearly everyone is familiar with the general shape and coloration of adult lady beetles. However, larvae are sometimes misidentified as pests. The larvae, in general, have an alligator shape but, depending on the species, may be covered with spines or waxy secretions. Adult and larval lady beetles feed on a wide range of soft-bodied prey including aphids, spider mites, and immature whiteflies.

Minute Pirate Bug

Minute pirate bugs (Hemiptera, Anthocoridae) are very small (<1/16 inch in length) predators which feed on thrips, spider mites and worm eggs. Adults are black with white markings. Nymphs are orange and faintly resemble thrips. Both the adults and nymphs may be found in the folds of leaves in the terminals of plants and under the square bracts.

Nabid

Nabids, also called damsel bugs, (Hemiptera, Nabidae) are slender cigar-shaped insects. They are 1/4 to 3/8 inch in length and have conspicuous long legs and antennae. The adults are tan to brown with grayish wings. Nymphs are cream to light green in color. Both the adults and nymphs feed on aphids, small worms and worm eggs.

Parasitic Wasps

Although parasitic wasps are difficult to find in cotton, evidence of the presence of several species is common. After the parasite, *Lysiphlebus testaceipes*, kills a cotton aphid, a distinctive tan-colored aphid mummy remains attached to the plant. The wasp lays an egg in the aphid. Prior to the death of the aphid, the wasp larva fastens the aphid's body to the leaf with silk and glue. The larva pupates inside of the aphid mummy and after 4-5 days the adult wasp emerges and cuts a small circular exit hole in the top of the mummy.

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The beet armyworm parasite, *Cotesia marginiventris*, also leaves a distinctive sign of its presence. After this parasite kills a beet armyworm larva, it pupates in a small cream-colored cocoon that is attached to the cotton plant. Even after the adult wasp emerges, the cocoon will remain on the plant.

Nematodes on Cotton

Reniform Nematode

Life Cycle

The reniform nematode, *Rotylenchulus reniformis*, named for its "reniform" or kidney shape can be found on both cultivated and wild hosts throughout Florida. Tobacco, soybeans, and cotton are the most common cultivated hosts for reniform nematodes. Reniform nematodes do not infect corn, sorghum, or peanuts. Among the more common wild hosts are cocklebur, crotolaria, jimson weed, Florida beggarweed, and Florida pusley.

Reniform nematodes overwinter in the field as eggs, juveniles, or adults. Young females embed in the roots of a plant and begin feeding immediately after seeds germinate. Once the female enters the root and begins feeding, she becomes immobile and will begin laying eggs within 7-9 days. During this time, the female lays between 40-70 eggs which are deposited in a gelatinous mass loosely connected to the female. It is possible to see the egg mass with a hand lens. The female dies when egg laying is complete. The eggs can hatch immediately and reinfect the root or remain dormant and overwinter. The entire life cycle takes approximately 21 days.

Damage

Root systems infected with reniform nematodes may be stunted, but galls are not present as with other nematode species. Infected plants show a range of symptoms depending on growing conditions. Plants under stress may be severely stunted and show signs of severe potassium deficiency, whereas plants under ideal growing conditions may exhibit no detectable symptoms.

Root-Knot Nematode

Life Cycle

The root-knot nematode, *Meloidogyne incognita*, is named for the knot-like galls it produces on the roots of its host plants. Some common crop hosts of root-knot nematodes are soybeans, corn, millet, many vegetables, and tobacco. Grazing or cover crops such as wheat, rye, oats, barley, and most legumes are also susceptible to the root-knot nematode. Peanuts are not a host for the species of root-knot nematode that infects cotton. Wild hosts such as Bermudagrass, nutgrass, sicklepod, cocklebur, crotolaria, and cowpea may also serve as hosts for the root-knot nematode.

The life cycle of the root-knot nematode is very similar to that of the reniform nematode. Root-knot nematodes overwinter as eggs or juveniles. Both young male and female nematodes begin feeding on roots immediately after seeds germinate. The life cycle takes about 30 days, during which time the female lays between 500 and 3,000 eggs. As with the reniform nematode, the eggs are deposited in a mass loosely connected to the female. The female dies soon after egg laying is complete. The eggs may hatch immediately and reinfect the root or overwinter and hatch in the spring.

Damage

Root systems infected with root-knot nematodes will have swellings or galls which occur on the tap root, or more commonly, on the secondary roots. These galls reduce the water and nutrient uptake in the plant and cause premature drought stress. Above ground, the plant may be stunted 50% or more, and under drought stress wilt much sooner than other plants. Plants may also experience a nitrogen deficiency as evidenced by chlorosis or yellowing of the leaves. These symptoms are usually first noticed in sandy areas of the field.

Sampling

Nematode sampling is generally carried out to: 1) confirm a field diagnosis that was based on plant symptoms or 2) at the end of the growing season check for the presence of nematodes in a field that does not necessarily show any nematode problems.

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This later type of monitoring is sometimes called an advisory or predictive sample. For nematode samples to give correct results, the nematodes in the sample must arrive alive at the assay laboratory. Since nematodes may be killed from overheating, freezing, or drying, the samples should be protected from temperature extremes and protected from drying out.

To Take a Sample:

When diagnosing a suspected nematode problem, take 10-20 cores of soil near the living roots of the cotton plants showing symptoms using a cylindrical soil probe. Cores should extend into the soil 6 to 8 inches deep. When a sufficient number of cores have been taken, mix the cores together, breaking up any clods or soil clumps. Take approximately one quart of the mixed soil along with fine feeder roots and place it into a plastic bag. Label the bag and provide any additional information requested by the assay laboratory. Samples should be submitted to the laboratory as soon as possible.

If the sample is for advisory purposes, the sampling scheme is somewhat different. This kind of sample should be representative of the whole field. One sample should represent no more than twenty acres. Predictive sampling is cotton is generally most useful when samples are taken as soon after harvest as possible. The cores should be taken through the root zone to a depth of 6 to 8 inches in a regular pattern over the entire field. When the entire area has been sampled the cores should be mixed and the sample handled as for a diagnostic sample.

Samples for Estimates of Fertility Needs:

Nematode samples taken for advisory purposes may be divided into two parts with the second sample being submitted for analysis of fertility needs for the field. This sample does not need to be protected from temperatures or moisture extremes as the sample for nematode analysis.

Sample Analysis:

The University of Florida has both a Nematology Assay Laboratory and a Soil Testing Laboratory. Kits for submitting samples to these labs are available from the county extension office.

Equipment for Monitoring Pests of Cotton

Although cotton pests can be sampled without the use of specialized equipment, some "tools" make scouting easier and more efficient. Selected pieces of equipment mentioned in this manual are listed below. The sources listed as suppliers of the equipment are presented for informational purposes only. Comparable equipment may be purchased from numerous other companies.

Great Lakes IPM

10220 Church Road NE

Vestaburg, Michigan 48891

517/268-5693

15 inch heavy-duty sweep net for monitoring plant bugs and stink bugs ($25.00)

10X hand lens ($5.50-10.00)

Forestry Supplies, Inc.

P.O. Box 8397

Jackson, MS 39284-8397

800/647-5368

Soil sampling tube (1" core) for taking nematode samples and sampling soil for fertility needs (approx. $18.00)

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Table 1. Summary of Insect Monitoring Activities in Cotton

PLANT STAGE	INSECT	COMMENTS
Seedling	Cutworms	Look for cut/missing plants.
	Thrips	Pull 50 to 100 plants and count thrips.
Squaring	Bollworm	Examine 5 sets of 10 plants each for eggs and larvae.
	Beet Armyworm	Examine field border for hits. If found, examine 20 -to feet of row at 5 locations in field for hits.
	Plant Bugs	Make 5 sets of 20 sweeps each and count plant bugs. Determine square retention.
	Beneficials	When sampling for other insects, note abundance of beneficials.
First Five Weeks of Flowering	Bollworm, Beet Armyworm, Beneficials	Same as above.
	Plant Bugs	Same as above if field has not been treated for 14 or more days.
	Aphids	Examine leaves on 10 plants at five different areas and look for colonies, diseased aphids, etc.
	Spider Mites	Look for "dusty-looking" leaves in scattered areas. If found, confirm presence of spider mites and note level of infestation.
	Fall Armyworm	Examine the lower third of the palnts along three feet of row (10-15 locations in a field) for signs of feeding. These signs include bract etching and boll feeding. On the samples involving individual plants, open the bracts of all squares and bolls on the lower half of the plants and count the fall armyworm larvae.
Late Fruiting	Bollworm, Beet Armyworm, Fall Armyworms, Aphids, Spider Mites, Beneficials	Same as above.
	Whiteflies	When checking for other insects look for flying adults. If found, determine percent infestation
	Stink Bugs	Take 5 sets of 20 sweeps each and count stink bugs.
	Loopers	If leaf feeding damage seen, take 5-10 3-foot shake cloth samples and count larvae.

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Table 2. Common and Scientific Names of Cotton Insect Pests in Florida

COMMON NAME	SCIENTIFIC NAME	ORDER	FAMILY
Bandedwinged Whitefly	*Trialeurodes abutilonea* (Halderman)	Homoptera	Aleyrodidae
Beet Armyworm	*Spodoptera exigua* (Hubner)	Lepidoptera	Noctuidae
Brown Stink Bug	*Euschistus servus* (Say)	Hemiptera	Pentatomidae
Cabbage Looper	*Trichoplusia ni* (Hubner)	Lepidoptera	Noctuidae
Cotton Aphid	*Aphis gossypii* (Glover)	Homoptera	Aphididae
Cotton Bollworm	*Helicoverpa zea* (Boddie)	Lepidoptera	Noctuidae
Cotton Leafworm	*Alabama argillacea* (Hubner)	Lepidoptera	Noctuidae
Cotton Stainer	*Dysdercus suterellus* (Herrick-Schaffer)	Hemiptera	Pyrrhocoridae
European Corn Borer	*Pyrausta nubilalis* (Hubner)	Lepidoptera	Pyralidae
Fall Armyworm	*Spodoptera frugiperda* (J.E. Smith)	Lepidoptera	Noctuidae
Garden Webworm	*Loxostege similalis* (Guenee)	Lepidoptera	Pyralidae
Granulate Cutworm	*Feltia subterranea* (Fabricius)	Lepidoptera	Noctuidae
Southern Green Stink Bug	*Nezara viridula* (Linnaeus)	Hemiptera	Pentatomidae
Soybean Looper	*Pseudoplusia includens* (Walker)	Lepidoptera	Noctuidae
Sweetpotato Whitefly	*Bemisia tabaci* (Gennadius)	Homoptera	Aleyrodidae
Tarnished Plant Bug	*Lygus lineolaris* (P. de Beav.)	Hemiptera	Miridae
Thrips	*Frankliniella* spp.	Thysonoptera	Thripidae
Tobacco Budworm	*Heliothis virescens* (Fabricius)	Lepidoptera	Nostuidae
Two-spotted Spider Mite	*Tetranychus urticae* (Koch)	Acari	Tetranychidae
Yellowstriped Armyworm	*Spodoptera ornithogalli* (Guenee)	Lepidoptera	Noctuidae

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Table 3. Summary of Thresholds for Common Arthropod Pests of Cotton in Florida.

PEST	THRESHOLD
Cutworm	If cutworm feeding threatens to reduce the plant stand below the minimum for optimum yields (25,000-27,000) plants per acre, action is justified. The action may be chemical treatment or replanting.
Thrips	Prior to the five true leaf stage a population of 2-3 or more thrips per plant usually justifies treatment.
Plant Bugs	During the first four weeks of squaring, treatment is justified if there are 6 to 7 tarnished plant bugs per 100 sweeps or if square retention is less than 80% and tarnished plant bugs are present.
Budworm/ Bollworm	On fields planted in conventional cotton cultivars that have not recently been treated, the theshold is 30% eggs or 10% larvae (less than 3/8 inch in length); in previously treated fields, 25-30% eggs or 5% small larvae justifies treatment. For Bt transgenic cotton cultrivars, treatment is justified if 8 or more larvae 1/4 or more inch in length are found per 100 plants using the modified whole-plant sampling procedure.
Beet Armyworm	Two to three active hits per 100 feet of row justifies treatment. Of only a few larvae are surviving per hit or *Cotesia* cocoons are present, the threshold should be raised.
Fall Armyworm	Fifteen to twenty fall armyworm larvae 1/2 inch or less in length per 100 plants justifies treatment.
Loopers	Populations of 4-6 small to medium-sized larvae per foot of row justifies treatment.
Stink Bug	A population of 1stink bug per 6 feet of row using a shake cloth or 15-20% boll damage usually justifies a chemical treatment.
Spider Mites	If the infestation is, on average, rated as medium (11-25 spider mites per leaf), treatment of the infested area is justified.