

**Integrated
Pest
Management**

**COTTON
PESTS
SCOUTING &
MANAGEMENT**

*Plant Protection Programs
College of Food, Agriculture
and Natural Resources*



This publication is part of a series of IPM Manuals prepared by the Plant Protection Programs of the University of Missouri. Topics covered in the series include an introduction to scouting, weed identification and management, plant diseases, and insects of field and horticultural crops. These IPM Manuals are available from MU Extension at the following address:

**Extension Publications
2800 Maguire Blvd.
Columbia, MO 65211
1-800-292-0969**

CONTENTS

Authors

Michael L. Boyd, Bobby J. Phipps, J. Allen Wrather
University of Missouri-Columbia

Diseases section in collaboration with Melvin Newman, University of Tennessee-Jackson, and Gabe Sciumbato, Mississippi State University-Stoneville

On the World Wide Web

For this and other Integrated Pest Management publications on the World Wide Web, visit <http://ipm.missouri.edu>.

Production

MU Extension and Agricultural Information
Dale Langford, editor
Dennis Murphy, illustrator

Cotton development	3
Insect management	4
Thrips	4
Cutworms	5
Cotton aphid	6
Cotton fleahopper, Plant bugs	6
Cotton bollworm, Tobacco budworm	7
Spider mites	8
Fall armyworm	8
Beet armyworm	9
Banded-wing whiteflies	9
European corn borer	10
Loopers	10
Stink bugs	11
Other cotton insect pests	11
Beneficial insects	12
Ants	13
Assassin bugs and other piercing-sucking predators	13
Lacewings	13
Ladybird beetles	14
Parasitoid flies and wasps	14
Diseases	15
Scouting cotton for diseases	15
General disease management	15
Cotton seedling diseases	16
Root-knot nematodes	17
Leaf spots	18
Bacterial blight	18
Wilts	19
Bronze wilt	20
Boll rots	20
Summary of general cotton disease control measures	21



Copyright 2004 by the University of Missouri
Board of Curators

COTTON DEVELOPMENT

Upland cotton was domesticated from a subtropical, perennial plant in its native desert habitat. Now it is grown as an annual crop in Missouri and throughout the cotton-growing regions of the United States. An understanding of the cotton plant's growth patterns is important for timely management practices. Several factors are involved in optimal cotton production, including temperature, solar radiation, water and healthy root systems. Cotton requires a minimum temperature of 60 degrees F to grow; however, temperatures around 90 degrees F are considered ideal for growth and lint production. Sunlight is necessary to drive the plant's photosynthetic "factory" to produce sugars necessary for plant growth and fruit production (square to flower to boll). Strong, early root development is essential for the uptake of soil nutrients and water to support maximum fruit production later in the season (Figure 1).



Figure 1. Cotton field ready for harvest.

To monitor plant development during the growing season, select five representative plants each week at 10 scouting locations in each field, and rate the plants' development according to the guidelines listed in Table 1. Heat units are calculated by adding together the daily maximum and minimum temperatures, dividing by two, and subtracting the base developmental temperature (60 degrees F). If the number calculated is negative, then round it off to zero. Seedling leaves or cotyledons are the first to emerge after planting. Cotyledons are borne on opposite sides of the main stem. Thereafter, the nodes (1st to nth) above the cotyledons (zero

node) will have a spiral, or alternate, arrangement around the main stem (Figure 2). The distance between nodes varies with seasonal growing conditions and the plant's growth stage. The following values are considered optimal height-to-node ratios:

- Seedling cotton: 0.5–0.75 inches per node
- Early squaring: 0.75–1.2 inches per node
- Large square to first bloom: 1.2–1.7 inches per node
- Early bloom: 1.7–2.0 inches per node

Generally, the lower branches are vegetative and the number present depends on plant population densities. Depending on environmental conditions, the first fruiting branches will vary from the fifth to the eighth node. The developing fruit branch terminates in a square, but a second square and leaf develops at the base of the first one, and a new internode branch extends away from the first fruiting position. This creates a zigzag pattern of fruiting forms, leaves, and internodes. Cotton should begin squaring and flowering five and eight weeks, respectively, after planting. New fruiting branches should be initiated every three days during optimal growth periods. The weather and pests (diseases, insects and weeds) can disrupt normal plant development throughout the growing season. For example, seedling diseases can stunt plant growth and

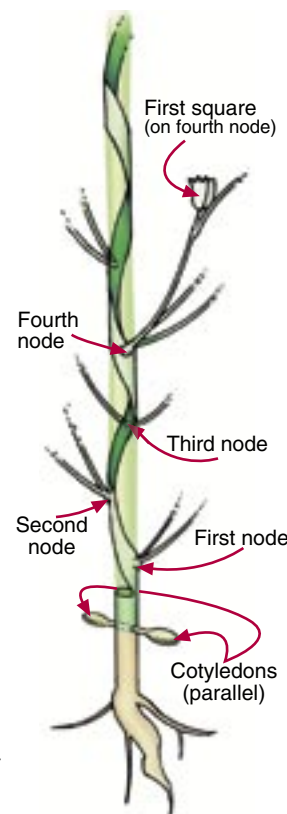


Figure 2. Ideal cotton plant development.

Table 1. Stages of cotton plant development.

Developmental stage	Heat units (DD60s)	Days from planting	Comments
Planting	0	—	—
Germination/radicle appearance	—	3	Soil temperatures greater than 65 degrees F are optimum.
Cotyledon emergence	55	7	—
First true leaf	>100	15	Photosynthetic activity peaks approximately 20 days after the leaves unfurl.
Add nodes to main stem	45–65/node	3/node	—
First square	500	46	High (greater than 80%) first position fruit set is desirable.
First bloom	850	67	—
Cutout	1,300–1,450	102	August 10 th is the latest date a flower has a 50% chance to reach maturity.
First open boll	1,700	112	—
Harvest	2,150–2,300	+153	—

reduce plant population densities. Early-season fruit loss from plant bug infestations stimulates plants to produce more vegetative growth and less lint. Competition from weeds for nutrients, soil moisture and light reduces crop growth and yields.

INSECT MANAGEMENT

From emergence until harvest, various pests attack the roots, leaves, stems or fruit (squares, blooms and bolls) of cotton. Growers and their field scouts must be vigilant in locating these pest outbreaks so that timely control measures can be undertaken (Figure 3). Economic threshold levels have been established for many cotton pests. A threshold infestation is the point at which control measures are needed to prevent the target pest from reaching its economic injury level (when control costs equal damage caused by the pest). The goal should be to suppress pest populations not annihilate them. Missing the opportunity to control threshold infestations and targeting the pests' earlier growth stages can lead to a greater number of pesticide applications. This increases production costs and yield losses, secondary pest outbreaks, and pest resistance to future chemical control measures. Growers are encouraged to use all practical integrated pest management (IPM) practices to maximize crop

production while minimizing economic and environmental costs. The philosophy of IPM is to incorporate different control practices and avoid relying on just one control method.

Missouri cotton growers generally have less pest pressure than growers in more southern states. Because of the unpredictable occurrence of various pest species, the type and severity of economic outbreaks will vary from year to year. A list of potential cotton pests, possible time frames for infestations, and cotton growth stages susceptible to damage are listed in Table 2.

Thrips

Identification and life cycle: These tiny, yellow to black, slender insects are annual pests in Missouri cotton fields (Figure 4). Thrips are active in the spring, feeding on wild host plants as well as cultivated plants, such as wheat. As these alternate host plants become less attractive, thrips begin migrating into

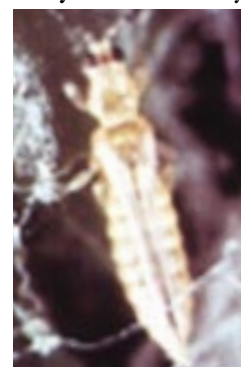


Figure 4. Thrips adult.

Table 2. Potential cotton pests in Missouri.

Insect	Seasonal occurrence	Susceptible crop stage(s)
Cutworms ¹	April, May	Seedling–4th leaf
Thrips ²	April, May	Seedling–4th leaf
Aphids	May–September	Seedling–Open boll
Plant bugs	May, June	1 st four weeks of squaring
Cotton bollworm and Tobacco budworm	June–September	Bloom–Harvest
Spider mites	May–September	Squaring–Harvest
Armyworms ³	April–September	Seedling–Harvest
Whiteflies	June–September	Bloom–Harvest
European corn borer	July–September	Bloom–Harvest
Cabbage looper	August–September	Bloom–Harvest
Stink bugs ⁴	August–September	Bloom–Harvest
Notes:		
1. The primary species that attack cotton are: black, granulated and variegated cutworms.		
2. Several different species of thrips (flower, soybean, tobacco and western flower) may attack cotton.		
3. Yellowstriped armyworms are seedling pests; whereas beet (foliage) and fall (boll) armyworms are more late-season pests.		
4. Both the green stink bug and several brown species may attack cotton bolls.		



Figure 3. Scouting is the foundation for any pest management program

adjacent cotton fields. Thrips have a generation (egg to adult) turnover of approximately two to three weeks with several generations occurring each year. Female thrips are each capable of laying 250 eggs during a two- to three-week period.

Damage: With their rasping-sucking mouthparts, thrips damage cotton by extracting plant juices from developing buds and foliage. Typical damage symptoms include leaves that are brown, wrinkled (spinach-like), or curled upward (Figure 5). Initially, thrips feeding damage reduces the plant's photosynthesis capacity and slows the plant's overall growth. A combination of reduced stand density, poor early-season crop growth, and delayed crop maturity can reduce overall cotton yields.



Figure 5. Thrips feeding damage. Note how the damaged leaves curl upward.

Control decisions: To scout for thrips, a cardboard box lined with white paper is recommended to spot these small insects (less than 1/20 inch in length) in the field. Place the box on the ground and angle it next to a group of cotton plants. Minimize the amount of soil that falls into the box so the thrips are easier to identify. Slap the plants over the box and count the small, slender, yellow to black thrips moving about in the box. Sample five plants at each of 10 random locations per field. Thrips infestations can be classified (damage and thrips infestation levels) as follows:

- None
- Low – new leaves with slight browning along edges; few thrips observed
- Medium – new leaves with considerable browning along edges and silvering on the underside; thrips common
- High – leaf silvering, terminal injury, deformed plants common; thrips numerous

Thrips injury usually ceases once plants reach the fourth leaf stage. A preventive, in-furrow insecticide application or seed treatment are the preferred methods of control. But preventive control measures are not always effective when cool, wet weather slows the seedling's

uptake of insecticide treatments or during years of above average infestations. In these situations a rescue, foliar, insecticide application also may be required. *Rescue treatments are recommended when thrips counts average one or more per plant.*

Cutworms

Identification and life cycle: Many cultivated (e.g., corn) and wild plant species are hosts for cutworms. Adult moths have mottled gray-brown forewings and light, uniform colored hindwings. Cutworm eggs are laid singly or in clusters of fewer than 30 next to plants and close to the ground. The larvae of the different cutworm species generally have a grayish coloration and will curl into a "C" shape when disturbed (Figure 6). The average life cycle (egg to moth) is approximately 30 days. Several generations may occur each year, but the first one is the most important economically.

Damage: Typical larval damage includes stems girdled at the soil level or leaves clipped off (Figure 7). Plant stand reduction can delay crop maturity and reduce yields, and severe stand loss may require replanting of heavily damaged fields. Potential damage to seedling plants is greatest during cool, wet springs following mild winters. Cotton fields most susceptible to cutworm damage are those with legume cover crops or ones with reduced-tillage systems that have high levels of organic matter present.

Control decisions: An effective cultural practice to help minimize cutworm damage is to destroy any winter cover vegetation 14 days before the cotton is planted. Elimination of this cover vegetation increases the larva's risk of starvation and predation. Preventive insecticide treatments are not recommended because of sporadic infestations. Cutworm larvae actively feed at night and hide during the day in underground burrows or beneath dirt clods or leaf trash. To scout for cutworm infestations, look for wilted plants or ones cut at the ground level and dig beneath dirt clods to locate the larvae. This process should be repeated at 10 locations within a field. *Rescue treatments are recommended to maintain a minimum plant stand density of three plants per row foot during years of abnormally high cutworm infestations.*



Figure 6. Cutworm larvae curl into a characteristic "C" shape when disturbed.



Figure 7. Cutworm feeding damage. Note the cut seedling near the larval burrows.

Cotton aphid

Identification and life cycle: Cotton aphids are tiny, variable-colored (green, yellow or black), soft-bodied insects (Figure 8). Female aphids give birth to live young; therefore, a new generation can be produced every five days during the summer. As the season

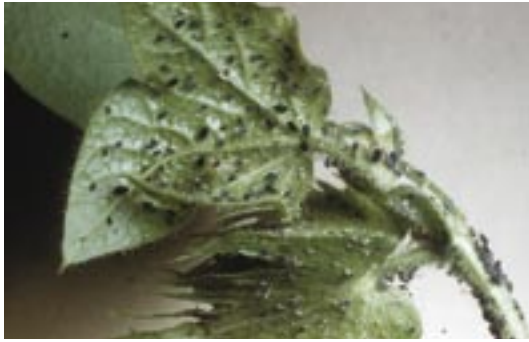


Figure 8. Cotton aphids.



Figure 9. Cotton aphid feeding damage. Note how the damaged leaves curl downward.

progresses, several generations can overlap in the field. Fortunately, a vast complex of beneficial insect parasitoids (small wasps) and predators (e.g., ladybird beetles, lacewing larvae) and diseases usually keep aphid populations below threshold levels.

Damage: Aphids use their piercing-sucking mouthparts to feed on cotton terminal buds and leaves. Feeding damage from severe aphid infestations can cause leaves to crinkle and curl downward (Figure 9), stunt or kill plants, and increase fruit loss. In addition to their feeding damage, aphids also deposit a sugary substance (honeydew) that serves as a growing medium for fungi (e.g., black mold). As the honeydew falls onto the lint, this moldy growth can stain the lint, reducing its quality and value.

Control decisions: To scout for aphids, examine the underside of leaves on five plants at each of 10 locations in a field. Aphid infestations can be classified as follows:

- Low – less than 10 aphids per leaf
- Medium – 11 to 25 aphids per leaf
- High – 26 or more aphids per leaf

Rescue treatments are warranted when aphid infestations are medium to high, honeydew is present, and beneficial insects are scarce or absent. Insecticides should be applied at maximum volume (five gallons by air and as many gallons as possible with ground rigs) with hollow-cone nozzles. The high water volume is necessary for thorough coverage of lower leaf surfaces where aphids feed. If one class of insecticide has been previously used in the field, a different class or combination of classes should be applied for subsequent aphid infestations. Cotton aphids have a history of insecticide resistance in Missouri and throughout the Cotton Belt.

Since these insects reproduce so quickly, they are more likely to become physically tolerant of, or resistant to, an insecticide.

Cotton fleahopper Plant bugs

Identification and life cycle: The cotton fleahopper and both the clouded and tarnished plant bugs are generalist feeders that cause injury by extracting plant juices with their piercing-sucking mouthparts. Clouded plant bug adults have mottled coloration (gray, brown and yellow) and the first antennal segment is enlarged (Figure 10); whereas tarnished plant bug adults are yellowish brown with black and yellow lines and a distinctive V-shaped area at the base of their wings (Figure 11). Tarnished plant bug nymphs are green with distinctive black spots on their back (Figure 12). Cotton



Figure 10. Clouded plant bug adult.

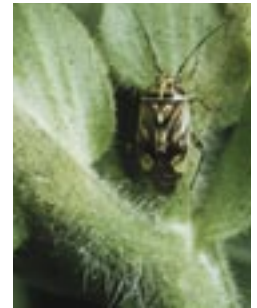


Figure 11. Tarnished plant bug adult.

fleahoppers are pale green with tiny black spots and are smaller ($\frac{1}{8}$ inch vs. $\frac{1}{4}$ inch in length) than plant bugs. In the spring tarnished plant bugs actively feed on many different cultivated (e.g., corn) and wild host plants (e.g., daisy fleabane) before moving into adjacent cotton fields. Plant bugs typically have a generation turnover of 20 to 30 days, and each female is capable of laying 30 to 70 eggs.



Figure 12. Tarnished plant bug nymph.

Damage: Overall, the tarnished plant bug has the greatest potential to cause economic damage to cotton. Typical damage symptoms include square shed, deformed and brownish colored blooms, and stunted bolls (initially with reddish brown specks and later turning yellow)

that the plant eventually sheds (Figure 13). Both square and boll shed also can occur due to environmental stresses (drought, overcast skies) or excessive plant populations (greater than 5 per foot of row) that cause carbohydrate stress in the plants; therefore, you should be certain that plant bugs are the primary cause of this fruit loss before applying any insecticide.



Figure 13. Plant bug feeding damage in a bloom.

Control decisions: To scout for plant bugs, use a 15-inch diameter sweep net and a 3-foot drop cloth. Plant bug infestations generally begin along field border areas before the insects migrate further into the field. Their distribution also may be “clumped” near these border areas adjacent to their alternative plant hosts. *Sweep nets are more effective in sampling for the adults; whereas the drop cloth is more useful for catching the nymphs. In each of 10 locations per field, sweep ten times and take one drop cloth sample.* Avoid taking sweep net counts during midday (11:30 a.m. to 3:30 p.m.) when plant bug adults are less active and deeper within the plant canopy. Scouting efforts for plant bugs should be intensified when square retention drops below 80 percent (first position sites) and before cotton plants start blooming. Treatment for plant bug infestations is particularly necessary during the first four weeks of squaring (late June to late July in Missouri). These fruiting positions are where the vast majority (greater than 80%) of the cotton lint is produced each year. Economic thresholds will vary according to plant’s growth stage:

Week of squaring	Plant bugs per 100 feet of row
1	6–8
2	8–10
3	10–12
4	>15

Mowing border vegetation around fields before cotton plants begin producing squares can help minimize the risk of plant bug infestations.

Cotton bollworm Tobacco budworm

Identification and life cycle: The cotton bollworm and the tobacco budworm are important caterpillar pests because of their potential feeding damage to squares and bolls; however, the cotton bollworm is usually the most common species each year in Missouri. Bollworm moths vary in color from reddish brown to a whitish green-brown (Figure 14); whereas, budworm moths are light green to brown with three darker green bands across the forewings. Female moths of both species usually lay their eggs (Figure 15) on the upper leaf surfaces in the terminal leaf bracts of fruiting forms, or blooms. The newly hatched larvae of both species are a whitish color with a black head (Figure 16). Larger larvae are light green to brown with several dark stripes down the body. Bollworm infestations may consist of both migratory and resident individuals, whereas tobacco budworm populations are primarily migratory. Annually, a majority (90% or more) of the larvae infesting Missouri cotton fields will be cotton bollworms. A generation is completed every 27–35 days with two to three generations occurring each year in cotton. A large complex of natural enemies readily attack both species unless eliminated or reduced by earlier insecticide applications. In the spring and early summer, cotton bollworm (the same insect as the corn earworm) feeds on alternative cultivated (e.g., corn) or wild host plants. Once these host plants mature and begin drying down, bollworm infestations shift to cotton.

Damage: Newly hatched larvae initially feed on terminals (Figure 17a) or small squares (Figure 17b); however, larger larvae tend to move downward into the plant canopy to feed on blooms (Figure 17c), large squares, and bolls. A single larva is capable of destroying several squares (6 to 7) and bolls (2 to 3) before pupating (Figure 17d).



Figure 14. Cotton bollworm moth.



Figure 15. Bollworm egg.



Figure 16. First-instar bollworm larva and egg.



Figure 17a. Bollworm terminal damage.



Figure 17b. Bollworm feeding on a square.



Figure 17c. Bollworm larva with frass in bloom.



Figure 17d. Bollworm larva and boll damage.

Control decisions: During the second week of squaring or once the first cotton blooms appear, examine plants at least once a week for feeding damage. When scouting for bollworm eggs and larvae it is important to examine the whole plant (particularly the top 3 to 5 inches of the main terminal) and its fruiting structures (particularly beneath bloom tags). Check five plants at each of 10 locations per field for eggs, larvae, and feeding damage (terminals wilted or fruit with holes and wet insect droppings present). *Insecticide treatments are recommended when 10 percent of the plants are infested with small larvae (less than 1/4 inch in length).*

Spider mites

Identification and life cycle: The two-spotted spider mite (Figure 18) is the most common spider mite species attacking cotton. These tiny (less than 1/80 inch in length), variable-colored (green, tan or red) relatives of insects feed on multiple plant hosts. A generation is completed every four to 14 days with multiple generations occurring each year in cotton. Hot, dry conditions favor the most rapid development.

Damage: Spider mite infestations in cotton fields generally start along field borders (Figure 19) and near ditches, weed patches, or dusty roads. Initially, spider mites start feeding along the leaf midrib before spreading across the leaf. As mite infestations increase and plants become more stressed by environmental factors (e.g., drought), small yellow spots appear on the infested leaves (Figure 20). Damaged leaves

eventually turn a red color and die after prolonged mite feeding damage. Extensive spider mite damage can prematurely defoliate plants and dramatically reduce lint quantity and quality (Figure 21).

Control decisions: To scout for spider mites, examine at least one leaf from each of 50 randomly selected plants per field. Spider mite infestations can be classified as follows:

- None
- Low – 1 to 10 mites per leaf
- Medium – 11 to 25 mites per leaf
- High – 26 or more mites per leaf

Spot treating hot spots within a field with miticides can help reduce the risk of more widespread infestations. *Miticide treatments are recommended once 50 percent or more of the plants are infested.* A second application within the next seven days is usually necessary because spider mite eggs are not killed by miticides. To obtain maximum control of spider mites, a miticide must be thoroughly applied to both sides of a leaf. Because spider mites are easily distributed from infested areas to non-infested ones by natural (animals, people, wind) or mechanical means, growers should maintain a vegetation-free zone of 10 to 20 feet in width between the cotton and border vegetation to minimize spider mite infestations. Preserving beneficial insects (e.g., big-eyed bug, minute pirate bug) can help minimize spider mite infestations.

Fall armyworm

Identification and life cycle: This armyworm species may prefer grass hosts; however, it also feeds on broadleaf plants like cotton. Fall armyworm is an infrequent economic pest in cotton, but it can potentially cause substantial boll damage in Missouri. Adult moths have mottled forewings, and the hindwings are whitish with a gray border. Small larvae are white with black heads; whereas larger larvae are dark and smooth, with an inverted “Y” mark on their cream-colored heads (Figure 22). Fall armyworms have a generation turnover of 24 to 35 days, and several generations can occur each year in Missouri; however, there is generally only one generation in cotton. Female moths are capable of laying 50 to several hundred eggs in masses covered with the grayish moth scales.

Damage: Infestations usually occur once



Figure 18. Two-spotted spider mite eggs, nymphs, and adults.



Figure 19. Border vegetation increases risk of mite infestations in the adjacent cotton field.

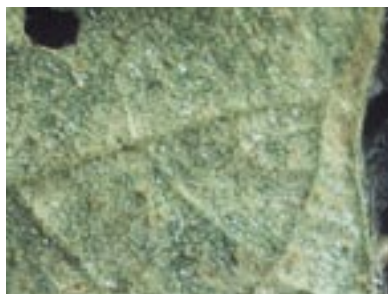


Figure 20. Spider mite webbing and leaf damage.



Figure 21. Spider mite feeding damage can weaken and even kill stressed plants.



Figure 22. Fall armyworm larvae.



Figure 23. Fall armyworm boll damage.

alternate host plants (e.g., corn) mature and dry down. Typical damage symptoms are blooms and bolls with holes at the base of the bracts (Figure 23).

Control decisions: To scout for fall armyworm infestations, examine five plants at each of 10 locations per field for egg masses, larvae or damage. These egg masses are typically laid on both sides of the leaf. The larvae are difficult to detect because they start feeding on the boll exterior within a few days of hatching from their eggs. *Insecticide treatments are recommended when four or more larvae per 100 bolls or blooms are present.*

Beet armyworm

Identification and life cycle: Beet armyworms are a migratory species that infrequently infests Missouri cotton fields. They have a wide range of hosts but favor broadleaf plants (e.g., cocklebur, cotton, pigweed). Adult beet armyworm moths are grayish with a pinkish white dot in the center of each forewing, and the hindwings have a dark border. The smoothed-skin larvae have variable coloration but all have a distinctive black dot on either side of the body and above the second pair of true legs (Figure 24). Beet armyworms have a generation turnover of 27 to 36 days, but there is typically only one generation in cotton. Female moths are



Figure 24. Beet armyworm larva.

capable of laying 80 to 150 eggs in masses covered with the grayish moth scales.

Damage: Typical damage symptoms in cotton initially begin with “skeletonized” leaves (Figure 25) followed by damage to squares, blooms, and bolls. Also take note of any foliar damage to weed hosts (e.g., pigweed) also present in the field.

Control decisions: To scout for beet armyworm infestations, examine five plants at each of 10 locations per field for egg masses, larvae or damage. Egg masses are typically laid on both sides of the leaf. *Insecticide treatments are recommended when 5–6 “bits” (egg masses or larval clusters) per 300 row feet are found before August 15. This threshold doubles after August 15.* Management practices to minimize beet armyworm infestations include: (1) early crop maturity, (2) proper weed (e.g., pigweed) control, and (3) preservation of beneficial insects.



Figure 25. Beet armyworm feeding damage. Note that the larvae do not chew through the leaf.

Banded-wing whiteflies

Identification and life cycle: Banded-wing whiteflies are small, piercing-sucking insects that occasionally reach economic infestation levels in Missouri. Adult whiteflies are snowy white (Figure 26) with three narrow wing bands; whereas, the nymphs are pale green and have an oval shape. Whiteflies have a rapid (about 18 days) life cycle (egg to adult), and several overlapping generations may occur in cotton. Many predaceous (e.g., ladybird beetles) and parasitic insects readily attack and suppress whitefly infestations unless eliminated by earlier insecticide applications.



Figure 26. Whitefly adults.



Figure 27. Honeydew-laden leaves (shiny) from whitefly infestation.

Damage: Whitefly feeding damage can cause premature defoliation and poor boll development. Their honeydew deposits (Figure 27) may eventually lead to staining of the cotton lint as black sooty mold grows on the contaminated lint.

Control decisions: To scout for whiteflies, examine five plant terminals at each of 10 locations per field. Take note of the number of whitefly colonies resting on the underside of leaves or flying about as you walk through the field. Insecticide treatments are recommended when 50 percent or more of the plant terminals are infested. Thorough coverage of the entire plant canopy is necessary for adequate whitefly control.

European corn borer

Identification and life cycle: This pest species has a wide host range, but it can be an infrequent cotton pest by damaging terminals and even mature bolls. Female moths are pale-yellow with irregular, wavy bands on their wings (Figure 28). Males are smaller, darker, and have olive-brown wing markings. Larvae are initially dull white with small brown spots arranged in rows, but older larvae are light tan



Figure 28. European corn borer moth.

to a pinkish gray with two rows of small, circular, brown spots. The European corn borer has a generation turnover of greater than 30 days, but only one generation is of economic importance in Missouri cotton fields. Female moths typically lay 5 to 50 eggs in masses on the underside of leaves (Figure 29).



Figure 29. European corn borer egg mass.



Figure 30. European corn borer stem damage.



Figure 31. European corn borer larva and boll damage.



Figure 32. Looper larva.



Figure 33. Looper foliar damage. Main leaf veins are left intact.

Damage: Infestations usually occur once alternative host plants (e.g., corn) mature and dry down. Typical damage symptoms in cotton are terminals (Figure 30) and bolls (Figure 31) with holes and sawdust-like droppings around the hole.

Control decisions: To scout for European corn borer infestations, examine five plants at each of 10 locations per field for larvae and feeding damage. Female moths readily penetrate deep into the canopy; therefore, the entire plant should be examined. Typically, European corn borer larvae bore into the bottom of the boll; whereas, cotton bollworm or tobacco budworm larvae initially bore further up and into the boll. Look for the small larvae between the bracts and boll wall. Currently, Missouri has no established threshold for this pest on cotton. In North Carolina, a recommended threshold is 3 percent or more of the plants infested with young live larvae. Growers can minimize the attractiveness of their cotton to European corn borers with early planting dates and uniform plant growth.

Loopers

Identification and life cycle: Two looper species (cabbage and soybean) may infest cotton fields, but the migratory soybean looper is rarely observed in Missouri. Looper moths have brown to gray forewings with a silver figure-eight design and lighter-colored hindwings with dark margins. The larvae are initially white before turning a pale green color. The larvae are easily identified by their looping gait (Figure 32). Looper larvae feed entirely on foliage for 14 to 28 days.

Damage: Typical damage symptoms are leaves with ragged holes with the leaf veins still intact (Figure 33).

Control decisions: To scout for looper

infestations, examine five plants at each of 10 locations per field for defoliation damage. Premature defoliation by loopers is rare because diseases and natural enemies usually suppress looper infestations. *Insecticide treatments are recommended once defoliation damage reaches 25 percent and developing bolls are still present.*

Stink bugs

Identification and life cycle: Both green and several species of brown stink bugs may feed on cotton. Stink bugs also feed on many other cultivated (e.g., corn, soybean) and wild host plants. Adult stink bugs are shield-shaped and their coloration is indicative of their name (Figure 34). Green stink bug nymphs are initially black and later turn green with orange and black markings (Figure 35). Brown stink bug nymphs are light green with no distinctive markings (Figure 36). Not all stink bug species are considered pests, and one predatory species looks similar to brown stink bugs. Adult spined soldier bugs differ from brown stink bugs by having more pronounced spines behind their head and a reddish underside with a black spot near the tip of the abdomen (Figure 37). Spined soldier bug nymphs are initially red and black but later turn a creamy yellowish orange coloration (Figure 38).

Damage: Stink bugs are robust insects that use their piercing-sucking mouthparts to remove plant fluids from squares and bolls. Stink bugs can damage even relatively mature bolls (Figure 39). External damage: small, sunken, black spots; Internal damage: discolored lint and seeds, “warty” growth on boll wall); however, economic infestations are sporadic in Missouri.



Figure 34. Stink bug adult.



Figure 35. Green stink bug nymph.



Figure 36. Brown stink bug nymph.



Figure 37. Spined soldier bug adult.



Figure 38. Spined soldier bug nymph.

Control decisions:

To scout for stink bug infestations, use a drop cloth and take beat samples at 10 different locations in a field. Also, open a few bolls and inspect the bolls for signs of stained lint and seeds. Because their eggs are laid in masses, infestations are rarely uniform across a field. *Insecticide treatments are recommended when stink bug infestations reach one large nymph or adult per 6 row feet, or when 20 percent of medium-sized bolls display internal signs of feeding damage and stink bugs are observed.*



Figure 39. Stink bug boll damage.

OTHER COTTON INSECT PESTS

Identification and life cycle: Cotton is host to many other plant-feeding insects and invertebrates (e.g., flea beetles, leafrollers, salt-marsh caterpillar, slugs, yellowstriped armyworm) that are rarely considered a pest of cotton. However, they have the potential to become pests under special circumstances. Flea beetles are small, shiny, dark-colored insects that have a third pair of legs enlarged for jumping (Figure 40). The variegated leafroller has an apple-green coloration on top and is amber green on the bottom. The saltmarsh caterpillar larva is covered in long hairs (red or black) and its body is initially gray after hatching; then it turns yellow.



Figure 40. Flea beetle adult.



Figure 41. Saltmarsh caterpillar larva.



Figure 42. Slugs and slime trail.



Figure 43. Yellowstriped armyworm.



Figure 44. Flea beetle damage to cotyledons.



Figure 45. Leafroller and rolled leaf.



Figure 46. Slugs damage to seedlings.

low to black as it matures (Figure 41). Slugs are soft-bodied, legless invertebrates without shells and leave a slime trail as they move about in the field (Figure 42). Yellowstriped armyworm larvae have two rows of black, triangular spots along the back between thin yellow lines (Figure 43).

Damage: Flea beetle adults occasionally attack plants at the seedling stage and remove the green tissue from the leaves, particularly the cotyledon leaves (Figure 44). This damage most often occurs in no-till fields where the cover vegetation was killed off after the cotton plants emerged. Leafrollers feed on many parts of the cotton plant, but the bracts of fruiting forms (squares, blooms and bolls) are typically the favored feeding sites. Leafrollers spin a web and feed on the plant tissue within this protective “shell” (Figure 45). The presence of extensive webbing helps distinguish leafroller damage to boll walls from that caused by fall armyworm larvae. Early-season infestations of saltmarsh caterpillars are a threat primarily when they destroy the terminal of two-leaf or smaller plants, whereas loopers and other late-season infestations that feed on leaves are much less of a threat. Slugs are another pest primarily found in no-till fields. Slugs may feed on the cotyledon leaves of small plants or clip the plants like cutworm larvae do (Figure 46).

Yellowstriped armyworms are primarily an early-season pest that can destroy young plants, but they also may feed on squares and bolls later in the season.

Control decisions: No threshold exists for flea beetles because economic infestations of this insect are rare; however, insecticide oversprays for cutworms in no-till fields also should control any flea beetles feeding in those same fields. Leafroller infestations only occur in non-Bt fields, and insecticide oversprays are not recommended unless early-season terminal damage reaches 20 percent in presquaring cotton. The saltmarsh caterpillar is another pest primarily found in no-till fields. No threshold exists for saltmarsh caterpillars, and late-season foliar damage should be pooled with similar damage caused by loopers. Beneficial insects typically control these late-season saltmarsh caterpillar infestations. Slug infestations currently have no action threshold on cotton. Generally, slug populations decline as weather conditions turn drier and warmer, and subsequent plant growth compensates for any slug feeding damage. There is no threshold for yellowstriped armyworms in cotton because economic infestations are rare; however, insecticide oversprays for other early-season (e.g., cutworms) and late-season (e.g., bollworm) pest infestations also should control yellowstriped armyworm infestations.

BENEFICIAL INSECTS

Honey bees and other insects help pollinate cotton. Cotton is primarily a self-pollinator, but it is partially pollinated by insects. These insect pollinators help set a good crop and good cross pollination is desirable; therefore, the selection and timing of insecticide application should be considered when pollinators are present in the field. Pollinators tend to leave cotton fields by midafternoon, but pest species may remain active into the night. Insecticides application later in the evening helps to minimize harm to pollinators while maximizing control of the pest species.

Numerous beneficial insect and arthropod species can be found in cotton fields attacking pest species. These beneficial species attack the

egg, immature (larval, nymphal and pupal), and adult stages of most pest species. Both beneficial parasitoid and predatory species are present throughout the field season. In addition to the beneficial arthropods, numerous disease organisms may infect cotton pests and further limit their population growth.

Ants

Ants are important and overlooked predators in cotton fields. Several different species may inhabit fields as the worker caste ants (approximately 1/8 inch in length, wingless, and with a narrow waist) forage for insect eggs and larvae. Ants are an important predator of bollworm eggs and larvae.

Assassin bugs and other piercing-sucking predators

Several different species of assassin bugs (yellow to black coloration) are predators of both immature and adult stages of insects (Figure 47). These piercing-sucking insects readily attack the large larval stages of lepidopteran insects (e.g., bollworm). It is important to exercise caution when handling these insects because their bite is very painful.

Other piercing-sucking predators include several species each of big-eyed bugs, damsel

bugs and minute pirate bugs. Minute pirate bugs (about 1/8 inch in length, black) are the most common of this predatory group (Figure 48). They attack thrips, aphids, mites and bollworms (eggs, small larvae). Both big-eyed bug adults and nymphs also frequently attack thrips, plant bugs, bollworms (eggs, small larvae), and many other insects. Adults are about 1/4 inch long with big eyes and gray to black coloration (Figure 49); nymphs are bluish gray. Damsel bugs (about 1/2 inch long, slender with long legs) (Figure 50) are less common, but they also attack plant bugs, spider mites, and bollworms (eggs, small to medium-sized larvae).

Lacewings

Two lacewing species (brown and green) occur in cotton fields, but the green one is more commonly found. Adult lacewings are fragile in appearance with long antennae and large wings with many pronounced veins (Figure 51). Female lacewings deposit their white eggs at the end of long, threadlike stalks (Figure 52). The larval stage is a mottled brown with long sickle-shaped mouthparts (Figure 53). Adults may feed on insect eggs, but the larvae are more important because they are voracious predators of aphids and bollworms (eggs and small larvae). A single lacewing larva can consume more than 40 bollworm eggs in one day.



Figure 50. Damselbug adult.



Figure 47. Assassin bug adult.



Figure 48. Minute pirate bug adult.



Figure 49. Big-eyed bug adult.



Figure 51. Green lacewing adult.



Figure 52. Lacewing egg.



Figure 53. Lacewing larva.



Figure 54. Ladybird beetle larva attacking aphids.



Figure 55. Ladybird beetle attacking aphids.



Figure 58. Mummified aphids.



Figure 56. Syrphid larva attacking aphids.

Ladybird beetles

Many species of ladybird beetle can be found in cotton fields. They range in size from $\frac{3}{100}$ to $\frac{1}{2}$ inch in length, have orange to black in coloration, and may or may not possess spots. The eggs (yellow-orange, football-shaped) are laid singly or in masses of 10 or more depending on the species. The larval stage is typically “alligator-shaped” and black with brightly colored markings. Both larval and adult stages (Figures 54 and 55) of ladybird beetles prey upon aphids, spider mites, the eggs and larvae of most lepidopteran cotton pests (e.g., cotton bollworm), and other soft-bodied insects.

Other predatory arthropods occasionally found in cotton fields include ambush bugs, earwigs, ground beetles, spiders, syrphid flies (Figure 56) and tiger beetles.

Parasitoid flies and wasps

Several parasitoid species of flies and wasps may attack cotton pests (Figure 57), especially aphids and the larvae of lepidopteran pests. Various tiny wasps regularly lay their eggs inside the bodies of aphids. Within a few days the aphids are paralyzed, become swollen and discolored, and eventually die (Figure 58). Several days later, the adult wasp (Figure 59) emerges through a circular hole cut in the “mummified” body of the aphid. Other tiny



Figure 59. Wasp parasitoid of cotton aphids.



Figure 60. *Neozygites fresenii*-infected aphid.

wasps and parasitic flies attack the egg or larval stage of armyworms, bollworms, loopers, and other lepidopteran cotton pests.

Several naturally occurring pathogens also may infect and reduce populations of cotton pests. For example, epizootics or outbreaks of the fungal pathogen *Neozygites fresenii* can rapidly reduce cotton aphid infestations within 7 to 10 days. Infected aphids typically die with their mouthparts still inserted into the leaf and are covered with a velvety white or light gray growth (Figure 60). Later, secondary pathogens infect the aphid bodies, giving them a fuzzy olive-brown appearance (Figure 61). Other pathogens (fungal or viral) are specific to lepidopteran pests and kill their hosts within a few days after infection. Infected, dead larvae (discolored) are typically found hanging from the bottom of a leaf (viral) or standing erect on a leaf (fungal). The viral particles or fungal spores are eventually released back into the environment to infect another generation of pests.



Figure 57. Parasitized yellowstriped armyworm larva in cotton blossom.



Figure 61. Aphid bodies overgrown by saprophytic fungi after being killed by *Neozygites fresenii*.

COTTON DISEASES

Diseases, including nematodes, reduced cotton production in Missouri an estimated 8.7 million pounds in 2001, 19.6 million pounds in 2002, and 39.7 million pounds in 2003. The value of the loss in 2003 was \$17.1 million. Clearly cotton diseases are a serious detriment to the cotton farmer's income and the economy of Missouri.

Strategies are available to help cotton farmers minimize the potential yield reduction that diseases can cause. This guide provides information to help farmers and consultants scout cotton for diseases, identify cotton problems caused by diseases, and determine which disease management strategies to use. Cotton yields in fields where pest control decisions were made using the results of pest surveys were conservatively estimated to be 50 pounds of lint per acre greater than where pest control decisions were made without knowledge about the pest populations present in the field.

Scouting cotton for diseases

Consultants and farmers should survey cotton for diseases at the same time the crop is surveyed for insects. Symptoms of individual diseases may not be evident throughout the season. The following table shows when disease symptoms are most often observed during the Missouri growing season.

Table 3. Potentially damaging cotton diseases in Missouri.

Diseases	Seasonal occurrence
Seedling diseases	Seed germination to 28 days after emergence
Root-knot nematode	Stunt and galls most evident 6 weeks after planting to harvest
Leaf spot	Seedlings to mature plants
Bacterial blight	Seedlings to mature plants
Wilts	Beginning bloom to first open boll
Bronze wilt	Beginning bloom to first open boll
Boll rots	From first open bolls to harvest

General disease management

There are several strategies for managing diseases in cotton. The three most important are crop rotation, planting disease-resistant varieties, and planting high-quality seed in warm, well-drained soil. An integrated approach that uses all of these methods usually is the most effective and profitable.

Rotating cotton with corn and certain soybean varieties will help manage several cotton diseases. For example, the number of root-knot nematodes in the soil declines when a soybean variety that is resistant to root-knot nematode is planted. The population of this nematode will fall below the cotton damage threshold after planting a resistant soybean variety for a few years.

No variety of cotton is resistant to all cotton diseases. However, some cotton varieties often have improved levels of resistance to root-knot nematode, Fusarium and Verticillium wilt, bacterial blight and bronze wilt. Farmers should choose varieties based on MU yield trials in their area and resistance to locally significant diseases.

Farmers should plant seeds that germinate quickly and produce vigorous seedlings for a uniform stand. There are two germination tests, a warm test and a cool test, that are useful for predicting how a seed lot will perform in the field. In general, the warm germ test (about 86 degrees F) will estimate the percent emergence under highly favorable conditions, while the cool germ test (64 degrees F) will estimate emergence under more typical, somewhat adverse conditions. Minimum acceptable percent germination levels for cotton planting seed are 80 percent on the warm test and 50 percent on the cool test. The warm germination test results are printed on most bags of seed. Growers should ask their seed dealer for the warm and cool germ test results for their seed, and should only plant seed that germinates well, especially when planting early or in heavy soil. Fungicide seed treatments on most commercially sold seed protect seed from rot.

When planting early or in poorly drained, clay soil, use an in-furrow fungicide for extra

University of Missouri Extension Plant Diagnostic Clinic

23 Mumford Hall
University of Missouri
Columbia, MO 65211

Phone: (573) 882-3019

Fax: (573) 882-4288

Web: <http://agebb.missouri.edu/pdc/>

protection against organisms that cause seedling diseases. The fungicides applied by the seed supplier help protect the seed and seedling against rot (see step 2), but will not protect the seedling from all seedling diseases. A fungicide applied in the furrow at planting will provide additional protection against seedling diseases. In-furrow applied fungicides are available in granule or liquid formulation.

More information about management of cotton seedling diseases and cotton nematodes is available in MU publications G4254, *Cotton Seedling Diseases: Answers to Frequently Asked Questions*, and G4259, *Cotton Nematodes in Missouri: Your Hidden Enemies*, and on the World Wide Web at aes.missouri.edu/delta.

Cotton seedling diseases

Several different, normally harmless, microscopic organisms called fungi live on organic matter in the soil and can attack cotton seedling roots in the spring. The fungi most commonly found attacking cotton in Missouri are *Pythium*, *Fusarium*, *Rhizoctonia* and *Thielaviopsis*. A plant may be attacked by one or several of these at the same time.

The organisms that cause seedling diseases are present in most soils. Once established, they remain there indefinitely because they produce structures that enable them to survive in the soil from year to year.

Seedling diseases become worse when the soil is cool and wet. These conditions do not develop in Missouri every year because of yearly variations in weather, so the severity of cotton seedling diseases also varies from year to year. Seedling diseases cause more yield loss in cotton than any other disease in Missouri.

The microscopic organisms that cause seedling diseases penetrate and grow within the cotton root by secreting chemicals that dis-

solve the root tissue. The organisms absorb the nutrients they need for growth from the damaged root. The root damage may vary from slight injury (which the root may outgrow), to moderate injury (the plant lives but the root is permanently damaged), to seedling death. Diseased roots are unable to absorb water and nutrients as well as healthy roots, and the plant will grow more slowly. Plants with permanently damaged roots usually shed young bolls more quickly during summer drought, mature later, yield less and produce poorer-quality lint than healthy plants.

Symptoms: A healthy cotton seedling root is white and firm, and the central root (taproot) is long with numerous secondary white roots. A stand of healthy cotton seedlings is uniform with no skips. Seedling diseases affect young plants in several ways. When damage is mild, dark, rotten areas (lesions) develop on infected roots (Figure 62). When damage is severe, the taproot may be destroyed, leaving only shallow-growing lateral roots to support the plant (Figure 63). When most severe, those diseases kill the root, then seedlings wither and die (Figure 64). Plants that survive infection are often weak, more susceptible to other diseases and environmental stresses, and unproductive. Sometimes seedling diseases will kill entire fields of young cotton, but the most frequent result of these diseases is thin, uneven stands (Figure 65) of weakened plants that grow slowly, yield poorly and have low-grade lint. For a positive diagnosis, send 5–10 seedlings with typical symptoms to the University of Missouri Extension Plant Diagnostic Clinic. Collect these seedlings by digging them up and gently shaking excess soil off roots. Put these seedlings into zip-lock plastic bags and store them in a cooler until shipment. Send the material by overnight express or deliver it to these individuals.



Figure 62. Rotten areas on roots damaged by seedling diseases.



Figure 63. Shallow lateral roots left after the top root has been destroyed by seedling diseases.



Figure 64. Seedling diseases can kill roots, causing seedlings to die.



Figure 65. Thin stand due to cotton seedling diseases.

Management:

- Plant only when the soil temperature 4 inches deep has warmed to about 60 degrees Fahrenheit by 8:00 a.m. and plant only when five days of warm weather are predicted.
- Plant seeds that germinate quickly and produce vigorous seedlings.
- Plant in fertile soil.
- Plant on raised beds to maximize drainage and the soil temperature of the seedbed.
- When planting early or in poorly drained clay soil, use an in-furrow fungicide for extra protection against organisms that cause seedling diseases.
- Use a device to move trash away from the row when planting no-till, so the sun can more quickly warm the soil around the seed.

Root-knot nematodes

Missouri scientists recently surveyed for cotton parasitic nematodes in Dunklin, New Madrid, and Pemiscot counties, which produce about 98 percent of Missouri's cotton. Reniform nematodes were found in only 3 percent of fields in Pemiscot County and no other county, and root-knot nematodes were present in many fields. Root-knot nematodes were found in 45 percent of fields in Dunklin, 20 percent in New Madrid, and 26 percent in Pemiscot. Fortunately, only a few fields had enough root-knot nematodes to cut yield.

Root-knot nematodes are so named because the galls they produce on roots look like knots in a rope. The most common species of root-knot nematodes are *Meloidogyne incognita*, *Meloidogyne arenaria*, *Meloidogyne hapla*, and *Meloidogyne javanica*. All four species occur in the U.S. Cotton Belt, but only some populations of the species *Meloidogyne incognita*

(also known as the southern root-knot nematode) attack cotton. This is the only species of root-knot nematode known to be present in Missouri.

Root-knot nematodes will be a greater problem when cotton is planted year after year and when planted in sandy soil. Root-knot nematodes are best adapted to coarse-textured, sandy soils rather than fine-texture silty or clay-based soils.

Southern root-knot nematode populations can be reduced by rotating cotton with a resistant soybean cultivar. The root-knot nematodes that hatch when this soybean variety is grown in a field die due to lack of food. Maintaining a clean, fallow field will also reduce nematode populations. However, this practice is impractical because of the loss of revenue during the fallow period.

Chemical nematicides are widely used to control root-knot nematodes. Numerous studies show that when nematicides are used to control nematodes, yields increase significantly. Yield increases of more than 50 percent are common in severely infested fields. The objective for using chemical nematicides is to protect the seedling roots from nematodes for four to six weeks. By protecting the roots during early development, yield losses will be reduced substantially even though nematodes may penetrate the roots during the latter part of the season. Several nematicides are labeled for use on cotton. All pesticides should be used only in accordance with label instructions.

Symptoms:

Root-knot nematodes are not uniformly distributed in soil; they occur in irregular patches. These patches may be small and limited in number, or they may be large and widely distributed. Depending on the nematode population, plants in these patches may be damaged and show symptoms ranging from mild to severe stunting (Figure 66). Leaves on infected plants may wilt at midday more readily than healthy plants. In addition, root-knot



Figure 66. Stunted cotton due to root-knot nematodes.



Figure 67. Galls on cotton roots due to root-knot nematodes.

nematodes cause visible galls or knots on roots (Figure 67). Swellings of the infected root tissues can be found on the cotton taproot and the lateral roots from about six weeks after emergence until harvest. The galls are easier to detect if cotton plants are carefully dug (not pulled) from the soil. For a positive diagnosis, send root and soil samples to a reputable soil and plant testing laboratory. The soil and roots should be kept cool from the time they are collected until shipment. Store the material in a plastic bag in a cooler and ship it by overnight express or deliver it to the laboratory.

Management

- Rotate cotton with resistant soybean varieties.
- Use a nematicide.

Leaf spots

Several diseases attack the leaves of cotton and cause lesions that under favorable conditions can cause considerable damage. The most important of these diseases are *Ascochyta* blight (wet weather blight), *Cercospora* leaf spot, and *Alternaria* leaf spot. These diseases cause various types of leaf spot symptoms.

Symptoms:

Ascochyta blight is known as “wet-weather blight” because it typically develops on cotyledons and leaves of young plants during wet weather in the spring. A dark brown circular spot (0.1 inch) develops first on cotyledons and leaves (Figure 68). These spots may enlarge over time (Figure 69).

Cercospora leaf spot usually appears on cotton leaves of potassium-deficient plants under stress from drought and on leaves of plants near harvest. The spots, 0.25 to 0.75 inch in diameter, are white to light brown with a narrow red



Figure 68. *Ascochyta* blight on cotyledons.



Figure 69. *Ascochyta* leaf spot symptoms on leaves.

margin.

Alternaria leaf spot usually develops on older leaves late in the season in Missouri. The spots are dull brown and circular and may be up to 0.4 inch in diameter. The tissue in older spots may be gray, and this tissue may fall away, leaving holes in the leaf (Figure 70).

For diagnosis, send 5–10 leaves with symptoms in a plastic bag by overnight express to a diagnostic laboratory.

Management

- Rotate cotton with corn or soybean plantings.
- Supplying high levels of potassium to the cotton may reduce the incidence and severity of leaf spot diseases.

Bacterial blight

Bacterial blight, sometimes called angular blight, occurs on cotton in most parts of the world. The severity of this disease in the United States was greater in the 1970s than in the 1990s. Weather greatly affects the severity of this disease. Bacterial blight is usually least severe or absent during hot dry conditions, but it can be severe during warm, wet weather. In Missouri, this disease was severe enough in the 1960s and early 1970s to cause yield losses. Missouri farmers experienced little if any yield losses due to bacterial blight in the 1980s, and it was rare in the 1990s. This disease has occurred rarely in Missouri since the mid-1980s because farmers planted acid-delinted seed of varieties with resistance to bacterial blight.

Symptoms:

On cotyledons, bacterial blight causes small, quarter-inch-diameter lesions that are initially dark green turning to dark brown. It may cause black cankers on the stems of seed-



Figure 70. Lesions on leaves damaged by *Alternaria* leaf spot.



Figure 71. Lesions on leaves damaged by bacterial blight.

lings and older plants. Symptoms on the leaves may appear throughout the growing season. Symptoms will be most severe on leaves when the humidity is high with air temperatures average 86–95 degrees F and when rain, heavy dew, fog or sprinkle irrigation are frequent. The first leaf symptoms are light-green spots that are visible on the upper and lower surfaces of the leaves. These spots are usually $\frac{1}{16}$ inch to $\frac{1}{8}$ inch in diameter and quickly turn dark brown to black (Figure 71). The margin of these spots will have some sharp angles. Leaves with lots of individual lesions may defoliate prematurely. This disease may also develop on bolls. The round, light-green lesions on bolls may develop into boll rot.

Management

- Rotating cotton with soybean or corn plantings for one or more years will help reduce the severity of bacterial blight on the next cotton crop.
- Plant only acid-delinted seed produced in fields free of this disease.
- Plant resistant varieties.

Wilts

There are two major wilt diseases of cotton in Missouri, Fusarium wilt and Verticillium wilt. Both are caused by microorganisms that live in the soil on organic matter but can attack cotton roots.

Verticillium wilt was first recorded as a cotton disease in the United States in the early 1900s. The microorganism that causes this disease can survive in soil for many years without cotton. The severity of this disease is greater during cool, wet growing seasons, and in

Missouri it is a greater problem than Fusarium wilt.

Fusarium wilt was first described in the United States in 1892. This disease has developed in most cotton-growing areas of the world.

Positive diagnosis of wilt diseases in the field is difficult because the symptoms of each are similar. For a positive diagnosis send the lower stems of 5–10 plants to a diagnostic laboratory.

Symptoms of Verticillium wilt:

Although Verticillium wilt can attack seedlings, symptoms of this disease are most often observed in Missouri on plants from first flower to harvest. There is a progressive yellowing and dying of the leaf tissue between the major veins of the leaves (Figure 72), beginning on the lower leaves and then progressing to the younger leaves. These symptoms are similar for Verticillium and Fusarium wilt.

Affected plants may shed both leaves and bolls prematurely (Figure 73), and the inside of the lower stem will be streaked with brown (Figure 71). This discoloration is usually evenly distributed throughout the stalk. Most plants will survive throughout the growing season and will put on new growth at the base of the plant.

Management of Verticillium wilt:

- Plant tolerant varieties.
- Do not use excessive nitrogen.
- Rotate cotton with corn and grasses (wheat, oats, etc.).

Symptoms of Fusarium wilt:

Fusarium wilt symptoms can appear at



Figure 72. Leaf yellowing and dying due to Verticillium and Fusarium wilt.



Figure 73. Premature defoliation due to Verticillium and Fusarium wilt.

any stage of plant development and will vary with environmental conditions. Generally, the first symptoms appear on leaves about the time of first flowering.

Symptoms appear first at the margin of the leaf, where small areas turn yellow and then brown (Figure 72), and the leaf then wilts. Although wilting is usually gradual, sudden wilting may occur shortly after a midsummer rain that follows a dry period. Tissue inside the lower stem of infected plants will be discolored (Figure 74).

Although Fusarium wilt can occur in the absence of root-knot nematodes, nematode feeding increases the susceptibility of plants to this disease.

When both the Fusarium wilt fungus and nematodes are present, there is a significant increase in the damage to plants.

Management of Fusarium wilt:

- Tolerant varieties should be planted.

Bronze wilt

During the late summer of 1995, cotton plants in several southeast Missouri fields began to discolor. The leaves turned from green to bronze, and the leaves wilted at midday. This malady was referred to as bronze wilt. These symptoms also developed on some plants in some fields in Arkansas, Louisiana, Texas and Tennessee. This malady did not develop in Missouri in 1996 and 1997. It affected many plants in several fields in 1998, and yields were reduced in some fields. Symptoms of bronze wilt also developed on a few plants in some Missouri cotton fields in 2000.



Figure 74. Brown streaks visible inside cotton stems are a symptom of Fusarium wilt.

Symptoms:

The first visible symptom of bronze wilt is the red and bronze discoloration of leaves (Figure 75). The discolored leaves will feel warmer to the touch than leaves of normal plants. The stems and petioles of affected plants turn red soon after the leaf color changes. The leaves of affected plants will droop during the hottest part of the day and may recover partially or completely by early morning. These plants may occur next to plants that appear normal. Affected plants will grow more slowly than normal plants and may become difficult to see in a few weeks because of overshadowing by nearby normal plants. The leaf discoloration may disappear soon after a rain or irrigation but will develop again as the soil dries. All squares and small bolls will shed from affected plants within a week of when symptoms begin to develop. However, squares that develop on these plants after soil moisture becomes abundant may remain attached and mature bolls may develop.

Management:

- Plant varieties that have exhibited few if any symptoms.

Boll rots

Boll rots cause losses in all cotton-growing regions of the world, but the extent of the loss varies widely with climate. Damage is generally much greater during wet growing seasons. Abundant rain and high humidity during late summer and fall are optimum conditions for boll rot. Some attack the boll themselves, and others enter the boll through wounds on the boll such as those made by insect feeding.



Figure 75. Red coloration is a sign of bronze wilt damage.

Symptoms:

Initial symptoms are small brown or reddish brown spots on the outside of boll capsules or bracts. If moisture is abundant, these spots enlarge (Figure 76) and may encompass the entire boll. In the later stages of the disease, the bolls turn brown or black. Then the boll dries rapidly and usually splits open, exposing the blackened cotton.

Management:

- Avoid excessive application of nitrogen fertilizer, which promotes rank growth.
- Control insects.
- Treat plants with growth regulators if rank growth is anticipated.



Figure 76. Dark, withered bolls damaged by boll rots.

Summary of general cotton disease control measures

- Plant high-quality seed.
- Plant on a high bed and enhance drainage of field.
- Plant when the soil temperature 4 inches deep at 8:00 a.m. is 60 degrees F and when five days of warm weather are predicted.
- Plant only in fertile soil.
- Use an infurrow fungicide when planting cotton early in the season (mid-April in Missouri), in clay soils and in poorly drained fields.
- Rotate cotton with wheat, soybean or corn crops.
- Plant varieties that have high yield potential and resistance to diseases.

Cotton Pest Management Scouting Report

Grower: _____ Date: _____
 Field name or #: _____ Acres: _____

Treatment thresholds

Thrips: 1 or more per plant (pre-5th leaf stage)

Aphids: medium to heavy infestations

Spider mites: 50% or more infested plants

Bollworms: 10% or more of plants infested with small larvae

Plant bugs (#/100 row ft.): 6–8 (1st week of squaring), 8–10 (2nd week of squaring), 10–12 (3rd week of squaring), >15 (4th week of squaring)

Beet armyworms: 5–6 “hits” (egg masses and/or larval clusters) per 300-row ft. (pre-August 15), 10–12 “hits” post-August 15

Fall armyworms: 4 or more larvae /100 bolls or blooms

Stink bugs: 1 large nymph or adult /6 row feet or 20% boll damage

Site	Thrips #/plant	Plant bugs #/100 row ft.	Bollworm (/100 plants)			Aphids L-M-H	Armyworms	Stink bugs #/ row ft.	Spider mites % infested plants	Beneficials L-M-H
			Eggs	Larvae						
				Small	Large					
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Comments:

Photo credits

Photographer	Figure number
Bobby Phipps, University of Missouri-Columbia	1
Ray Nabors, University of Missouri-Columbia	3, 4, 5, 9, 16, 17b, 21, 54
Armon Keaster, University of Missouri-Columbia	6
Michael Boyd, University of Missouri-Columbia	7, 10, 12, 13, 17a, 19, 27, 33, 38, 45, 57
Lee Jenkins Slide Collection, University of Missouri-Columbia	8, 11, 14, 15, 17c, 17d, 20, 22, 28–31, 34, 40, 43, 44, 49, 51-53, 55, 56
Ken Gray Image Collections, Oregon State University	18, 35, 39, 59
Scott Stewart, University of Tennessee-Knoxville	23, 42, 46
Jack Bachelor, North Carolina State University	24, 41
John Adamczyk, U.S. Department of Agriculture, Agricultural Research Service, Stoneville	25
Wayne Bailey, University of Missouri-Columbia	26
Alan Wier, Monsanto Company	32
Jeremy Greene, University of Arkansas	36
David Orr, North Carolina State University	37, 47, 48, 50
Don Steinkraus, University of Arkansas	58, 60, 61
J. Allen Wrather, University of Missouri-Columbia	62–76

For further information

From Extension Publications 1-800-292-0969

- G4050 - *Troubleshooting Field Crop Problems*
- G4259 - *Cotton Nematodes in Missouri: Your Hidden Enemies*
- G4261 - *Cotton Disease and Nematode Management*
- G4268 - *Cotton Plant Development and Plant Mapping*
- G7110 - *Corn Earworm in Missouri*
- G7112 - *Black Cutworm in Missouri*
- G7113 - *European Corn Borer: A Multiple-Crop Pest in Missouri*
- G7115 - *Management of the Armyworm Complex in Missouri Field Crops*
- IPM1006 - *Introduction to Crop Scouting*
- MP734 - *Cotton Seedling Diseases: Answers to Frequently Asked Questions*

Other information sources

Boyd, Michael L., and B. J. Phipps. University of Missouri Cotton Insect Management Guide. <http://aes.missouri.edu/delta/muguide/ctnmgts.stm>

