Integrated Pest Management

An Integrated Pest Management (IPM) program integrates control tactics including cultural practices, variety selection, biological control and insecticides to manage insect pest populations so that economic damage and harmful environmental side effects are minimized. Insecticides should only be used on an as-needed basis; therefore, insect scouting must be conducted regularly throughout the season to determine if an insecticide application is warranted.

Scouting/Monitoring

Insect populations vary from year to year and field to field during the growing season. All fields should be monitored for both insect pests and beneficial populations at least weekly during the season, preferably twice weekly after blooming has begun. In areas of high insect pressure or increasing populations, twice-a-week scouting is recommended. Monitoring plant growth and development is an important aspect of crop management, maximizing yield potential and managing insects.

Two basic components of decision making in IPM are the economic injury level (EIL) and the economic threshold (ET). The EIL is defined as the lowest pest population density that will cause economic damage. The EIL is a pre-determined number that will justify the cost of treatment. The ET is defined as the pest population level at which control should be initiated to keep the pest population from reaching economically damaging numbers.

Economic thresholds have been established for specific insect pests. Multiple pest thresholds are not well established. Therefore, it is important to monitor the plant for fruit loss and retention levels to evaluate treatment thresholds, involving either single or multiple pests. When losses from multiple pests are occurring, fixed individual pest thresholds may become dynamic or change. Decisions to apply controls should be based on thorough scouting and identification of pests, cost of insecticide, the price of cotton, yield potential and fruit retention goals. The economic value of each fruiting form changes on each fruiting branch (node); therefore, it is important to know how this value is distributed on the plant. The value and placement of fruit being protected should be considered when making treatment decisions. Monitor fruit retention levels weekly, along with insects. Scheduled insecticide sprays should be avoided. Unnecessary applications of insecticide are not cost effective. Applications of insecticides on an as-needed basis will preserve beneficial insects, reducing the likelihood of secondary pest outbreaks.

Certain production practices can have a significant impact on insect pest infestations. Some practices may increase the risk of insect attack and should be avoided, while others may have some level of control value. A production practice that has a negative impact on insect pests is desirable and is termed a cultural control. Some common cultural control practices include:

Pre-plant Vegetation Management: Destruction of weeds and/or cover crops by tillage or herbicide three or more weeks prior to planting will reduce the risk of cutworm infestations and some other pests.

Field Border Maintenance: Plant bugs often build up on flowering plants surrounding cotton fields and move into fields when these preferred hosts dry up or are destroyed. Timely mowing of such vegetation can aid in reducing available hosts for plant bugs.

Managing for Earliness: Early crop maturity decreases the period of crop susceptibility to yield loss by insects, reduces insect control costs and lowers selection pressure for resistance development to insecticides.

Crop Management Considerations

Insecticide Resistance

Management of tobacco budworm in non-Bt cotton varieties has become more difficult in Tennessee due to the development of pyrethroid-resistant populations. Historically, budworm populations have been higher in the southern part of the state, but high populations can also occur in other areas. In response to tobacco budworm resistance, and the potential for resistance in bollworm and tarnished plant bug populations, a resistance management plan will continue to be recommended.

The goal of the Insecticide Resistance Management Plan is to improve the potential of maintaining effective full-season control of tobacco budworm, bollworm and tarnished plant bug by the use of different classes of chemistry in a logical sequence throughout the season, without placing excessive reliance on any single class of chemistry.

In general, levels of resistance are lowest during the early part of the growing season but increase sharply following repeated exposure to a single class of chemistry. Therefore, repeated use of a single class of chemistry may no longer provide effective control. As a result, there is a potential risk of sustaining economic losses. Following a resistance management plan is a recommended method to reduce the risk.

Because cotton insect pest management is dynamic, these guidelines cannot address all situations. Therefore, these recommendations are not intended to limit the professional judgment of qualified individuals. However, the **maximum benefit of a resistance management strategy can only be realized if all producers in a wide geographic area participate**.

Selection of insecticides should be based on insect pests present in the field, stage of crop development, effects on non-target organisms and the risk of contributing to resistance problems in subsequent generations.

Insecticide selection for bollworm and tobacco budworm control should be made after determining the population mix and size of the infestation within a community, farm or field. When dealing with resistance, this determination can mean a control success or failure. Use all available information and techniques including scouting reports, pheromone trap catches, moth flushing counts and identification of “worms.”

Phase I (Planting through June)

Phase I corresponds to that time between planting and first bloom. The first field generation of tobacco budworm and bollworm generally occurs during this time.

The primary objective in Phase I is to preserve the efficacy of the pyrethroids and organophosphate (OP) insecticides. Use of these insecticides in June will foster resistance in tobacco budworm, bollworm and tarnished plant bug populations. Insecticides should not be applied for control of any insect pests unless scouting techniques suggest economic losses are occurring. Producers should strive for a minimum of 80 percent square retention during Phase I.

Consider multiple pests and adjust treatment thresholds to achieve square retention goals. A goal of 100 percent pre-bloom square retention is not realistic if multiple insecticide applications are required. These additional insecticide sprays may increase cost, flare secondary pests and increase resistance selection pressure. Selection of specific compounds should consider all insect pests in the field to be treated, activity on beneficial insects and risks of contributing to control failures in subsequent generations. Automatic applications are discouraged.

Calculating Percent Square Retention

- Select 20 representative plants within a field.
- Examine each first fruiting position on the top five fruiting branches (nodes).
- Record the total number of missing fruit from 100 possible positions.
- 100 minus number missing = percent square retention.

Phase II (July to end of season)

Phase II includes the blooming and boll development period, during which the second and subsequent field generations of tobacco budworm/bollworm occur. It is during this window that cotton is most susceptible to insect injury, and pyrethroid or other appropriate classes of insecticides should be used whenever pest densities exceed economic thresholds. However, **pyrethroid insecticides should not be used for tobacco budworm.** Pyrethroid resistance in tobacco budworm populations is well established in Tennessee. If a failure occurs with a pyrethroid or pyrethroid tank mixture, a second application with full rates of a non-pyrethroid insecticide should be made immediately. It is not realistic to expect follow-up applications made after an insecticide control failure to totally "clean-up" remaining larvae.

When Unsatisfactory Control with Foliar Insecticide Occurs

All control problems are not related to insecticide resistance, and several factors should be considered in response to these problems. Treatment decisions should consider a variety of factors that influence insecticide efficacy and damage potential: species composition, population density, population age structure, application timing, insecticide dosage, application methods, application carriers, treatment evaluation timing, need for multiple applications, environmental conditions and insecticide resistance levels. Good coverage using labeled rates adjusted to infestation levels is necessary for satisfactory control. Do not expect 100 percent control with any insecticide treatment. Attempts to reduce insect populations to zero damage levels are not cost-effective and result in early field-control failures.

Managing for Earliness

Managing crop maturity is an important component of these guidelines. Cotton producers should plant an early-maturing cotton variety during a 20-day period between April 20 and May 10. At-planting fungicides and insecticides are recommended to promote plant establishment and seedling growth, manage early-season insect pests and accelerate crop maturity.

The goal is to obtain an optimal stand of healthy and actively growing cotton that initiates squaring 35-45 days after planting. Producers should avoid practices that delay crop maturity (some herbicides and excessive nitrogen) and increase the attractiveness of cotton to late-season insect pests. With timely planting and proper insect pest management, most of the harvestable bolls will be set on the plant by early August. Under these conditions, the cotton crop should mature soon enough to avoid severe damage by the August generations of tobacco budworm and bollworm. Early crop maturity will also reduce the probability of economic losses from other late-season insect pests.

Nodes Above White Flower (NAWF) and Terminating Insect Control

NAWF is the number of fruiting branches (nodes) above the uppermost first-position white flower of a plant. Counting from the top, the first node will have an unfolded leaf the size of a quarter or larger. NAWF is a useful measure of plant maturity and can be used to help make insect management decisions. NAWF=5 is referred to as cutout (see below). Average NAWF counts should be recorded weekly for each cotton field once blooming has begun.

The plant physiological stage of "cutout" is when there are five or fewer nodes above the uppermost first-position white flower (i.e., NAWF5). At cutout, cotton starts becoming less attractive and less sensitive to late-season insect pests. Insect treatment thresholds can be adjusted to higher levels after cutout. Insecticide applications for some pests can be terminated once fields have accumulated 350-450 heat units (DD60s) after the cutout date (approximately 18-21 days). Research has shown that accumulating 350 - 450 DD60s after cutout is enough time to mature yield-contributing bolls beyond the point where economic losses from bollworm, tobacco budworm, plant bugs and stink bugs are likely to occur. It may be necessary to control some pests beyond NAWF5 + 350 - 450 DD60s. For example, fall armyworm can damage more mature bolls. Also, because leaves are important to complete boll maturation, treatments for spider mites or loopers may be necessary to prevent excessive defoliation before the crop is fully mature (about NAWF5 + 850 DD60s).

> **Calculating Heat Units (DD60s):** Use the maximum and minimum temperature for a 24-hour period to determine the average temperature for the day. Subtract 60 degrees from the average. The remainder is the number of heat units (DD60s) accumulated for that day. Add these daily units to obtain the accumulated total.

Guidelines to Managing Tobacco Budworm and Bollworm in Non-Bt Cotton

- Promote earliness (plant between April 20 and May 10 with an early maturing variety, use an at-planting fungicide and insecticide, avoid excessive fertilization, control all insect pests when populations exceed thresholds, consider multiple pests and maintain 80 percent or higher square retention prior to bloom).
- Do not apply automatic applications of insecticides.
- Scout fields twice each week if possible.
- Time insecticide applications against eggs and 1- to 2-day-old larvae.
- Two treatments on a 4- to 5-day interval may be needed.
- Multiple applications, at median rates, are often more effective than a single application at a high rate.
- Consider pheromone-trapping data and moth-flushing counts to determine species composition (tobacco budworm vs. bollworm) before choosing an insecticide.
- Pyrethroids are generally not recommended for control of mixed budworm/bollworm populations.
- Only use pyrethroids, or pyrethroids tank mixed with carbamates or organophosphates, if tobacco budworms are a small part of the population (< 25 percent) **and** overall larval **and** egg numbers are < 8-10 per 100 plants.
- Use insecticides from different classes of chemistry if a pyrethroid failure occurs.
- Improve insecticide coverage by use of nozzles producing relatively small droplets while maintaining adequate spray volume.
- Monitor crop maturity and terminate insecticide applications when yield-contributing bolls are no longer susceptible to insect damage.

Bt Cotton Management

Bt cotton varieties, which produce toxins from the bacterium *Bacillus thuringiensis*, are widely used in Tennessee. The use of Bt cotton is recommended in areas with high occurrence of tobacco budworm and bollworm. Bt cotton must be monitored on a regular basis for pests, including bollworm. Tobacco budworm should not cause economic damage to Bt cotton at any time during the season, and damaging infestations of bollworm are uncommon prior to bloom. Prior to bloom, concentrate efforts in Bt cotton on monitoring square retention and scouting for pests such

as plant bugs. However, fields should be checked for the presence of surviving larvae if a bollworm egg lay occurs. Larvae must feed on plant tissue to ingest a toxic dose of Bt toxin. This feeding is generally superficial and will not cause economic damage. A larva that is 1/4 inch or greater in length is considered to have survived or "escaped" the toxin.

During the blooming period, bollworms can sometimes cause economic damage to Bt cotton. Twice a week scouting and closer examination within the plant canopy may be necessary to locate and determine bollworm survival before making a treatment decision. The Bt toxin should be given an opportunity to work; therefore, treatment based just on the presence of eggs is not usually recommended. Spray coverage and timing are critical for best control.

Bt Cotton and Bt Resistance Management

Bt cottons — including Bollgard II, Bollgard III, TwinLink, TwinLink Plus, WideStrike and WideStrike 3 technologies — are more effective than the original Bollgard technology, including better activity on bollworm, armyworms and loopers. However, insecticide treatments may still be needed if sufficient pest pressure occurs, particularly for bollworm or fall armyworm. Bt cotton does not control tarnished plant bugs, stink bugs or other non-caterpillar pests.

A refuge is not required for Bt cotton varieties, but planting a refuge is still a potentially valuable resistance management strategy. Planting non-Bt cotton will provide a source of susceptible moths for mating with resistant moths that survive in Bt cotton.

Relative Efficacy of Selected, Commercially Available Bt Cotton Products

Brands	Traits	Tobacco Budworm	Bollworm	Fall Armyworm	Beet Armyworm	Pink Bollworm
WideStrike	**Cry1F, Cry1A**	Excellent	Fair	Very Good	Very Good	Excellent
Bollgard 2 / TwinLink	**Cry1A, Cry2A**	Excellent	Good	Good	Very Good	Excellent
WideStrike 3	**Cry1F, Cry1A, Vip3A**	Excellent	Very Good	Excellent	Excellent	Excellent
Bollgard 3 / TwinLink Plus	**Cry1A, Cry2A, Vip3A**	Excellent	Very Good	Excellent	Excellent	Excellent

Excellent (spraying not needed), Very Good (spraying is only rarely needed), Fair to Good (spraying is commonly needed at least during some times of the season or when pest pressure is high)

Boll Weevil

The boll weevil has been successfully eradicated from Tennessee. Post-eradication pheromone trapping will continue in order to detect reinfestations that may occur. **Evidence of boll weevil infestations should be reported immediately to boll weevil eradication officials.**

Expected Occurrence of Insect Pests in Cotton

Below is a timetable of when pests are typically encountered in cotton, although conditions vary from season-to-season or farm-to-farm within a season.

Stage of Plant Development	Common Pests	Occasional Pests
Emergence to first square	Thrips	Aphids, Cutworms, Plant bugs, Spider mites
First square to first bloom	Plant bugs	Aphids, Spider mites, Bollworm, Tobacco budworm
After first bloom	Bollworm, Tobacco budworm, Plant bugs, Stink bugs	Aphids, Loopers, Fall and Beet armyworm, Spider mites, Whiteflies

Cutworms

Several species of cutworm larvae (caterpillars) may reduce stands by cutting the stems of seedling plants below the cotyledons. Larvae are active at night and hide in the soil during the day. Cutworm damage occurs most frequently following legume cover crops or in reduced tillage systems. They often become established on existing vegetation and feed on emerging cotton once this vegetation has been killed. Destroying all green vegetation at least 21 days prior to planting reduces the likelihood of cutworm attack.

Sampling: Scout for cutworms by counting the number of cut and undamaged plants in 50 feet of row at multiple locations in a field. A pocket knife or garden trowel can be used to dig up larvae from the soil around damaged or adjacent plants to confirm their presence.

Treatment Thresholds: Treat when cutworms threaten to reduce stands to less than three plants per row foot. Alternatively, consider treating if 5 percent or more of plants have been freshly cut. Infestations may be spotty within a field and only require treatment where damage and live cutworms are found.

- **Do not expect Bt cotton to provide adequate control of cutworms, although it provides some protection against small larvae or low infestation levels.**
- **A near-planting foliar insecticide application may be justified if non-crop vegetation was not burned down at least 21 days prior to planting. This application can be applied in a band over the row.**

Insecticide (Trade Names) for CUTWORMS	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
acephate 90 (Orthene 90S)	0.72	0.8 lb	6
bifenthrin (Brigade 2, Discipline 2, Fanfare 2)	0.05 - 0.1	3.2 - 6.4 oz	6
chlorpyrifos (Lorsban 4, Nufos 4)	0.75 - 1	24 - 32 oz	7
chlorpyrifos (Lorsban Advanced 3.755)	0.75 - 1	25.6 - 34.1 oz	7
cypermethrin 2.5	0.025 - 0.1	1.3 - 5 oz	8
deltamethrin (Delta Gold 1.5)	0.013 - 0.019	1.11 - 1.62 oz	8
esfenvalerate (Asana XL 0.66E)	0.03 - 0.05	5.8 - 9.6 oz	8
β-cyfluthrin (Baythroid XL 1)	0.0065 - 0.0125	0.8 - 1.6 oz	8
γ-cyhalothrin (Declare 1.25)	0.0075 - 0.01	0.77 - 1.02 oz	8
λ-cyhalothrin (Warrior II 2.08)	0.015 - 0.02	0.96 - 1.28 oz	8
Z-cypermethrin (Mustang Max 0.8)	0.008 - 0.012	1.28 - 1.92 oz	8

Thrips

Despite their small size, thrips are a consistent pest of seedling cotton. Tobacco thrips are the most common species observed in Tennessee, but several other species may also occur. Winged adults migrate into fields when seedlings emerge. Adult and immature stages feed by puncturing leaf cells and emptying their contents. Injury causes foliar deformity (leaves crinkle and cup upward), stunting, delays in maturity, and may cause stand loss. Preventative in-furrow insecticides or seed treatments are recommended. A foliar treatment may also be needed in some cases. Tobacco thrips have recently developed resistance to some neonicotinoid insecticides such as thiamethoxam (i.e., Cruiser).

Sampling: The presence of deformed, crinkled leaves and a silvery color is often a sign of thrips infestations. Scouts should visually assess the level of injury on emerging leaves. Numbers of thrips can be sampled by vigorously shaking/thumping seedling plants over a white-surfaced container (e.g., cigar box or Cool Whip container). A 5-10 X hand lens is suggested to help distinguish adult and immature stages.

Treatment Thresholds: In-furrow insecticides or seed treatments are recommended. Treatment is recommended prior to the third leaf stage when an average of one or more thrips are found per plant, especially when immature thrips are present and there are obvious signs of injury on newly emerged leaves.

Insecticide (Trade Names) for THRIPS	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating Thrips/WFT**
In-furrow Systemic Sprays:			
acephate 90 (Orthene 90S)	0.9 - 1	1 - 1.1 lb	7 / 5
disulfoton (Di-Syston 8)	0.75 - 1	12 - 16 oz	6 / ?
imidacloprid (Admire Pro 4.6)	0.27 - 0.33	7.4 - 9.2 oz	8 / 2
imidacloprid (Velum Total 2.17)	0.24 - 0.31	14 - 18 oz	8 / 2
Foliar Sprays: *			
acephate 90 (Orthene 90S)	0.18	3.2 oz	7 / 5
dicrotophos (Bidrin 8)	0.1 - 0.2	1.6 - 3.2 oz	8 / 5
dimethoate 4	0.125 - 0.25	4 - 8 oz	7 / 2
spinetoram (Radiant SC 1), suppression **	0.012 - 0.023	1.5 - 3 oz	8 / 7
Treated Seed			
imidacloprid (Gaucho 600, Aeris, Acceleron Standard, Acceleron Elite, Avicta Elite Cotton Plus)	0.34 - 0.375 mg active ingredient per seed		8 / 2
Orthene 97 ST or Acephate 80S *	Acephate can be applied to a seed at 6.4 oz/100 lb seed (Orthene 97 ST) or 8 oz/100 lb seed (Acephate 80 S)		5 / 3

* Not recommended as a standalone treatment for thrips control.

** Radiant SC is suggested if western flower thrips (WFT) are present in significant numbers. The use of an adjuvant is recommended when using Radiant SC for control of thrips.

Plant Bugs

The tarnished plant bug is among the most important pests of cotton. Clouded plant bugs and cotton fleahoppers are two other plant bug species sometimes observed in Tennessee. Both adults and immature stages (nymphs) feed on squares, flowers, and bolls. Small squares and small bolls that have been fed upon will often shed from the plant. This fruit loss can directly reduce yields or delay crop maturity. Bolls that do not shed may have reduced size and quality. Bolls more than 14 days old are not preferred feeding sites and are relatively immune to injury. However, clouded plant bugs will injure larger bolls. Tarnished plant bugs have developed resistance to some insecticides (e.g., pyrethroids).

Sampling: Small squares and small bolls that have been fed upon will usually shed from the plant. Larger squares may not shed, but evidence of plant bug feeding is evident by yellow staining (“dirty squares”) and anther damage that is observed when a square opens into a flower (“dirty blooms”). Feeding may cause cat-facing (dark spotting) on the surface of the boll, similar to stink bug injury.

Square retention: A management goal is to maintain 80 percent or higher square retention up to early bloom. Low or dropping square retention can be a warning sign of plant bug problems. Square retention should be monitored prior to flowering and during early bloom. In the top 5 nodes of plants, count the number of shed, first-position squares until at least 25 fruiting sites have been examined and repeat this in at least 4 locations in a field. Record percent square loss.

Sweep net: A sweep net is an effective tool for monitoring adult plant bugs and detecting movement into the field. It is recommended prior to flowering and during early bloom. Take a minimum of 25 sweeps with a standard 15-inch diameter sweep net at 4 locations in a field. Record the number of adult and immature plant bugs.

Drop cloth: Also called a beat sheet or ground cloth, this is the preferred method of sampling plant bugs during bloom because it is more effective at detecting nymphs. The cloth is typically 2.5-3 feet in length, and black is a preferred color. At 4-6 locations in a field, shake plants from two rows over the drop cloth and record the number of adult and immature plant bugs. Record numbers of plant bugs per drop cloth (or per feet of row sampled). Also count stink bugs that may be observed.

Treatment Thresholds

First two weeks of squaring: Treat when plant bugs number **eight** or more per 100 sweeps (standard sweep net) or one or more per drop cloth (0.2 per row foot).

Third week of squaring until first bloom: Treat when plant bugs number **15** or more per 100 sweeps or two or more per drop cloth (0.4 per row foot).

From first square to first bloom: Low or dropping square retention can be a warning of plant bug problems. If square retention drops below **80 percent** and plant bugs are present, treatment should be considered even if numbers are below threshold. The objective is to maintain the square retention goal. Consider if multiple pests are contributing to this square loss before selecting an insecticide.

After first bloom: Treat when plant bugs number **three** or more per drop cloth (0.6 per foot) or 15 or more per 100 sweeps. Count clouded plant bugs as equivalent to 1.5 tarnished plant bugs when determining if populations are above treatment level. Treatment should also be considered if 15 or more plant bugs are observed per 100 plants during visual examination, or 10 percent or more of squares show external evidence of plant bug feeding (i.e., dirty squares).

- **Consecutive insecticide applications at a 4- to 7-day interval are often required to control high populations of nymphs and adults.**
- **Plant early maturing varieties.**
- **Attempt to plant cotton in a block of fields. This improves the efficiency of management and often reduces infestation levels.**
- **Insecticide applications can be terminated when cotton has accumulated 250-300 DD60s past NAWF5 (NAWF5 = average of 5 nodes above a first position white flower).**

Insecticide (Trade Names)	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
PLANT BUGS - PHASE I, PRE-BLOOM WINDOW*			
acetamiprid (Intruder Max 70WP, Strafer Max 70WP)	0.074 - 0.101	1.7 - 2.3 oz	6
flonicamid (Carbine 50WG)	0.081 - 0.089	2.6 - 2.8 oz	5
imidacloprid 2.0	0.047 - 0.062	3 - 4 oz	7
imidacloprid 4.0 (Couraze Max)	0.047 - 0.062	1.5 - 2 oz	7
imidacloprid 4.6 (Admire Pro)	0.047 - 0.062	1.3 - 1.7 oz	7
sulfoxaflor (Transform 50WG)	0.047 - 0.07	1.5 - 2.25 oz	8
thiamethoxam (Centric 40WG)	0.0375 - 0.05	1.5 - 2.5 oz	7
PLANT BUGS - PHASE II, BLOOMING WINDOW			
acephate 90 (Orthene 90S)	0.45 - 0.675	0.5 - 0.75 lb	9
acephate 97 (Orthene 97SP)	0.49 - 0.73	0.5 - 0.75 lb	9
dicrotophos (Bidrin 8)	0.31 - 0.5	5 - 8 oz	8
dimethoate 4	0.25 - 0.5	8 - 16 oz	6
malathion 5	1.25	32 oz	6
novaluron (Diamond 0.83, Mayhem 0.83)**	0.058 - 0.078	9 - 12 oz	7
oxamyl (Vydate C-LV 3.77)	0.29 - 0.35	10 - 12 oz	6
pyrethroids***	See labels (use highest recommended rates)		2 – 4
sulfoxaflor (Transform 50WG)	0.047 - 0.07	1.5 - 2.25 oz	9

* These products tend to perform better prior to bloom and are primarily recommended in this window. Applications can be banded to reduce costs. Avoiding the use of pyrethroid, organophosphate and carbamate insecticides prior to bloom is suggested as a resistance management tool.
**This product controls only immature plant bugs. Tank mixes with other insecticides are recommended if significant numbers of adults are present.
***Pyrethroid insecticides applied alone will not provide adequate control of tarnished plant bugs. However, tank mixing pyrethroid insecticides with other Phase II recommended insecticides will often improve their performance.

Aphids

Aphids occur in most cotton fields every year but only occasionally cause economic damage. Economic damage is most likely when environmental conditions such as dry weather are already stressing cotton growth. Aphids are usually found on the undersides of leaves or feeding in the terminals. They feed by sucking sap from phloem tissue. Heavily infested leaves will often curl downward along their edges. The accumulation of honeydew causing sticky and shiny leaf surfaces often indicates the presence of aphids (or whiteflies). Severe infestations can stunt plants and reduce yields, particularly if populations persist for a long period of time. Honeydew secretions on open bolls may result in lint staining or “sticky cotton.” This is rarely a concern in Tennessee because late-season aphid infestations are generally uncommon and cleansing rains often occur prior to harvest.

Sampling: The presence of honeydew or leaves that curl downward along the edge is a sign of aphid infestations. Check for aphids on the undersides of leaves. Estimate the average number of aphids found per leaf on leaves located 3-5 nodes below the top node.

Treatment Thresholds: Treat when aphids are numerous, honeydew is present, and plants are showing signs of stress. Treatment with insecticides is sometimes recommended when populations exceed an average of 50 aphids per leaf and honeydew is accumulating, especially under conditions of drought stress. Parasites and predators usually keep aphids populations below treatment levels. Consider the possibility of a fungal epizootic (*Neozygites fresnii*) before treating. This may be recognized by a sudden crashing of populations in the same or nearby fields where insecticides were not applied.

- **In the Mid-South, cotton aphids have developed resistance to several classes of insecticides including pyrethroids, neonicotinoids, and several organophosphates (OP's). Spray for aphids and other pests only as needed to help reduced selection for insecticide resistance.**
- **When possible and especially prior to bloom, avoid using insecticides that disrupt populations of natural enemies such as pyrethroid insecticides and acephate.**

Insecticide (Trade Names) for APHIDS	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
acetamiprid (Intruder Max 70WSP, Strafer Max70WSP)*	0.026 - 0.048	0.6 - 1.1 oz	8
dicrotophos (Bidrin 8)*	0.25 - 0.5	4 - 8 oz	6
dimethoate 4*	0.125 - 0.5	4 - 16 oz	5
flonicamid (Carbine 50 WP)	0.044 - 0.089	1.4 - 2.8 oz	8
imidacloprid 2.0*	0.031 - 0.047	2 - 3 oz	4
imidacloprid 4.0 (Couraze Max)*	0.031 - 0.047	1 - 1.5 oz	4
imidacloprid 4.6 (Admire Pro)*	0.047 - 0.062	0.9 - 1.3 oz	4
thiamethoxam (Centric 40WG)*	0.031 - 0.05	1.25 - 2 oz	4
sulfoxaflor (Transform 50WG)	0.023 - 0.031	0.75 - 1 oz	8

* Because of resistance, these products give variable performance and may fail or only provide suppression, especially if the same class of insecticide was used previously.

Bollworm/Tobacco Budworm

Both bollworm and tobacco budworm cause similar injury to cotton by feeding on squares, flowers, and bolls. In the field, it is difficult or impossible to distinguish between the caterpillars (larvae) of these two species. Damaged fruiting structures typically shed or large bolls may rot. The bollworm continues to be a serious threat in Tennessee despite the use of Bt cotton on most acres. Tobacco budworm typically causes little damage because of the wide adoption of Bt cotton, to which it is highly susceptible. However, infestation of tobacco budworm on non-Bt cotton can cause substantial yield loss, and they are highly resistant to insecticides from several classes of chemistry (e.g., pyrethroids).

Sampling: Larvae feed on squares, flowers, and bolls. Holes and frass on these structures are a sign of infestation. Treatment is based on the average number (and size) or larvae found or the percentage of damaged fruiting structures. Examine a group of 5 plants at a minimum of 10 locations in a field. Look for larvae and signs of injury in the top 5 nodes and also examine at least one white or pink bloom and one additional boll in the mid canopy on each plant. Record the average number and size of larvae found per plant. A supplemental or alternative method is to examine 25 squares and 25 bolls in at least 4 locations in a field and record the number of squares and bolls with injury.

Treatment Thresholds

Non-Bt Cotton: Prior to bloom, treat when eight or more small larvae are present per 100 plants (or when populations threaten to reduce square retention below 80 percent). After first bloom, treat when four or more small larvae per 100 plants are present (or when 6 percent or more of squares and bolls are damaged and larvae are still present).

Bt Cotton: Economic infestations are unlikely prior to bloom, but treat when eight or more surviving larvae (> 1/4 inch or longer) are present per 100 plants (or when populations threaten to reduce square retention below 80

percent). After first bloom, treat when four or more surviving larvae are found per 100 plants (or when 6 percent or more of squares and bolls are damaged and larvae are still present).

- **Plant early maturing varieties and avoid unnecessary insecticide applications that may disrupt populations of natural enemies.**
- **Bt cotton varieties provide excellent control of tobacco budworm.**
- **Bt cotton varieties provide good but variable levels of control of bollworm. Insecticide applications may be needed in some cases, particularly in flowering cotton.**
- **Insecticide applications can be terminated when cotton has accumulated 350-400 DD60s past NAWF5 (NAWF5 = average of 5 nodes above a first position white flower).**

Insecticide (Trade Names)	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
BOLLWORM*			
bifenthrin (Brigade 2, Discipline 2, Fanfare 2)	0.078 - 0.1	5 - 6.4 oz	7
cypermethrin 2.5	0.078 - 0.1	4 - 5 oz	7
deltamethrin (Delta Gold 1.5)	0.023 - 0.03	2 - 2.56 oz	7
esfenvalerate (Asana XL 0.66E)	0.036 - 0.05	7 - 9.6 oz	7
β-cyfluthrin (Baythroid XL 1)	0.0156 - 0.02	2 - 2.6 oz	7
γ-cyhalothrin (Declare 1.25)	0.0146 - 0.02	1.5 - 2.05 oz	7
λ-cyhalothrin (Warrior II 2.08)	0.03 - 0.04	1.92 - 2.56 oz	7
Z-cypermethrin (Mustang Max 0.8)	0.0188 - 0.0225	3 - 3.6 oz	7
BOLLWORM AND TOBACCO BUDWORM			
acephate 90 (Orthene 90S)	0.9	1 lb	5
chlorantraniliprole (Prevathon 0.43 SC)	0.047 - 0.09	14 - 27 oz	9
chlorantraniliprole, λ-cyhalothrin (Besiege)	See label	7 - 12.5 oz	9
emamectin benzoate (Denim 0.16)	0.01 - 0.015	8 - 12 oz	7
indoxacarb (Steward 1.25)	0.11	11.3 oz	8
methomyl (Lannate LV 2.4)	0.45	24 oz	4
spinetoram, methoxyfenozide (Intrepid Edge)	See label	6 - 8 oz	8
spinetoram (Radiant SC 1)	0.033 - 0.0625	4.25 - 8 oz	8
spinosad (Blackhawk 36% WDG)	0.056 - 0.072	2.0 - 3.2 oz	8

* Pyrethroids have often been used when the population is exclusively bollworm, such as would be expected on Bt cotton varieties, but the efficacy of pyrethroid insecticides for the control of bollworm has declined. Thus, alternative chemistries or tank mixes with alternative chemistries may be needed for adequate control.

Stink Bugs

Stink bugs are a common pest of cotton in Tennessee. The green stink bug is the most common species observed, but the brown stink bug, dusky brown stink bug, and others may also be found. Stink bugs are primarily seed feeders and migrate into cotton from wild hosts or other crops when bolls begin to develop. Infestation may occur first on field edges. Both adult and immature stink bugs will feed on bolls, and injury may reduce lint production in one or more locks, reduce fiber quality, and damaged bolls may rot because of secondary infection by plant pathogens.

Sampling: Scouting specifically for stink bugs is suggested once bolls are present. Stink bugs prefer bolls between 7-21 days in age. External signs of feeding injury include the appearance of circular black lesions on the surface of bolls (i.e., "catfacing"). These sunken lesions are typically about 1/16th of an inch in diameter. The lint of bolls may be stained, seed may be destroyed, and feeding warts may be observed on the internal surface of the boll wall. Stink bugs can be scouted for visually, but most thresholds are based on drop cloth samples or the occurrence of internal symptoms of feeding damage to bolls.

Drop cloth: Also called a beat sheet or ground cloth, is a preferred method of sampling stink bugs. The cloth is typically 2.5-3 feet in length. In at least 4-6 locations in a field, shake plants from two rows over the drop cloth and record the number of adults and nymphs. Record the number of stink bugs per drop cloth or per feet of row sampled.

Boll damage: Examine 25 thumb sized bolls in 4 locations in each field, and record the number of bolls with internal signs of stink bug feeding (stained lint).

Treatment Thresholds: Treat when infestations exceed an average of 1 or more stink bugs per drop cloth (5-6 row feet). Treatment is also recommended if 20 percent or more of 12- to 16-day-old (thumb-sized) bolls have internal feeding warts and/or stained lint. Because stink bug infestations may co-occur with plant bug infestations, a rule of thumb is to count stink bugs as equivalent to 3 tarnished plant bugs when determining if treatment thresholds have been exceeded for a complex of stink bugs and plant bugs.

- **Plant early maturing varieties.**
- **Infestations are more likely in fields that have not recently been treated with insecticides.**
- **Insecticide applications can be terminated when cotton has accumulated 400-450 DD60s past NAWF5 (NAWF5 = average of 5 nodes above a first position white flower). However, fields free of stink bugs at 350 DD60s past NAWF5 are unlikely to develop economically damaging infestations after this point.**
- **Predatory stink bugs such as the spined soldier bug are sometimes confused for pest species.**

Insecticide (Trade Names) for STINK BUGS	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating Green / Brown
acephate 90 (Orthene 90S)	0.49 - 0.72	0.54 - 0.8 lb	6 / 9
acephate 97 (Orthene 97SP)	0.49 - 0.73	0.5 - 0.75 lb	6 / 9
bifenthrin (Brigade 2, Discipline 2, Fanfare 2)*	0.05 - 0.1	3.2 - 6.4 oz	9 / 8
dicrotophos (Bidrin 8)	0.33 - 0.5	5.3 - 8 oz	9 / 9
oxamyl (Vydate C-LV 3.77)	0.32 - 0.5	10.9 - 17 oz	8 / 7

* Most pyrethroid insecticides are labeled and effectively control green and southern green stink bugs. Bifenthrin is the only pyrethroid recommended if brown stink bugs are present in significant numbers.

Spider Mites

Two spotted spider mites are occasional pests in Tennessee cotton. Infestations are often most severe during hot and dry weather, in part because a fungus (*Neozygites floridana*) that attacks this species is not effective in these conditions. Immature and adult spider mites injure cotton by feeding on the contents of individual cells. They may feed on all plant structures but are most commonly observed on the undersides of leaves. Mites reduce the plant's ability to produce photosynthate, and under severe infestations, cause premature defoliation and stunting. Spider mites disperse by crawling or by wind. Eggs are usually deposited on the undersides of leaves. Infestations often

occur on field edges or in isolated spots and then spread across the field. Spider mites can complete a generation in as little as 4-5 days, so infestations may grow quickly under the right conditions.

Sampling: The top surface of infested leaves may have white or yellow stippling/speckling. Older damage often appears as a reddening of leaves. Injury is often concentrated on the leaf near the petiole, around leaf veins and at leaf folds. Sample by observing the percentage of plants with symptoms of injury, and confirming the presence of spider mites. Look for mites on the undersides of leaves, and a 5-10 X hand lens is suggested to see mites and their eggs.

Treatment Thresholds: Treat when 30-50 percent of plants are affected and mites are still present. More than one application on a 4- to 5-day interval may be required depending upon the miticide selected and intensity of infestation.

- **Avoid unnecessary insecticide applications. Spider mite infestations are flared by the repeated use of some broad spectrum insecticides such as pyrethroids and acephate.**
- **Spider mite infestations often start and end suddenly. Population crashes following a rain are sometimes observed, and irrigation or frequent rainfall generally reduces the impact of spider mites on yield.**
- **Equipment, sweep nets or people can spread spider mites.**

Insecticide (Trade Names) for SPIDER MITES	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
abamectin (Abba 0.15, Agri-Mek 0.15, Zoro 0.15) (Agri-Mek SC 0.7)	0.0047 - 0.019 0.0055 - 0.019	4 - 16 oz 1 - 3.5 oz	7
bifenazate (Acramite 4)	0.375 - 0.75	16 - 24 oz	6
bifenthrin (Brigade 2, Discipline 2, Fanfare 2)*	0.06 - 0.1	3.8 - 6.4 oz	5
dimethoate 4*	0.25 - 0.5	8 - 16 oz	3
emamectin benzoate (Denim 0.16)*	0.01 - 0.015	8 - 12 oz	5
etoxazole (Zeal 72 WSP) (Zeal SC 2.88)	0.034 - 0.045 0.300 - 0.045	0.75 - 1 oz 1.33 - 2 oz	9
fenpyroximate (Portal 0.4)	0.05 - 0.075	16 - 24 oz	8
propargite (Comite II 6)	0.94 - 1.69	20 - 36 oz	6
spiromesifen (Oberon 4)	0.094 - 0.25	3 - 8 oz	8

See label for specific use rates at different times of the season.

* These products may only suppress spider mite populations.

Fall Armyworm

Fall armyworm is an occasional pest of cotton grown in Tennessee. The caterpillars (larvae) feed on fruiting structures and especially on flowers or bolls. The injury they cause is similar to that of bollworm. Larger larvae can often be distinguished from bollworm or tobacco budworm by having a dark-colored head with a light-colored inverted Y. Infestations almost always occur after flowering has begun and are more likely to cause yield loss in late maturing fields. Bt cotton varieties have reduced the importance of this pest, but insecticide applications may still be justified.

Sampling: Small larvae are often found in white blooms, pink blooms, or behind the bracts of medium-sized bolls. Large larvae are often seen in blooms or found inside bolls. Scout by examining 25 flowers (white or pink) and 25 mid-sized bolls at a minimum of 4 locations in a field. Alternatively, the number of fall armyworm larvae can be counted while inspecting plants for bollworm or tobacco budworm.

Treatment Thresholds: Treat when an average of 4 or more larvae are found in 100 blooms and/or bolls, or treat when 10-20 larvae are found per 100 plants. Timing applications to control small larvae is more effective than trying to control larger larvae.

- **Plant early maturing varieties.**
- **Bt cotton varieties provide good but variable levels of control. Insecticide applications may be needed in some cases, particularly in flowering cotton.**
- **Insecticide applications can be terminated when cotton has accumulated 400-450 DD60s past NAWF5 (NAWF5 = average of 5 nodes above a first position white flower).**

Insecticide (Trade Names)* for FALL ARMYWORM	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
acephate 90 (Orthene 90S)	0.9	1.0 lb	5
chlorantraniliprole (Prevathon 0.43 SC)	0.067 - 0.09	20 - 27 oz	9
chlorantraniliprole, λ-cyhalothrin (Besiege)	See label	8 - 12.5 oz	9
emamectin benzoate (Denim 0.16)	0.01 - 0.015	8 - 12 oz	8
indoxacarb (Steward 1.25)	0.09 - 0.11	9.2 - 11.3 oz	8
methomyl (Lannate LV 2.4)	0.45	24 oz	7
methoxyfenozide (Intrepid 2)	0.06 - 0.16	4 - 10 oz	8
novaluron (Diamond 0.83, Mayhem 0.83)	0.039 - 0.078	6 -12 oz	8
spinetoram (Radiant SC 1)	0.033 - 0.0625	4.25 - 8 oz	7
spinetoram, methoxyfenozide (Intrepid Edge)	See label	6 - 8 oz	9
spinosad (Blackhawk 36% WDG)	0.056 - 0.072	2.4 - 3.2 oz	7

* Most pyrethroid insecticides provide some suppression of fall armyworm infestations, and using the highest labeled rates or a tank mixture with products listed above will often improve control.

Beet Armyworm

The caterpillar (larval) stage of beet armyworm feeds on leaves and reproductive parts of the plant. The use of Bt cotton varieties has greatly reduced the risk of infestations, and economically damaging infestations in cotton are rare. Also, newer insecticide chemistries have made infestations easier to control.

Sampling: Egg masses and freshly hatched larvae are typically found on the undersides of the leaves in the mid and lower canopy. Small larvae feed in a group and leave a windowpane-like feeding sign on the leaves. The larvae can be recognized by a characteristic small black dot directly above the second true leg. Scout by counting the numbers of “hits” (active clusters of small larvae) observed while walking down a row. Infestations are often worse where wide- or skip-row spacing is used, and they are sometimes associated with the presence of alternate hosts like Palmer amaranth or other pigweed species.

Treatment Thresholds

Prior to Aug. 15: Treat for beet armyworm when 5-6 “hits” (active clusters of small larvae) are found per 300 row feet.

After Aug. 15: Treat when 10 or more “hits” are found per 300 row feet.

- **Production of an early crop and preservation of beneficial insects will reduce the risk of a beet armyworm outbreak.**

- **Bt cottons generally provide good control of beet armyworms. Supplemental insecticide applications are unlikely unless infestation levels are unusually high.**

Insecticide (Trade Names) for BEET ARMYWORM	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
chlorantraniliprole (Prevathon 0.43 SC)	0.067 - 0.09	20 - 27 oz	9?
chlorantraniliprole, λ-cyhalothrin (Besiege)	See label	8 - 12.5 oz	9?
emamectin benzoate (Denim 0.16)	0.0075 - 0.01	6 - 8 oz	9
indoxacarb (Steward 1.25)	0.09 - 0.11	9.2 - 11.3 oz	9
methoxyfenozide (Intrepid 2)	0.06 - 0.16	4 - 10 oz	9
spinetoram (Radiant SC 1)	0.033 - 0.0625	4.25 - 8 oz	9
spinetoram, methoxyfenozide (Intrepid Edge)	See label	4 - 8 oz	9
spinosad (Blackhawk 36% WDG)	0.056 - 0.072	2.4 - 3.2 oz	9

Loopers

Loopers have become an uncommon pest of cotton due to the use of Bt cotton varieties. Both the cabbage looper and soybean looper may occur. Both are light green and have two pairs of prolegs, which distinguishes them from other caterpillars found in cotton. Looper infestations almost always occur after plants have begun to flower. The caterpillars (larvae) feed on leaves, causing irregularly shaped holes. Looper populations are often held below damaging levels by natural biological control agents.

Sampling: Scout by estimating the percent of defoliation observed throughout the field. Use a sweep net or drop cloth to confirm the presence of loopers.

Treatment Thresholds: Treat when loopers cause 25 percent or more defoliation.

- **Plant early maturing varieties and avoid unnecessary insecticide applications that may disrupt populations of natural enemies.**
- **Bt cotton varieties typically provide good control, and supplemental insecticide applications are rarely needed.**
- **Insecticide applications can be terminated when cotton has accumulated 600-700 DD60s past NAWF5 (NAWF5 = average of 5 nodes above a first position white flower).**

Insecticide (Trade Names) for LOOPERS	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating Soybean / Cabbage
chlorantraniliprole (Prevathon 0.43 SC)	0.067 - 0.09	20 - 29 oz	8 / 9
chlorantraniliprole, λ-cyhalothrin (Besiege)	See label	10 - 12.5 oz	8 / 9
emamectin benzoate (Denim 0.16)	0.01 - 0.015	8 - 12 oz	9 / 9
indoxacarb (Steward 1.25)	0.09 - 0.11	9.2 - 11.3 oz	9 / 9
methoxyfenozide (Intrepid 2)	0.06 - 0.16	4 - 10 oz	9 / 9
spinetoram (Radiant SC 1)	0.033 - 0.0625	4.25 - 8 oz	8? / 9?
spinetoram, methoxyfenozide (Intrepid Edge)	See label	4 - 8 oz	9 / 9
spinosad (Blackhawk 36% WDG)	0.056 - 0.072	2.4 - 3.2 oz	9 / 9

Bandedwinged Whitefly

Bandedwinged whitefly is a relatively uncommon pest of cotton. Infestations may occur at any time but are most commonly observed late in the season. Adults are small, white, moth-like insects feeding on the undersides of leaves and readily fly when disturbed. Immatures are immobile and also found on the undersides of leaves. Both adults and

immatures feed on sap (phloem) similar to aphids, and like aphids, the presence of honeydew and sticky leaves is a sign of infestations. Yield loss may occur when infestations are high and especially when plants are already under drought stress. Sooty mold may develop on leaves and lint.

Sampling: The presence of honeydew or sooty mold is a sign of infestation. Look on the undersides of leaves for the presence of adults or immatures. Adults will often fly when disturbed.

Treatment Thresholds: Treat when whiteflies are present on most plants and particularly if honeydew is accumulating on leaves. A second application made at a 4- to 5-day interval may be required in some cases, depending upon the insecticide used and the intensity of infestation.

- **Infestations are often associated with repeated insecticide applications for other pests that have disrupted populations of natural enemies. Avoid unnecessary insecticide applications.**

Insecticide (Trade Names) for WHITEFLY	Lb Active Ingredient per Acre	Amount Formulation per Acre	Performance Rating
acephate 90 (Orthene 90S)	0.45 - 0.9	0.5 - 1 lb	7
spiromesifen (Oberon 4)	0.125 - 0.25	4 - 8 oz	8?
thiamethoxam (Centric 40 WG)	0.05	2 - 2.5 oz	7

Premixed Insecticide Products

The following products are available as premixes of two or more insecticides. The use of these premixes may provide suppression or control of multiple pests, and thus, are typically recommended when several pests are present at treatment level. Use of these products is suggested primarily after first bloom. These products may be appropriate for pest complexes but are not generally listed under the recommendations for individual pests.

Trade Name (Insecticides)	Amount Product per Acre	Primary Target Pests (see label for other pests that may be controlled)
Athena (bifenthrin, abamectin)	10 - 17 oz	Spider mites
Besiege (chlorantraniliprole, λ-cyhalothrin)	7 - 12.5 oz	Most caterpillar pests, stink bugs
Bidrin XP II (dicrotophos, bifenthrin)*	8 - 12.8 oz	Plant bugs, stink bugs, bollworm
Brigadier (imidacloprid, bifenthrin)	5.1 - 7.7 oz	Plant bugs, stink bugs, bollworm
Cobalt Advanced (chlorpyrifos, γ-cyhalothrin)	22 - 42 oz	Plant bugs, stink bugs, bollworm
Double Take (diflubenzuron, λ-cyhalothrin)	4 oz	Stink bugs, bollworm
Endigo ZC (thiamethoxam, λ-cyhalothrin)	4 - 5.5 oz	Plant bugs, stink bugs, bollworm
Fyfanon Plus ULV (malathion, γ-cyhalothrin)	10 - 16 oz	Plant bugs, stink bugs, bollworm
Hero (bifenthrin, Z-cypermethrin)	5.2 - 10.3 oz	Stink bugs, bollworm
Intrepid Edge (methoxyfenozide, spinetoram)	4 - 8 oz	Most caterpillar pests
Leverage 360 (imidacloprid, β-cyfluthrin)	2.8 - 3.2 oz	Plant bugs, stink bugs, bollworm
Stallion (chlorpyrifos, Z-cypermethrin)	9.25 - 11.75 oz	Plant bugs, stink bugs, bollworm
Triple Crown (Z-cypermethrin, bifenthrin, imidacloprid)	4.5 - 6.4 oz	Plant bugs, stink bugs, bollworm

* Bidrin XP II may only be used prior to squaring or after flowering has begun.