TO KEY

Corn Insect Pests

A Diagnostic Guide

Seedcorn maggot
Seedcorn beetles
Wireworms
White grubs
Corn flea beetle
Billbugs
Thrips
Grape colaspis
Black cutworm
Sod webworm
Southern corn leaf beetle
Chinch bug
Armyworm
Stalk borer
European corn borer
Southwestern corn borer
Corn rootworms
Grasshoppers
Fall armyworm
Corn earworm
Corn leaf aphid

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Introduction

Insects outnumber human beings by 200 million to 1. They make up some 40 million species, of which entomologists have studied and classified about 1 million. Yet despite these overwhelming numbers, only about 10,000 species of insects cause problems in food and fiber production or affect the well-being of mankind and domestic animals. Fewer than 100 species cause most of the pest damage to corn production in the United States. This guide focuses on about 20 of the most important insect pests affecting corn production in the north-central states and is meant to be used in the field, where preventive and corrective action can be taken.

The difficulty of identifying and managing insect pests in the cornfield stems from the diversity of the insects themselves and the complex interaction of conditions that affect their movement and growth. Some insects are active only at night or may simply be difficult to find in the field. Certain insect pests are abundant almost every year and tend to be chronic problems. Other pests are sporadic and occur only every 5 to 10 years in numbers great enough to reach economic thresholds. Some of the most important corn pests, including black cutworm, fall armyworm and corn earworm, are migratory; others, such as European corn borer, overwinter in the field. For the migratory pests especially, it takes almost perfect timing to make a "successful" infestation. Weather events must favor the movement of migrating insects into corn-producing regions; corn or other suitable host plants must be available and in the preferred growth stage when the insects arrive; local weather conditions must also be favorable for the insects to survive and reproduce.

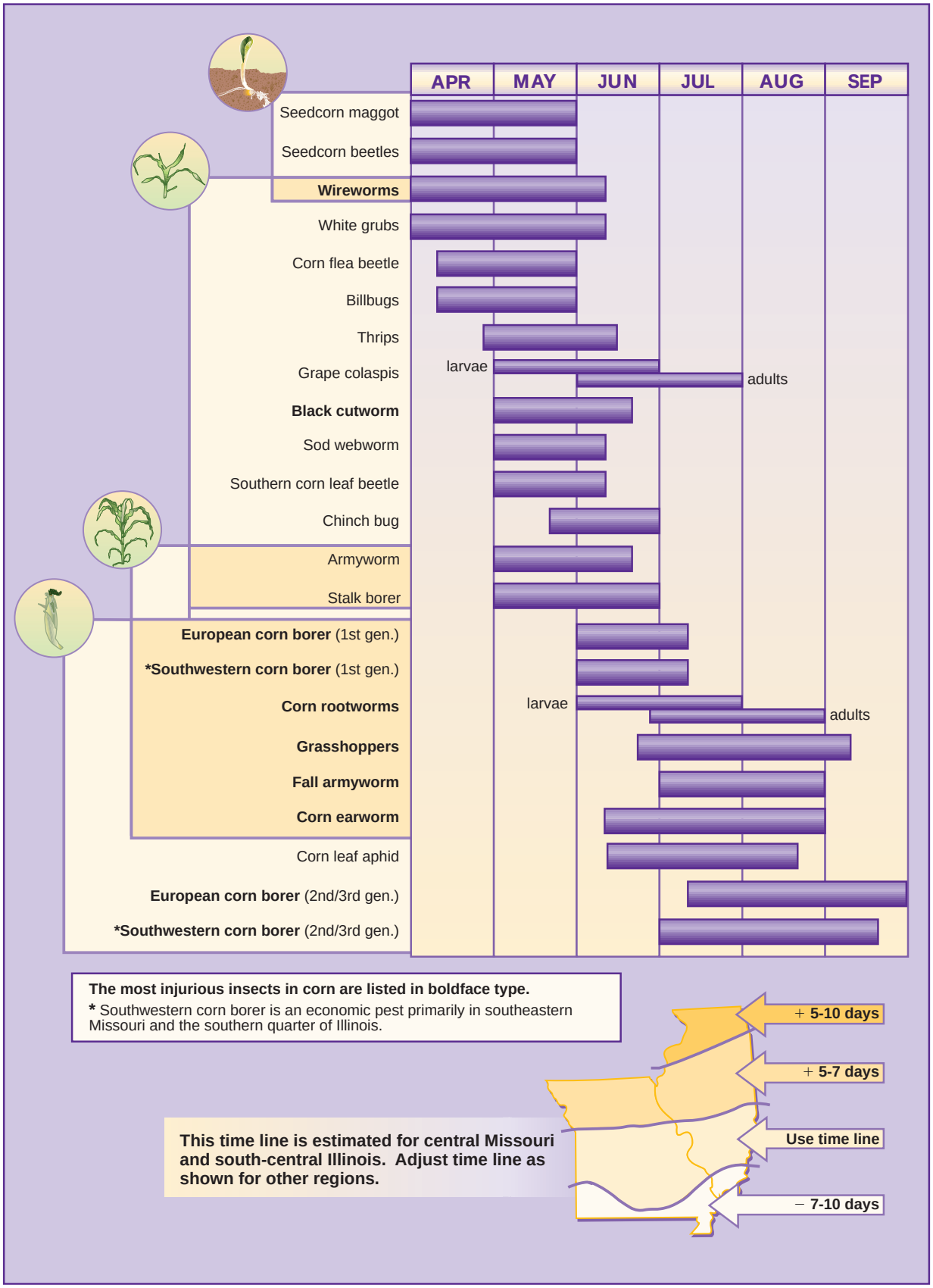
Research both in the laboratory and in the field has provided important information about many pest species and has led to development of economic thresholds and management strategies. However, methods for predicting insect pest outbreaks are by no means perfect. The first step in the effective management of corn insects is accurate and timely identification of the pest. Hence this guide.

We developed the guide with an awareness that sometimes the symptoms of crop injury are obvious, but the insect pests are not. Consequently, it is based not on insect taxonomy but on diagnosis of insect injury to corn. Diagnostic aids include damage symptoms expressed at four progressive growth stages of the corn plant: from planting to full emergence, from emergence to knee-high, from knee-high to tasseling, and from tasseling to maturity. Although the guide focuses primarily on diagnosis of crop injury, it includes condensed insect "profiles," drawing upon photos and descriptions. It also describes which fields are most likely to sustain injury and discusses field distribution of pests, economic thresholds (if established), and management options.

There is a growing need for highly trained field diagnosticians and advisers in pest management, especially with the introduction of new production technologies such as precision agriculture and transgenic hybrids. We anticipate that *Corn Insect Pests: A Diagnostic Guide* will serve as a useful tool for those individuals with agronomic backgrounds who are required to troubleshoot insect pest problems in corn: extension agronomists, crop consultants and scouts, and agricultural input dealers and applicators. However, our most sincere desire is that this diagnostic guide will be of greatest ultimate benefit to the producers who plant and harvest corn — one of this nation's most important crops.

Armon J. Keaster
University of Missouri-Columbia

Time line for corn insects in central Missouri and south-central Illinois



Garry Brix

Diagnostic key

This diagnostic key divides corn growth stages into four periods. To use the key, find the appropriate growth stage and locate the symptoms you are observing in the field; additional choices can be found under some symptoms. Page numbers will direct you to photos and detailed information about each symptom and the insects that most likely cause it.

Pictures representing each growth stage (right) have been used throughout this guide and on the time line. For reference, corn growth stages are defined on the inside back cover, where you will also find a pest index and a short glossary.

Planting to V2

VE to V8

V8 to VT

VT to R6

Corn planting to full emergence (up to V2)

Gaps or skips in the row

Seedlings pulled up and eaten ..... **page 7**
- *Birds*
- *Rodents*

Seeds bored into or hollowed out **7**
- *Seedcorn maggot*
- *Seedcorn beetles*
- *Wireworms*

Emergence to knee-high corn (VE to V8)

Stunting or wilting

Stunting or wilting **11, 12**
- *Wireworms*
- *White grubs*
- *Grape colaspis larva*
- *Chinch bug*

"Dead heart" (center leaves are dying or dead) **12**
- *Wireworms*
- *Black cutworm*
- *Stalk borer*

Unnatural growth (stem twisting or excessive tillering) **18**
- *Stalk borer*
- *Billbugs*
- *Stink bugs*

Speckled or "sandblasted" leaves **20**
- *Thrips*

Removal of plant tissue

Irregular narrow lines or "tracks" scratched from top layer of tissue **20**
- *Corn flea beetle*

Whole plants cut off near base **20**
- *Black cutworm (less commonly, claybacked cutworm)*
- *Sod webworm*

Chunks of leaf tissue or entire leaves eaten **23, 24**
- *Cutworms*
- *Sod webworm*
- *Leafrollers*
- *Southern corn leaf beetle*
- *Stalk borer*
- *Armyworm*

Small, symmetrical, rounded holes in leaves **24**
- *Billbugs*

Lacy, skeletonized leaves **24**
- *Southern corn rootworm beetle*

Knee-high to tasseling corn (V8 to VT)

Leaf tissue removed

Chunks of plant tissue removed from leaf margins, or ragged holes in leaves ..... **page 28**

- *Stalk borer*
- *Armyworm*
- *Fall armyworm*
- *Grasshoppers*
- *Corn earworm*

Small, circular holes or elongated lesions in leaves **29**

- *European corn borer*
- *Southwestern corn borer*

Stalks malformed: Lodging or growing upward in a gooseneck shape **38**

- *Corn rootworm larvae*

Holes bored in stalk **38**

- *Stalk borer*
- *European corn borer*
- *Southwestern corn borer*

Tasseling to corn maturity (VT to R6)

Leaf tissue removed

Chunks of plant tissue removed from leaf margins, or ragged holes in leaves **42**

- *Armyworm*
- *Fall armyworm*
- *Grasshoppers*

Small, circular holes or elongated lesions in leaves **43**

- *European corn borer*
- *Southwestern corn borer*
- *Corn rootworm beetle (esp. western)*

Stalks malformed or broken

Lodging or growing upward in a gooseneck shape **43**

- *Corn rootworm larvae*

Stalks broken **43**

- *European corn borer*
- *Southwestern corn borer*

Tassels damaged

Tassels broken **43**

- *European corn borer*

Tassels eaten (in whorl) **43**

- *Fall armyworm*

Tassels discolored **43**

- *Corn leaf aphid*

Silks clipped **45**

- *Grasshoppers*
- *Corn rootworm adults*
- *Corn earworm*
- *Japanese beetle*
- *Yellow woollybear*

Ear damage

Large chunks of kernels removed, often at blister and milk stages **47**

- *Grasshoppers*

Tunneling or chewing damage **47**

- *Fall armyworm*
- *European corn borer*
- *Corn earworm*

Ear drop **47**

- *European corn borer*

Corn planting to full emergence (up to V2)

OVERVIEW

From planting to emergence, look for:

Gaps or skips in the row ..... page 7
- seedlings pulled up and eaten
- seeds bored into or completely hollowed out

SYMPTOMS

Gaps or skips in the row

Seedlings pulled up and eaten

When gaps or skips are found in a row of emerging corn seedlings, first rule out planter malfunction, pesticide misapplication, and seedling diseases. Check to see if seedlings have been pulled up and eaten by birds or rodents. Birds (often red-winged blackbirds, or geese if near a waterway) leave clues in the rows such as beak marks, tracks, or droppings. Rodents frequently leave a small mound of soil to one side of the row where the seed or seedling was dug up.

Seeds bored into or hollowed out

Dig up ungerminated seed to pinpoint the cause of poor emergence. If seeds are bored into or completely hollowed out, check for the following three insect pests:

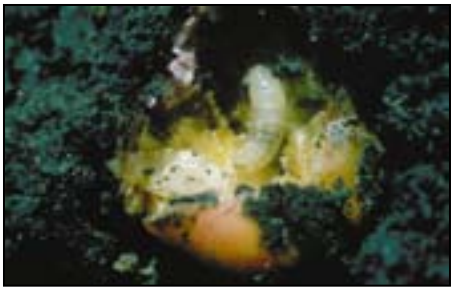
- Seedcorn maggot ..... page 8
- Seedcorn beetles..... 8
- Wireworms 9

University of Missouri

Gaps in the stand. Examine field for clues such as patterns of damage or nonemergence. Dig up seeds or damaged seedlings to assess cause of injury.

Maureen O'Day

Seedlings uprooted by birds. Birds leave clues such as beak marks along the row. Rodents may leave small mounds of soil.



Iowa State University

Seedcorn maggot consuming interior of corn kernel. This pest may be most problematic in early-planted fields high in organic matter.

Seedcorn Maggot

Appearance / Life cycle

Seedcorn maggots taper toward the front end and are ¼ inch long, yellow-white, legless and apparently headless. Maggots burrow into the seed, and seeds either fail to germinate or produce weak seedlings. The adults are ¼ inch long, gray-brown in color, and resemble small house flies. The maggot life cycle requires 3 weeks at temperatures above 50 degrees F. Although there are three to five generations each year, later generations are of little economic importance.

Management

The egg-laying adults (flies) are attracted to moist soils high in organic matter or decaying residues. Insecticide seed treatments should be considered for early-planted cornfields in which a large amount of manure or spring vegetation has been recently incorporated. Damage can be more severe when cool, wet spring weather delays seedling emergence. No rescue treatment exists. If spot replanting, use a seed treatment if the soil temperature is expected to remain cool.

Fields most likely to sustain injury

Early-planted fields high in organic matter or crop residue are the most vulnerable, especially during prolonged periods of cool, wet weather.

Distribution

Stand reduction due to seedcorn maggot is usually more uniform than the spotty damage typical of wireworms.

Incidence

April and May

© photos by Marlin Rice

Slender seedcorn beetle (top) and seedcorn beetle (bottom). Both beetles are about ⅓ inch long.

Seedcorn Beetles

Appearance / Life cycle

Two types of seedcorn beetles cause the same injury symptoms and are both about ⅓ inch long. The seedcorn beetle is dark brown with two darker stripes on the wing covers; the slender seedcorn beetle is reddish brown in color and slightly more elongated and narrow. These beetles are opportunistic feeders and will attack germinating corn when insect prey is in short supply. Seedcorn beetles scurry across the soil surface and are rarely found on plants.

Management

No rescue treatment exists. If spot replanting, use a seed treatment containing an insecticide if the soil temperature is expected to remain cool.

Fields most likely to sustain injury

No-till fields in areas where the seed furrow is not completely closed are

susceptible to seedcorn beetle damage. The potential for injury is higher when cool, wet spring weather delays seedling emergence.

Confusing look-alikes

Many species of beneficial ground beetles resemble seedcorn beetles in shape and color but are generally larger.

Incidence

April and May

Wireworms

Wireworm larvae feed primarily on germinating seeds and roots and may spend 3 to 6 years in the soil.

Appearance / Life cycle

Wireworms are insect larvae that become small to medium-sized beetles. Adult wireworms, when placed on their backs, can flip themselves upright with an audible click and are known as click beetles. Because of their long life cycles, a range of larval ages and sizes can be found in an infested field. Larvae are segmented, shiny and wirelike, yellow to reddish brown, and from ½ to 1½ inches long. Wireworms are attracted to the carbon dioxide from germinating seeds and are active in the root zone (upper 2 to 6 inches) when the soil temperature is from 55 to 75 degrees F. As the season progresses and the soil becomes hot and dry, wireworms migrate downward in the soil so that it may be difficult to find them during a dry summer, even in heavily infested cornfields.

Lee Jenkins

Wireworm adult or click beetle.

Damage

Gaps in the stand or nonuniform growth may result from wireworms tunneling into germinating seeds. However, wireworms can also weaken or kill emerged seedlings by

- Feeding on tender young roots
- Boring into the base of corn plants below ground
- Drilling upward into stalks of larger corn plants

Injured seedlings often are stunted and wilt as drier soil conditions develop; leaves are sometimes tinged with blue or purple at the tips. Severe wilting can be expressed as "dead heart," in which the center leaves of a plant are dying. Dead heart is caused by damage to the growing point and may be accompanied by stunting and excessive tillering.

Most of the damage to corn in Missouri and Illinois is caused by species of wireworms belonging to the genus *Melanotus*.

Lee Jenkins

Armon Keaster

Wireworm (above), the damaging stage. Wireworms feed on seeds and young roots (below); they also bore into the base of corn below ground.

Management

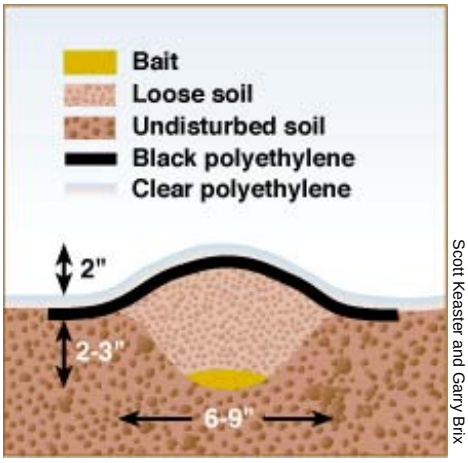
No postemergence treatment is available, so management strategies must be implemented at planting or before. The need for control is based on field history or the results from wireworm solar bait stations. The solar-baiting technique makes it possible to estimate before planting whether a wireworm population will be economically damaging. Two to three weeks

University of Illinois

Wireworm drilling in older corn plants. Although plants typically survive this damage, they may be stunted.

Armon Keaster

Solar bait station installed in field. Survey flags help mark the spot for inspection before planting.



Scott Keaster and Garry Brix

Cross section of a solar bait station for detecting presence of wireworms.

before the anticipated planting date, establish 5 to 10 bait stations per field (more if the field is larger than 30 acres). Any grassy spots in the field and any areas where wireworms caused injury last season should be baited. Dig each bait station 2 to 3 inches deep and 6 to 9 inches wide at the soil surface. Bury ½ cup of a mixture of equal parts untreated corn and wheat at the bottom of the station. Mound a soil "dome" over the covered bait to serve as a solar collector and prevent standing water. Cover with an 18-inch-square sheet of black plastic topped with a 1-yard-square sheet of clear plastic, and cover edges with soil to hold the plastic sheets down. A few days before planting, dig up and sift through the soil and germinated grain to determine the number of wireworm larvae found within each station. The economic threshold is an average of one wireworm per bait station within the baited field.

Management options if you find wireworms in the bait stations:

- Seed treatment containing insecticide (if wireworms are present but average less than the economic threshold). Seed treatment protects only the seed and will not protect the seedling following germination.
- Application of banded or in-furrow insecticide at planting time (if bait trap numbers average one or more wireworms per trap).

Fields most likely to sustain injury

Female click beetles lay eggs mostly near the roots of grasses. Therefore, wireworm injury is likely to be most severe in first- and second-year corn following long-standing meadows, pastures, and small grains. Cornfields with chronic infestations that are left uncontrolled for several years may also suffer heavy damage. Porous, well-drained loam soils are more likely to be infested with wireworms than are heavy clay soils.

Distribution

Wireworm populations are not uniformly distributed, so infestations often appear in hot spots within the field. Stunted, wilted, or dead corn plants may be found next to healthy plants.

Confusing look-alikes

Ground beetle larvae are about the same shape and size as some species of wireworms, but they have two large, curved "jaws" and two soft projections on the tail end.

Incidence

Wireworm larvae are found from April through early June; adult click beetles are found from mid-May through June.

Emergence to knee-high corn (VE to V8)

OVERVIEW

From emergence to the knee-high stage, look for:

Stunting or wilting ..... pages 11, 12
- stunting
- overall wilting
- "dead heart"

Unnatural growth 18
- stem twisting or excessive tillering

Speckled or "sandblasted" leaves 20
- leaves with speckled appearance

Removal of plant tissue 20
- irregular narrow "tracks"
- plants cut off near base
- chunks of leaves eaten
- small rounded holes in leaves
- lacy skeletonized leaves

SYMPTOMS

Stunting or wilting

Stunting of corn plants, sometimes with the leaf tips tinged blue or purple, can be the result of root pruning by several insects. **Overall wilting** of corn plants can sometimes be observed in conjunction with stunting.

Often an affected plant will be only inches from a healthy and vigorous plant. This patchy, hot spot distribution can help distinguish insect damage from agronomic stresses such as herbicide injury, phosphorus deficiency, or compaction. Dig up and check for root pruning, and examine the soil around the root mass for these possible culprits:

- Wireworms. ..... page 9
- White grubs 12
- Grape colaspis larva 13

(More stunting or wilting symptoms on page 12)

Armon Keaster

Stunted corn plant next to a healthy one (above). Patchy distribution of wilted plants (below) is often a clue that the cause is insect feeding.

Armon Keaster

Lee Jenkins

Wilted corn plants next to ripening grain field. Check wilted plants near their base for clusters of chinch bugs.

Armon Keaster

"Dead heart" resulting from injury to growing point below ground.

(Stunting or wilting symptoms continued from page 11)

SYMPTOMS

When **wilting or stunting occurs in localized areas bordering ripening small grains**, and masses of small, active, reddish or black-and-white sucking bugs are clustered in the soil near the bases of stressed corn plants, the pest is

- Chinch bug . . . . . page 14

Severe wilting can be expressed as "dead heart," in which the center leaves of a plant wilt and die; sometimes the affected leaves take on a blue-green tint before dying. Dead heart is caused by an insect tunneling through the stalk into the growing point and may be accompanied by stunting and excessive tillering. The three prime suspects are

- Wireworms 9
- Black cutworm. 15
  - Older larvae occasionally tunnel into the stalks of larger corn, especially during dry periods.
- Stalk borer 18

Lee Jenkins

Laura Kabrick

Characteristic C-shape of white grubs (top). Bristles of the true white grub form a "zipper" on the raster (bottom) located on the underside of the last abdominal segment.

White Grubs

White grubs are the larval form of scarab beetles (June beetles and several species of chafers). All of the grub species prefer to feed on the roots of grasses, and the majority of eggs are laid in sod and grassy areas of the field. The two types of grubs commonly found in Missouri and Illinois cornfields are true white grubs (June beetles or Phyllophaga *spp.) and annual grubs.*

Life cycle

True white grubs have a 3-year life cycle and spend two consecutive seasons pruning roots and eating organic matter in the soil. Annual grubs complete a single generation each year; they feed very little in the spring.

Diagnostic tip

These two types of grubs can be distinguished from each other by the pattern of dark, bristly hairs on the bottom of the "tail" (called the raster). True white grubs have two zipperlike parallel rows of bristles on the raster; on annual grubs, the bristly hairs are scattered and have no pattern.

Damage

True white grubs chew off roots, and this root pruning results in aboveground stunting and wilting (especially in dry soils). Leaf tips occasionally turn purple from the tips back; lower leaves are affected first. Annual white grubs can cause some injury, occasionally resulting in minor stand loss, when growing conditions are not optimum.

Management

Although no established threshold exists, two or more true white grubs per cubic foot of soil (as noted during a tillage pass) may cause stand loss in corn. No rescue treatment exists. Consider an in-furrow insecticide treatment if corn is planted over pasture or grassy ground brought out of the Conservation Reserve Program. For annual grubs, soil insecticides are not recommended.

Fields most likely to sustain injury

Because scarab beetles favor grassy areas for egg laying, corn following sod is most at risk for root pruning by true white grubs.

Incidence

White grub larvae are found from April through early June.

White grub damage to corn seedling. Root pruning results in wilting and stunting.

Grape Colaspis

The grape colaspis has a broad host range, including corn. Although both the adult beetle and larval stages feed on corn, damage is seldom economically significant.

Appearance / Life cycle

The immatures (larvae) are also called clover rootworms and resemble miniature white grubs. They are stout, gray-white and about ⅛ inch long, with light brown heads and three pairs of true legs (near the head). The adult beetles are tan-colored and about ⅙ inch long. The wing covers appear striped due to longitudinal rows of shallow pits.

The partially grown larvae overwinter, and root feeding resumes in May. Females deposit eggs, usually in clumps of about 36, near the roots of host plants. There is a single generation each year.

Confusing look-alikes

Grape colaspis adults should not be confused with newly emerged, pale northern corn rootworm beetles. The tan color will be similar, but grape colaspis beetles can be distinguished by their smaller size and also the rows of shallow pits that appear to form stripes on the wing covers.

Also, don't confuse the tiny, ⅛-inch grape colaspis larvae with early-stage white grubs. Grape colaspis larvae are less strongly curved (more comma-shaped than C-shaped) and have small bumps that bear a clump of hairs on the underside of the abdomen.

Damage

Grape colaspis larvae prune the root hairs or gnaw narrow, lengthwise

Lee Jenkins

Grape colaspis larvae and pupa (upper right). Root pruning by larvae produces aboveground symptoms similar to damage by white grubs.

Lee Jenkins

Grape colaspis adult and its feeding damage.

strips from the roots of corn seedlings. Corn plants appear purple and stunted, seldom reaching a height of 10 inches, and may wilt on hot, dry days.

Adult beetles chew holes in the leaves, or strip one surface away to give a "windowpane" effect. This minor defoliation does not result in economic injury to corn.

Management

No economic threshold for grape colaspis injury has been established, and no soil insecticide is labeled for control of this infrequent pest in corn.

Fields most likely to sustain injury

First-year corn following clover or timothy sod, favorite egg-laying sites of grape colaspis, are most susceptible to feeding by the larvae. Occasionally, corn planted after soybeans or alfalfa is injured by larval feeding. Adults also favor patches of smartweed for egg laying, and soybean fields with heavy smartweed pressure may be infested with the larvae the following spring. Injury is usually more severe when unfavorable weather slows the growth of seedling corn.

Distribution

The damage typically occurs in patches within a field, because grape colaspis eggs are laid in large clumps near the bases of host plants.

Incidence

Larvae are found in May and June; adults appear in June and July.

photos by Lee Jenkins

Chinch bug adults and nymphs. They frequently congregate behind leaf sheaths at the base of corn plants.

© Thomas J. Riley

Chinch bug injury to corn. The plant is stunted and the stalk has failed to elongate, so that leaves appear clustered around the base of the plant.

Chinch Bug

Appearance / Life cycle

Full-grown adults are 3⁄16 inch long. Chinch bugs have a black body and white forewings with two black spots. Wingless nymphs change from bright red to black as they develop and have a white band across the back. Adults prefer to overwinter at the base of warm-season bunch grasses and then migrate to small grains early in the spring. As the small grains mature, chinch bugs move into adjacent fields of more succulent corn and sorghum.

Diagnostic tip

When crushed, chinch bugs give off a distinctive, musty odor.

Damage

Chinch bugs induce wilting by removing plant juices with their piercing-sucking mouthparts. Injury is first evident on lower leaves, which turn yellow and wilt. The stalk fails to elongate properly and damaged plants become stunted, with the leaf sheaths clustered at the base of the plant. Leaves of stunted plants often show yellow or reddish streaking from chinch bug feeding. Young plants are often killed, especially if drought-stressed. Heavily damaged plants that survive remain stunted and may produce suckers.

Adults and wingless nymphs are found near the base of the stalk, behind

leaf sheaths, or on the stem and roots below ground during dry conditions. The potential for chinch bug damage is higher during hot and dry springs and early summer.

Confusing look-alikes

Newly hatched reddish chinch bugs can resemble small, bright red soil-dwelling mites, and chinch bug adults can be mistaken for false chinch bugs. False chinch bug adults are ⅛ inch long and grayish with wings that are clear and lack the black spots of the chinch bug's wing covers. False chinch bug nymphs are brownish gray with tiny reddish spots on the tan abdomen, and they lack the white band found across the middle of chinch bug nymphs. False chinch bugs prefer to suck sap from mustard, pepperweed, shepherd's-purse, and other weeds. Corn is attacked only when the weed hosts become unavailable. Like chinch bug injury, heavy feeding by false chinch bugs may cause wilting and browning of the outer leaf margins in corn.

Management

Treat border rows at first migration if lower leaves begin to turn yellow and wither. A tentative threshold is 10 chinch bugs per seedling up to the V4 stage.

Distribution

Infestations first develop near the outer 30 to 40 rows of cornfields bordering ripening small grains. An area of wilted or stunted corn grades into undamaged plants at the margin of the infestation.

Incidence

Late May through June

© Thomas J. Riley

Wilted plants. If wilting is localized near small grains or grasses, check the base of plants at and below ground level for chinch bugs.

Black Cutworm

The black cutworm is by far the most destructive species of the cutworm complex in corn. However, there are other less common subterranean cutworms that clip or injure seedlings in the same way as the black cutworm. See box on the claybacked cutworm.

Appearance / Life cycle

The adult moths are gray with a small black "dagger" marking on each forewing. The black cutworm does not overwinter in Missouri or Illinois (except occasionally in Missouri's Bootheel region). Moths migrate to the Corn Belt from coastal areas of the Gulf of Mexico in early spring. Most eggs are deposited on low, dense vegetation, especially early season broadleaf weeds such as chickweed and curly dock. The grayish larva has no distinct markings and is paler on the underside. The black cutworm progresses through six or seven larval stages (called instars), but larvae must reach the fourth instar before they are large enough to cut seedling corn. The larvae are nocturnal feeders, hiding in shallow burrows or under soil clods during the day. Although there are several generations each year, only the first generation causes economic injury in corn.

Lee Jenkins

Sixth-instar black cutworm larva next to clipped stem. Cutting of corn begins when larvae reach the fourth instar.


Jim Jarman

Pinhole leaf feeding by third-instar or younger cutworm larvae.


Jim Jarman

Signs of black cutworm cutting. Plants can be severed above or below ground (above). A cutworm may drag a cut plant into its burrow and feed on it later. Gently dig around wilted or severed plants to expose the culprit for positive identification (below).


Laura Kabrick

Identification tips:

Black cutworm
- Grainy, rough skin texture
- Front "inner" pair of dorsal tubercles is about half the diameter of back "outer" pair on each segment
- Cuts corn at or below the soil level
- Damage may be economic

Dingy cutworm
- Smooth skin texture
- All four of the dorsal tubercles (on each segment) are approximately equal in diameter
- Leaf feeder; rarely cuts corn
- Not an economic problem


David Pinkerton

Black cutworm


David Pinkerton

Dingy cutworm

Confusing look-alikes

Do not confuse the black cutworm with other leaf-feeding cutworms of minor importance or with crane fly larvae. Distinguish black cutworm from the dingy cutworm by skin texture and the size of the tubercles (dark-pigmented bumps) on each segment on the back.

The larva (maggot) of a species of crane fly commonly found in wet cornfields in early May is about the same length and color as a young black cutworm, but does not injure plants. There are obvious physical distinctions:

Black cutworm
- Well-developed head capsule
- No tail-end projections
- Three pairs of true legs behind the head and fleshy prolegs on the middle and rear segments

Crane fly larva
- Poorly developed head
- Fleshy projections around the tail end
- Legless

Damage

Signs and symptoms include:
- Leaf feeding, usually consisting of small pinholes and light margin feeding by larvae too small to cut plants (third instars or smaller)
- Plants cut at or just above the soil surface
- Purplish, lodged plants cut below ground
- Wilting, or dead heart, often due to tunneling of larger plants by older instars
- Cut corn leaves partially buried in burrows

The removal of the black cutworm's weed hosts at or near planting often sets the stage for injury to seedling corn. The injurious cutting stage (fourth instar to pupation) lasts 2½ to 3 weeks (depending on temperature). Corn is

vulnerable to cutting from the coleoptile through the V4 growth stage. Early-planted corn may outgrow the threat of black cutworm damage, especially if the moth migration peaks as late as May. On average, each larva is capable of cutting four V1 plants or one V4 plant before pupation.

Management

Planting-time insecticide treatments are generally not advisable for this sporadic pest because of the difficulty of predicting which fields will have economic black cutworm infestations.

The recommended management plan has two parts:

- Scout fields.
- Treat with a postemergence "rescue" insecticide if the economic threshold is reached.

A moth trapping program tracks the spring migration of black cutworm moths and is used in conjunction with a degree-day model that predicts larval growth. Intensive pheromone trap captures serve as a "biofix," triggering the accumulation of the 300 degree-days required for development from egg to the fourth-instar cutting stage. This forecasting model indicates when to begin field scouting but cannot predict the severity of black cutworm damage. An accurate assessment of whether the economic threshold has been reached depends on the following information:

- Percentage of plants damaged above and below ground
- Average instar of the larvae, as measured by a head capsule gauge (not length of larvae)
- Corn growth stage (coleoptile through the V4 stage)
- Plant population

Economic thresholds

Different thresholds are set for above- and below-ground damage, because the extent of yield reduction is linked to the location of cutting (and the growing point). Only half of V1 seedlings generally survive subsurface cutting, and the mortality rate decreases with the corn growth stage. Insecticide treatment may be justified if

- 2% to 4% of corn seedlings are cut below ground
- 6% to 8% of corn seedlings are fed upon or cut above ground

Use the lower end of each threshold if the plant population is low.

Fields most likely to sustain injury

- Reduced tillage or no-till fields
- Corn planted into soybean stubble (the fine-textured residue is attractive to egg-laying moths)
- Early spring weed cover just before planting
- Poorly drained low areas or recently flooded river bottoms
- Late-planted fields in cool, wet growing conditions

Incidence

Fourth-instar or larger black cutworm larvae may damage seedling corn from early May through mid-June.

Jim Jarman

Purplish, lodged plant gouged below the soil surface by black cutworm.

University of Illinois

Wilted V4-stage plant. This injury is typically caused by wireworms or older black cutworms tunneling into underground portion of stalk.

University of Missouri

Stand loss caused by black cutworm.

Armon Keaster

Stem twisting. Injury to the growing point by stalk borer can cause twisting of the stem.

Mitchell Roof

Transverse rows of holes. Potential suspects are small stalk borers or billbugs.

photos by Lee Jenkins

Stalk borers. Young borers (left) have a prominent purple heart coloration that fades as the larva ages (right).

SYMPTOMS

Unnatural growth

Stem twisting or excessive tillering may be due to growing point injury by insects that bore into corn.

Tunneled plants that survive may also express

- Dead heart (center leaves wilt and die)
- Stunting and delayed development
- Barrenness or small ears

Although incidental to the more serious growing point injury, holes produced in the leaves by tunneling or drilling activity can be diagnostic.

- Stalk borer . . . . . page 18
  - Irregular rows of large and ragged holes in emerging leaves are often the result of entry into the stalk. Examine whorls for frass (excrement).
- Billbugs 25
  - Rows of small circular and symmetrical holes may be the result of a billbug using its snout to gouge a cavity in the stem just below the soil surface. No frass is left in whorl.
- Stink bugs
  - Transverse row of oval holes usually ringed with yellow.
  - No obvious puncture near the base of the plant, but may have a slimy, decaying area inside the lower stalk where the piercing-sucking beak has penetrated the stalk.
  - An infrequent pest.

Stalk Borer

Appearance / Life cycle

The distinctive larvae are white with brownish purple stripes extending the length of the body. There is a purple heart or band behind the true legs, but the purplish stripes and "heart" fade in older larvae. The adult moths lay eggs during late summer on grasses and some broadleaf weeds (e.g., bromegrass, ragweed, smartweed, lambsquarters, and pigweed). The larvae typically hatch in early May and tunnel into weedy host plants. Larvae eventually outgrow their original hosts and migrate to larger diameter plants, which often include corn if planted nearby. Larvae actively feed for 8 to 10 weeks. There is a single generation each year.

Diagnostic tips

The presence of noticeably stunted corn rows next to permanently grassy areas or fence rows may indicate a stalk borer infestation. The stalk borer is the only larva found in Missouri and Illinois cornfields that has a distinct diagonal black stripe on each side of the orange head.

Damage

The stalk borer may attack corn at any time after emergence, but the corn plant's tolerance to injury increases greatly after the V6 growth stage.

Stalk borers can injure corn plants in two ways:

- Leaf feeding is the more commonly seen type of damage. Larvae enter the whorl from above and feed deep in the whorl leaves. This feeding produces irregular rows of ragged holes, which enlarge as the leaves unfold. Although foliar feeding may appear severe, it does not reduce yield.
- Drilling into the base of the stalk is the much more severe type of injury. Destruction of the growing point during boring typically results in dead heart of the inner whorl, although the outer whorl leaves remain healthy. Tunneled plants that survive are often stunted and delayed in development, show unnatural growth such as stem twisting and excessive tillering, and can either be barren or produce smaller ears.

University of Illinois

Classic stalk borer feeding injury on leaves. Ragged holes are obvious in the shadow of the plant in this photo.

Stalk borer tunneling injury to growing point. Surviving plants may express stunting, dead heart, and stem twisting.

Management

As with other stalk-boring insect pests, insecticide treatment is not effective once stalk borers have tunneled into corn. Therefore, control measures should be properly timed to target vulnerable stages, such as eggs, newly hatched larvae, and migrating larvae. Management options include the following:

- Plant early in fields with a history of stalk borer damage, or if there is high potential for infestation due to grassy weed problems.
- Control grassy weeds in the field before egg laying begins in August to minimize problems the following season.
- Burn grass waterways and ditches before spring green-up in fields without grassy weed problems.
- If grassy areas are not burned, scout the first two corn rows for migrating larvae and leaf feeding, or target hatching larvae by spraying egg-laying sites with a pyrethroid insecticide. However, timing this activity is difficult.
- Begin scouting border rows when 1,300 to 1,400 degree-days (base 41 degrees F) have accumulated since January 1, to determine if larvae are migrating into corn.
- Recurrent, fieldwide infestations can be treated after hatch by a spring application of a burndown herbicide (to force larvae out of grassy weed hosts) in combination with a compatible insecticide.

Economic injury level

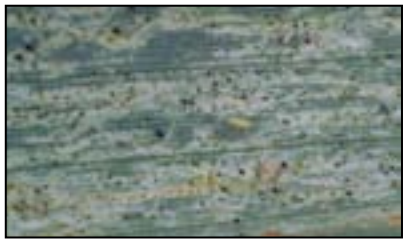
The economic injury level is the lowest pest density that can cause economic damage. Economic injury levels for stalk borer rise as corn grows, doubling from 14% of corn infested at the V5 stage to 28% infested at the V6 stage. An insecticide treatment of border rows may be justified if only 10% of V2 corn is infested with stalk borer. (These economic injury levels assume a market value of $2.50/bushel corn, management costs of $13.00/acre, and 80% control with an insecticide.) Target larvae with an insecticide *before* they have tunneled into corn plants (i.e., when still feeding in the whorls).

Fields most likely to sustain injury

- Late-planted cornfields are most at risk as larvae migrate from their earlier weed or grass hosts, because corn younger than the V7 stage is more vulnerable to injury.
- Damage (especially in tilled corn) is often confined to the four border rows next to prime egg-laying sites, such as grass waterways, fence lines, and ditches.
- In no-till corn, fieldwide infestations are possible if weedy grass control was poor the previous season.

Incidence

May and June



Brian Christine

Feeding damage by thrips. Shiny black frass pellets are present with thrips damage.

University of Illinois

Narrow "tracks" from flea beetle feeding.

Claybacked Cutworm

- Overall grayish body with broad yellowish brown stripe down the back.
- Small larvae pull leaves into burrows and feed from tip to base.
- Larger larvae cut seedlings at or just above the base of the plant.
- Like the dingy cutworm (page 16), overwinters as partially grown larva and resumes feeding in early spring.
- Economic thresholds are the same as for black cutworm (page 17).

SYMPTOMS

Speckled or "sandblasted" leaves

Speckled or mottled leaves, especially on seedlings, may signal the presence of thrips. Although this feeding injury may be confused with "sandblasting" from blowing soil, the shiny black frass (excrement) pellets do not appear on wind-damaged foliage.

- Thrips . . . . . page 21

Removal of plant tissue

Irregular narrow lines or "tracks" scratched from top layer of tissue

Leaf tissue is stripped from the top layer, and damage appears as irregular, narrow lines running parallel to the veins.

- Corn flea beetle. 21

Whole plants cut off near base

- Black cutworm. 15
  - Most cutting is done by the black cutworm. It may be confused at times with its less common subterranean cousin, the claybacked cutworm, because of the similar appearance and feeding habits of the two cutworm species.
- Sod webworm. 22
  - An occasional pest in corn following sod or grassy fields.

(More tissue removal symptoms on page 23)

Thrips

Appearance

Grass thrips, commonly found in corn, are minute (1/16-inch), elongate, yellow insects. Adult thrips have slender wings fringed with long hairs (as viewed under magnification); the immatures are wingless and yellow-orange.

Damage

Thrips rasp plant tissues and suck the exuding juices. They feed deep in the whorl, under the leaf sheaths, and on the underside of the lower leaves. When injury is extensive and the corn plant is stressed, leaves may appear to have a silvery cast. Thrips feeding is rarely an economic problem unless corn is less than 1 foot tall, numerous plants are damaged, and wilting is obvious.

Incidence

Late April through mid-June

Brian Christine

Grass thrips (yellow, elongated insects) with green corn leaf aphids. Due to their size and feeding sites, thrips are not commonly seen.

Corn Flea Beetle

Appearance / Life cycle

Flea beetles are so named because enlarged hind legs enable impressive leaping when disturbed. Although several species of flea beetles can be found in cornfields, the corn flea beetle is the most commonly encountered. It is a tiny, 1/16-inch, shiny black beetle. Survival of the overwintering beetles is favored if the mean monthly temperatures of December, January, and February sum to more than 90 degrees F.

Damage

The upper green layer of tissue is stripped off during feeding, leaving gray "tracks" etched on leaf surfaces. While feeding, adults can transmit Stewart's bacterial wilt to susceptible inbreds in seed production fields and sensitive sweet corn varieties. Most commercial field corn hybrids are resistant to Stewart's wilt, and the bacterial infection remains localized.

Management

Consider insecticide treatment of field corn if each seedling is infested with more than five corn flea beetles up to the V4 stage of growth, especially if the corn is undergoing environmental stress. In seed production fields, control is probably justified when the corn flea beetle is first noticed in those inbreds susceptible to Stewart's wilt.

Fields most likely to sustain injury

Corn planted early during cool, wet springs is more vulnerable to corn flea beetle injury because it is growing slowly and exposed to feeding for an extended period. Damage is also more likely after a mild winter.

Incidence

April and May

Lee Jenkins

Adult corn flea beetle on corn. First signs of flea beetle feeding are narrow "tracks." Extensive feeding may result in a "frosted" appearance, especially on the leaf tips and margins.

Lee Jenkins

Sod webworm. The shiny, dark spots on sod webworms help to distinguish them from other larvae infesting cornfields in May.

Mitchell Roof

Signs of sod webworm. Leaf feeding or plant cutting can look similar to black cutworm damage. However, only sod webworms make silk tunnels at the base of plants.

Sod Webworm

Appearance / Life cycle

The larva has a dark brown head with a light gray-brown body. It has numerous, polished tubercles (dark spots) and is sparsely covered with coarse bristles. The adults (moths) lay eggs in grassy areas, and small larvae overwinter until active feeding resumes in early May.

Damage

Damage can appear similar to black cutworm clipping when plants are cut off at or just below the soil surface, or similar to cutworm or armyworm feeding when holes are chewed in leaves or along margins. Because sod webworms overwinter, they may be found slightly earlier in the season than black cutworm larvae. Corn plants severed early in the spring frequently regrow because the growing point is still protected below ground when cutting occurs.

Diagnostic tip

Sod webworms can often be found in short, silk-lined tunnels at the base of corn plants. Cutworms and armyworms do not shelter in silken tunnels (although some cutworms do burrow in the soil).

Confusing look-alikes

Do not confuse sod webworms with European corn borer larvae, which are less strongly spotted and without coarse hairs. In addition, European corn borer larvae do not construct silken tunnels or shelter at the base of young corn plants and are not encountered so early in the spring (May).

Management

Although economic thresholds have not been developed specifically for sod webworms, thresholds established for black cutworms can be used through the V4 growth stage. Economic damage to corn by sod webworms is uncommon.

Fields most likely to sustain injury

Sod webworm feeding tends to be more extensive when corn follows sod or very grassy fields.

Incidence

May through early June

(Tissue removal symptoms continued from page 20)

SYMPTOMS

Chunks of leaf tissue or entire leaves eaten

Several insects will chew notches along the leaf margins, sever leaves from the plant, or feed so deep in the whorl that leaves emerge ragged and torn.

These leaf feeders generally damage corn from May through mid-June and are less active or hidden during the day. If you cannot find the insect that you suspect caused the damage, look for associated plant injury or insect clues. Such evidence, in conjunction with the time of the season or stage of corn growth, may help pinpoint the culprit. Keep in mind that a single field may contain several species of insect pests (e.g., cutworms, sod webworms, and billbugs).

- Cutworms . . . . . pages 15, 16, 20
  - Although the dingy cutworm is the most common foliage feeder in the cutworm complex in corn, the subterranean cutworms (black and claybacked) sometimes consume clipped leaves or seedlings that are dragged into their burrows.
- Sod webworm. 22
  - Often hides in silken tunnels at the base of plants.
- Leafrollers
  - Web together the tips of corn leaves and feed inside.
  - Not an economic problem.
- Southern corn leaf beetle 25
  - Chews notches in the leaf margins and sometimes in the stems.

(More symptoms of tissue removal on page 24)

Laura Kabrick

Cut corn plant dragged into black cutworm burrow.

University of Illinois

Sod webworm damage to corn seedling.

© Marlin Rice

Leafroller damage. Leafrollers web together tips of leaves for a protected feeding site.

Maureen O'Day

Rows of ragged holes. Leaf feeding by stalk borer deep in the whorl becomes obvious when the leaves expand.

Mitchell Roof

Light leaf feeding by armyworm. Irregular notching of leaf margins is usually the first sign of their presence.

Classic billbug damage (right). Feeding results in transverse rows of holes. Asymmetrical, lacy holes in leaves (below) from southern corn rootworm beetle feeding.

Laura Kabrick

Laura Kabrick

(Tissue removal symptoms continued from page 23)

SYMPTOMS

Look for different patterns of leaf feeding, the presence or absence of stalk tunneling, and the location of larvae to distinguish stalk borer and armyworm damage.

- Stalk borer . . . . . page 18
  - Leaf feeding deep in the whorl produces ragged holes as emerging leaves expand.
  - Reddish brown, moist frass (excrement) found in the whorl.
  - Tunneling through the stalk causes dead heart when the growing point is injured.
  - Plants that survive growing point injury may be twisted and stunted, or tiller excessively.
  - Larvae frequently found inside stalks.
- Armyworm 22
  - Margins of the leaves are stripped, sometimes to the midvein; corn up to V8 may be completely defoliated.
  - Feeding starts on the lower leaves and progresses up the plant.
  - No tunneling through the cornstalk or associated injury symptoms (twisting, tillering, etc.).
  - Larvae hide under soil clods or crop residue during the day.

Small, symmetrical, rounded holes in leaves

A transverse row of symmetrical holes across the leaves as they unfurl may be the result of tunneling or drilling into the base of corn younger than V5. Black cutworms and sod webworms occasionally leave such signs of damage, in conjunction with their more typical leaf feeding and cutting; however, the prime suspect is billbugs. Adult billbugs gouge through stems at the base of seedlings with their snouts, producing a row of circular to elliptical holes across leaves as they expand.

- Billbugs 25

Lacy, skeletonized leaves

If the leaves have asymmetrical, lacy holes or lesions, look for the

- Southern corn rootworm beetle 38
  - The adults will occasionally strip tissue from between the veins so that the leaf appears skeletonized, with lacy foliage.

Southern Corn Leaf Beetle

Appearance / Life cycle

The southern corn leaf beetle is generally an infrequent pest of seedling corn. The adult is 3/16 inch long and gray-brown and sometimes bronze-tinted. Bits of soil sometimes cling to its thick covering of short, stiff hairs and serve as camouflage. The adult beetles overwinter and then deposit clumps of eggs near the base of corn as soon as plants are available. The overwintering beetles feed in early spring on corn, as well as weeds such as cocklebur, smartweed, and crabgrass.

© Marlin Rice

Southern corn leaf beetle. It may be difficult to find because of its soil camouflage.

Damage

The beetles chew holes in the leaves, and notches in the leaf margins and occasionally in the stems. Basal clipping of corn up to the V2 stage can occur but is not as common as foliar damage. Corn seedlings can sometimes be killed when the beetles feed in large clusters.

Diagnostic tips

Southern corn leaf beetles may infest corn from May through mid-June. Thus, their seasonal feeding, evidenced by notching in the leaf margins, often overlaps with similar damage caused by three larval pests: cutworms, sod webworm, and armyworm. In addition, all four suspects prefer to feed at night. The southern corn leaf beetle often drops to the ground and hides when disturbed, so it is difficult to find. Therefore, be prepared to spend time searching under soil clods and crop residue for the foliage feeder(s) responsible for the damage.

University of Illinois

Feeding damage by southern corn leaf beetle. Damage can be confused with that of black cutworm.

Management

There is no economic threshold established and no insecticide labeled for control of this infrequent pest of seedling corn.

Fields most likely to sustain injury

No-till corn or corn following grass or sod appears to be more susceptible to feeding by the southern corn leaf beetle.

Incidence

May through mid-June

Billbugs

Appearance / Life cycle

Although several species of billbugs are found in corn, the maize billbug is the most common. Maize billbugs are gray-brown "snout" weevils about 2/5 inch long. They overwinter in grasses and sedges (especially yellow nutsedge), field residue, or soil. In the spring, billbugs feed, mate, and lay up to 200 eggs over a 2-month period. The tiny grubs develop inside the stem. Adults are often cryptic and difficult to find, even around injured plants, because their color blends in with the soil and they are mostly active at night. Billbugs seldom fly, but they will crawl up to ¼ mile in search of food. There is a single generation each year.

Lee Jenkins

Adult billbugs.

University of Illinois

Transverse rows of holes from adult billbug damage. Although billbugs are difficult to find in the field, leaf damage may indicate their presence.

Damage

Soon after they emerge as adults, billbugs begin feeding on corn by inserting their long snouts into the base of cornstalks. A narrow feeding slit (usually below ground) up to ½ inch long in the side of the young stalk is an indication of billbug injury. Small plants may be stunted or even killed by billbug gouging and feeding on the tender inner stem tissues. As leaves emerge from larger injured plants, a symmetrical row of holes appears across the leaves from billbug feeding while the leaves were still rolled. If feeding has injured the growing point, excessive suckering and distorted growth results. Developing grubs that feed inside the stems near the soil surface may also cause stunting.

Management

Leaf feeding does not result in economic injury to the crop. Control is warranted only if a significant number of plants are being injured by gouging of the inner stem and adults are still present. Treatments are not effective against grubs feeding inside the stem. There are no economic thresholds established for billbug injury.

Fields most likely to sustain injury

Damage is more common in corn following sod or in fields infested with yellow nutsedge.

Incidence

April and May

Wayne Bailey

Young, pale green armyworm larvae. Larva on the upper right has the looper-like posture typical of young larvae. As larvae age, they acquire characteristic stripes.

Armyworm

The armyworm is also referred to as the "true armyworm" to distinguish it from other armyworm species (fall, yellowstriped, etc.). In outbreak years, large numbers of armyworms migrate from field to field, consuming grasses and grain crops.

Appearance / Life cycle

The sand-colored moths have a small but prominent white spot in the center of each forewing. Newly hatched larvae are pale green and move like loopers. The full-grown larvae are 1½ inches long, nearly hairless, and dull-green to brown with alternating light and dark stripes running the length of the back and sides.

In Missouri and southern Illinois, the overwintering armyworm population of partly grown larvae is supplemented by spring migrants, which typically arrive during the first week of April. The moths lay the eggs of the first generation in lush, grassy vegetation in April and May. Larvae feed at night (and on overcast days) for 3 to 4 weeks on grass crops, especially corn, sorghum, and wheat. During the day, armyworms remain hidden under soil clods or crop residue. There are typically three generations in Missouri and Illinois each year, but the larvae of the first generation do most of the damage (in May and June).

Diagnostic tips

Two characteristic markings distinguish mid-size to large armyworms from other striped leaf-feeding larvae, such as fall armyworms:

- Dark bands at the top of each proleg
- White-bordered orange stripes running laterally along the body

Damage

In corn, armyworms generally feed on the whorl leaves of young plants; the damage frequently first appears as irregular notching of the margins. Heavy infestations of armyworms may completely defoliate corn less than 8 inches tall and may strip all leaf tissue to the midrib in older corn. Heavy defoliation can occur virtually overnight if high numbers of fully grown larvae move all at once into a seedling cornfield.

Armyworms undergo great fluctuations in population from year to year, reaching destructive peaks at sporadic and unpredictable intervals. Outbreaks appear to be more common after cool, wet springs, due in part to the suppression of normal activity of the parasitoids and predators that hold populations in check.

Management

Armyworms generally feed during the night and hide by day, so often they are not discovered until they are at least half-grown. Scout early in the morning or later in the evening, when larvae may be more active. If an early infestation is detected in a grassy border or ripening wheat adjacent to corn, spray a few swaths to form a barrier strip between the infestation and the cornfield. Good grass control within and around fields often reduces the likelihood of an armyworm outbreak.

Corn often recovers from moderate feeding unless the growing point is damaged. Treatment may be justified when 25% of corn plants are damaged and larvae are still present. Avoid "revenge spraying" when crop damage is discovered after major defoliation, because the worms are often large and difficult to kill by this time. Armyworms larger than 1¼ inches are preparing to pupate.

Fields most likely to sustain injury early in the season include corn no-tilled into

- A small grain cover crop
- Pasture or sod
- A field with heavy grassy weed pressure

Outbreaks usually originate in fields of small grain or grasses, especially where there is rank vegetative growth. Therefore, cornfields adjacent to maturing small grains are vulnerable to attack later in the season. Larvae may also move in unison ("armies") from pastures, fence rows, or other grassy areas as they deplete a food supply.

Distribution

In the typical tilled field, infestations are first found in field margins where armyworms have migrated in from a maturing grain field or grassy border.

Incidence

May to late June

Lee Jenkins

Older armyworm larva. Look for dark bands at the top of each proleg and the white-bordered orange stripes along the side.

Lee Jenkins

Armyworm defoliation. Except for the midvein, armyworms may eat the entire leaf. A parasitoid's egg can be seen behind the head region.

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Heavy armyworm damage. Larvae feed nocturnally and typically hide during the day.

Knee-high to tasseling corn (V8 to VT)

OVERVIEW

From knee-high to tasseling stage, look for:

Leaf tissue removed ..... pages 28, 29
- margin feeding or ragged holes in leaves
- small, circular holes or elongated lesions

Stalks malformed..... 38
- lodging or gooseneck growth

Holes bored in stalk..... 38

Lee Jenkins

Typical grasshopper feeding pattern. Grasshoppers often consume foliage from the leaf margins inward.

Anastasia Becker

Fall armyworm feeding damage. Copious amounts of frass are left in the whorl when feeding.

SYMPTOMS

Leaf tissue removed

Chunks of plant tissue removed from leaf margins, or ragged holes in leaves

- Stalk borer ..... page 18
  – Transverse rows of ragged holes.
- Armyworm 26
  – Margin feeding; starts on lower leaves and works upward.
- Fall armyworm 29
  – Ragged holes anywhere in whorl leaves.
  – Lots of moist, reddish brown frass.
- Grasshoppers 31
  – Feed from margin inward.
- Corn earworm..... 46
  – More commonly seen feeding in ear tips.
  – Ragged holes in whorl leaves.
  – Moist, tan frass.

(Symptoms of leaf feeding continued on page 29)

(Leaf tissue removal symptoms continued from page 28)

SYMPTOMS

Small, circular holes or elongated lesions in leaves

Young European corn borer and southwestern corn borer larvae feed on leaf tissue before they are large enough to tunnel into stalks.

Small European corn borer larvae feeding deep in the protected whorl produce a random, buckshot pattern of small circular holes in the expanding leaves.

Elongated lesions may result from the feeding of larger European corn borers just before stalk entry or the more extensive whorl feeding of southwestern corn borers.

- European corn borer . . . . . page 32
- Southwestern corn borer 35
  – Southern portions of Missouri and Illinois.

Jim Jarman

Shot-hole damage. Small holes result from feeding by young European corn borer larvae.

University of Illinois

Lesions from whorl feeding by southwestern corn borer. Damage appears similar to, but more extensive than, that of European corn borer.

Fall Armyworm

Appearance / Life cycle

The fall armyworm is primarily a pest of corn and other grass crops. Newly hatched larvae are light green with dark heads and move like loopers. The full-grown larva is 1½ inches long and striped. It varies in color from light tan or green to almost black. Three narrow, whitish lines run down the back; extending along the side (just above the legs) is a wide, wavy yellowish stripe with red splotches. Conspicuous black spots (tubercles) with spines are scattered along the body. The dark gray moth is mottled with light and dark patches and has a prominent white spot near the extreme tip of each forewing. Layered clusters of the spherical, pearl-gray eggs are generally deposited on the lower leaves of host plants; each egg mass is covered with a coating of moth scales and hairs.

Fall armyworm moths migrate northward from the Gulf Coast, and the first large migratory waves typically arrive in late June in mid-Missouri and southern and central Illinois. Moths deposit eggs (in masses averaging 150) on all stages of corn from whorl to silking. After hatching, the larvae migrate to the whorl, developing tassel, or ear, and feed for 2 to 3 weeks.

Wayne Bailey

Lee Jenkins

Fall armyworm egg mass and larvae. Larvae frequently vary in size and coloration.

University of Illinois

Jim Jarman

Fall armyworm. Diagnostic features are a white, inverted Y-shaped suture on head and four black spots that form a square near the hind end.

Anastasia Becker

"Windowpane" feeding by young fall armyworms.

Lee Jenkins

Whorl feeding by fall armyworm. Ragged leaves are first noticed after they have expanded.

Unlike armyworms, fall armyworms are daytime feeders and are particularly active in the early morning or late afternoon. Larger larvae tend to be cannibalistic; generally only one survives in each whorl. Full-grown larvae pupate in the soil, and the moths that lay the eggs of the second generation emerge after 10 to 14 days. While Missouri usually has three complete generations, Illinois has two to three each season.

Diagnostic tips

Three characteristic markings distinguish fall armyworms from other striped larvae feeding on corn (especially armyworms):

- White, inverted Y-shaped head suture (seam)
- Four distinct black spots (tubercles) in a square on top of the 8th abdominal segment (near the hind end)
- No dark bands on the tops of the prolegs (as in armyworm)

Damage

Damage generally has no economic significance unless feeding is deep in whorl and injures the undeveloped tassel. The most common injury is to late-planted, pre-tassel corn, and the feeding is often first noticeable in early to mid-July. The first three larval instars are small and leave "windowpanes" in the foliage as they consume the top layer while leaving the lower leaf surface intact. Mid-sized to large larvae cut large, ragged-edged holes in the leaves of whorl-stage plants, leaving lots of moist, reddish brown frass in their wake. As the larvae feed deep inside the whorl on developing leaves, they occasionally kill the tassel before it emerges. Later generations of larvae may chew circular patches of kernels from anywhere on the ear.

The fall armyworm may bore an entry hole through the husk on the side of the ear to feed on kernels. In contrast, corn earworms enter ears through the silk channel and therefore do not leave entry holes. Also, corn earworm feeding is often limited to the ear tips, but fall armyworms devour kernels from any part of the ear.

Management

An insecticide application may be economically justified when 75% of plants show leaf feeding and larvae are less than 1¼ inches long. Treatment to control larvae already inside the ears is not effective.

Fields most likely to sustain injury

Late-planted corn, especially if less than 3 feet in height, is more susceptible to whorl and tassel injury. Egg-laying moths are also attracted to cornfields with an abundance of grassy weeds.

Distribution

Larvae hatch from layered masses of 50 to several hundred eggs and then move to adjacent plants. Consequently, there are often localized hot spots throughout a field.

Incidence

July through August

Grasshoppers

Appearance / Life cycle

The two most common grasshoppers in Missouri and Illinois cornfields are the differential and redlegged grasshoppers. The differential grasshopper is a robust, olive-green to brownish grasshopper, reaching 1¾ inches in length. The underside of the body is yellow, with complete, black chevrons (V-shaped patterns) on the femurs ("thighs") of the yellow hind legs. The redlegged grasshopper is brownish red and smaller, less than 1 inch long when full-grown; hind legs are red with black spines. Both species of these grasshoppers have a single generation each year.

Adult and nymphal grasshoppers are similar in appearance, except that the nymphs are smaller and lack wings. Older nymphs can be distinguished from newly hatched grasshoppers by the development of wing pads, which resemble stunted, nonfunctional wings and extend to the second abdominal segment.

Both differential and redlegged grasshoppers overwinter in egg pods laid in uncultivated ground, such as field margins, roadside ditches, fence rows, waterways, pastures, and no-till fields. After egg hatch from May to June, nymphs feed for 2 to 3 weeks on grasses and weeds in their hatching beds. Nymphs require approximately 40 days to reach the winged adult stage. Both adults and nymphs are general feeders and readily migrate to adjacent crops when the vegetation in hatching sites is consumed, mowed, or limited by drought.

Damage

Grasshoppers will attack most aboveground parts of the corn plant: leaves, tassels, green silks, and ears. They feed from the margins of the leaves inward, and heavy infestations may consume all leaf tissue except the midrib. In severe infestations, the corn stand is stripped of leaves and only bare stalks remain. Crop damage is usually worse in years when drought reduces natural vegetation and grasshoppers migrate to succulent cornfields.

Management

Target the less mobile, smaller nymphs while they are still confined to the hatching beds along field margins. Younger grasshoppers are more effectively controlled with insecticides, and treatment over a smaller area is required before the older grasshoppers disperse throughout the field. A walking survey through the hatching sites allows a rough assessment of grasshopper pressure. Count the number of grasshoppers per square yard in grassy and weedy areas bordering fields. Take at least five surveys in infested areas to derive an average number of grasshoppers per square yard, with surveyed areas at least 50 feet apart.

Treatment may be justified if there is an average of 15 or more nymphs or adults per square yard in noncrop field margins. The economic threshold within the cornfield is eight or more nymphs or adults per square yard. Do not mow grasses in field borders until grasshoppers are controlled. Before spraying, check for the natural suppression of grasshopper populations by diseases. The presence of dead grasshoppers perched head-up at the top of plants, tightly gripping the stems, is evidence of a fungal

Lee Jenkins

Differential grasshoppers.

Lee Jenkins

Redlegged grasshopper. Red hind legs and smaller overall size distinguish this grasshopper from the differential.

Lee Jenkins

Several grasshoppers feeding on leaves. Unlike many other insects, grasshoppers are easily seen.

Lee Jenkins

Severe grasshopper damage. Outbreaks are more widespread in dry years.

pathogen *(Entomophaga grylli)* favored by wet, warm weather in late summer. In some years, this fungal pathogen significantly reduces late-season populations.

Fields most likely to sustain injury

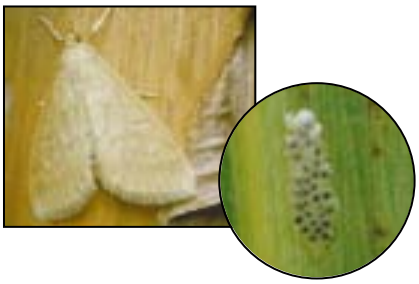
Corn bordering crops that persist for more than one season (such as alfalfa) are more vulnerable to grasshopper infestations. Dry conditions are conducive to outbreaks, because grasshoppers move readily from drought-stressed natural vegetation into more succulent crops. Conversely, wet and warm weather promotes grasshopper mortality from naturally occurring diseases.

Distribution

In tilled fields, damage may be confined to a few corn rows bordering grassy or weedy field margins or waterways. Grasshopper infestations in no-till corn may be more uniformly distributed throughout the field because eggs were deposited the previous season in undisturbed soil.

Incidence

June through early September



photos by Lee Jenkins

Female European corn borer moth and egg mass at "black head" stage.

European Corn Borer

In a typical season in Missouri and Illinois, there are two generations of the European corn borer in the northern halves of both states and a third generation in the southern third of both states.

Appearance / Life cycle

Overwintering full-grown larvae are approximately 1 inch long and off-white to faded gray. A dark gray line runs down the middle of the back, and the top of each abdominal segment is marked with two round, dark spots (tubercles). Female moths have a wing expanse of about 1 inch and are pale yellowish brown with darker, irregular bands running in wavy lines across the wings; males are slightly smaller and darker, with olive-brown markings on the wings. Egg masses are approximately ¼ inch in diameter, and the individual, flattened eggs overlap like fish scales. Eggs are initially white but turn yellowish with continued development and hatch within 3 to 7 days (depending on temperature). About 1 day before hatching, the black heads of the young borers inside the translucent egg shells become visible ("black head" stage). Young larvae have dark heads and are dull white with several rows of small brown spots. European corn borer larvae develop through five stages; growth from egg hatch to pupation requires 29 to 33 days, depending on temperature (Table 1).

Jim Jarman

Young European corn borer larva in unrolled whorl leaves.

First generation: The European corn borer overwinters as a full-grown, fifth-instar larva inside cornstalks and stubble. When spring temperatures exceed 50 degrees F, the larvae break diapause (suspended development) and pupate. Spring-flight females emerge in late May and typically lay masses of 15 to 20 eggs. The preferred oviposition site is the lower two-thirds of the corn leaf near the midrib on the underside of the leaves, especially on the lower leaves of mid- to late whorl stage corn. The newly hatched larvae ini-

Table 1. European corn borer life stages and activities, based on degree-days accumulated after appearance of first spring moths.

Accumulated degree-days (base 50° F)	First occurrence of stage (or event)	Days to first occurrence[a]	Activity
0	First spring moth		Mating and egg laying
First generation:			
212	Egg hatch (first instar)	12.3	Pin hole leaf feeding
318	Second instar	5.1	Shot hole leaf feeding
435	Third instar	5.4	Midrib and stalk boring[b]
567	Fourth instar	5.5	Stalk boring
792	Fifth instar	9.1	Stalk boring
1,002	Pupa	8.0	Changing to adult
1,192	Adult moths	6.6	Mating and egg laying
Second generation:			
1,404	Egg hatch (first instar)[c]	7.4	Pollen and leaf axil feeding
1,510	Second instar	3.8	Leaf axil feeding
1,627	Third instar	4.2	Sheath, collar, and midrib boring
1,759	Fourth instar	4.9	Stalk boring[b]
1,984	Fifth instar	8.5	Stalk boring

Modified from *European Corn Borer: Ecology and Management.* North Central Regional Extension Publication No. 327, by Charles E. Mason et al., 1996. Published by Iowa State University, Ames, Iowa.

[a] Average number of days required to reach the first occurrence of the stage since initiation of the previous stage listed, based on 30-year average temperatures recorded in Columbia, Missouri.

[b] First-generation larvae bore into stalks earlier than second-generation larvae because the younger stalks are more tender than those of older, more mature plants.

[c] Peak egg hatch occurs 10 days or approximately 200 to 250 degree-days later than first hatch.

tially feed on the surface of the leaves before migrating deep inside the whorl. First and second instars remove mesophyll from the leaves so that a layer of transparent epidermis remains, thus creating a "windowpane" effect. When these tender, newly developing leaves grow out from the infested whorl, they show signs of feeding ranging from pinholes to the distinctive buckshot appearance. As the larvae grow, they crawl out of the whorl and begin to feed on leaf sheaths and tunnel into midribs. After reaching the third instar (approximately ½ inch in length), larvae bore into the stalks, usually at one of the lower nodes, and feed until pupation. Frass and silk at entrance holes signal the presence of borers inside the stalks. First-generation larvae pupate in early July and produce adults that lay the eggs of the second generation in mid-July.

Jim Jarman

"Windowpane" feeding by early instars of European corn borer.

© Marlin Rice

Buckshot damage by European corn borer.

Jim Jarman (left), University of Illinois (right)

Split stalks. Entry tunnel made by mid-size European corn borer is visible (left). As larva grows inside stalk, it excavates a larger tunnel (right) which weakens the stalk.

University of Nebraska

Classic signs of second-generation European corn borer feeding. Look for "windowpanes," rounded holes, and frass around the leaf collar area.

Lee Jenkins

Shot-hole feeding damage and frass made by young European corn borer larva.

Jim Jarman

Frass at European corn borer's entry hole into midrib. By the time the borer population begins tunneling into the midrib or the stalk, it is often too late to apply insecticide.

Second generation: Second-generation borers typically infest tasseling and silking corn. Egg masses average 20 to 30 eggs for second (summer) flight moths. About 90% of egg masses are deposited on the lower two-thirds of the undersides of the three leaves above and below the primary ear, on the ear husk, and on the underside of the ear (i.e., within the ear zone). Egg laying during the second (summer) moth flight normally occurs over a 3- to 6-week period, with peak egg deposition 10 days after the first eggs are deposited.

Approximately 75% of the newly hatched larvae feed on sheath and collar tissue and on pollen that has collected in leaf axils; the remaining 25% move to the ear. Third instars feed on sheath and collar tissue and tunnel into midribs. The stalks of the more mature corn are tougher to penetrate than the tender stalks infested by first-generation borers. By the fourth instar, the majority of larvae tunnel into the stalk within and above the ear zone; some will continue to feed in the ear or bore into the tassel or ear shank. During the fifth instar, larvae prepare to enter diapause, or pupate and become moths. Diapause, induced by day length and temperature, prepares the population for survival during the winter.

Third-generation larvae: Second-generation (third flight) moths lay eggs to produce a third generation in the southern portions of the Corn Belt (e.g., the Missouri Bootheel) each season. These eggs are usually deposited on tasseled corn plants when the kernels have not matured beyond the milk stage. From September through frost, the full-grown larvae construct flimsy, silken cocoons, typically inside the cornstalk, but occasionally under the leaf sheaths. The larvae then enter diapause and overwinter. The first hard freeze kills larvae that have not reached the fifth instar.

Damage

European corn borer damage (by first- and second-generation larvae) is primarily physiological because tunneling through the conductive tissue of the stalk disrupts the corn plant's "plumbing." The plant's ability to produce maximum yield is reduced by the interrupted transport of nutrients and water. Losses are mostly due to poor ear development; however, broken stalks and lodging, dropped ears, and secondary invasion of stalk rots in susceptible varieties also contribute to reduced yield.

Signs of first-generation European corn borer infestation begin at the mid-whorl stage:

- Pinhole or "windowpane" feeding on leaves
- Buckshot appearance when leaves grow out of infested whorls
- Broken midribs from tunneling (late second and early third instars)
- Frass at entry holes: after reaching the third instar, larvae bore into stalks
- Stalks broken at one of the lower nodes

Signs of second-generation European corn borer infestation begin at the tasseling stage:

- Egg masses laid on the undersides of leaves in the ear zone
- Frass or small larvae in the sheath, collar tissue, and leaf axils of the ear zone
- Broken midribs from tunneling (third instars)
- Frass at entry holes: after reaching the fourth instar, larvae bore into

stalks (typically in the ear zone), tassels, and ear shanks
- Broken stalks (in and above the ear zone) and tassels
- Dropped ears from shank tunneling
- Feeding or "skimming" on kernels

Management

Information on scouting procedures and worksheets to aid in insecticide treatment decisions are included in the Appendix (page 48). Also consider controlling European corn borer by planting transgenic Bt hybrids (with refuges of non-Bt corn to manage resistance).

Fields most likely to sustain injury

Although corn is susceptible to European corn borer infestation after the V6 growth stage, spring-flight moths are more attracted to taller, early-planted corn. Larval survival is higher on older corn plants at the mid- to late whorl stage (V8 to V12) because of lower concentrations of the plant compound DIMBOA, a "built-in insecticide" that interferes with the successful development of European corn borer larvae. Summer-flight moths prefer to deposit their eggs during pollen shed in late-planted fields with fresh silks.

Low wind velocity and high humidity are favorable for egg laying by moths and for egg survival, because these conditions reduce losses from desiccation. The combined effects of high temperature, low humidity, and high winds increase egg and larval mortality. Heavy rain may inhibit both egg deposition and survival of newly hatched larvae. The survival rate of early instar larvae averages about 20%, depending on environmental conditions, the corn stage infested, and hybrid resistance (to first-generation attack).

Incidence

June through early July (first-generation larvae) and mid-July through early September (second-generation larvae)

Jim Jarman

Numerous broken midribs. Leaves appear snapped near the midpoint as a consequence of midrib tunneling by second-generation European corn borer.

Southwestern Corn Borer

The southwestern corn borer is primarily a pest of the southern Corn Belt and is economically damaging in the Bootheel of Missouri and in the southern quarter of Illinois.

Appearance / Life cycle

Moths are dull white and have a wing expanse of approximately 1¼ inches. Fresh eggs are white and generally laid in groups of two to five, overlapping slightly like fish scales. Although most eggs are laid on the upper leaf surface, they may also be deposited on the lower leaf surface and occasionally on the stalk. Within 36 hours, each egg develops three transverse red bands; eggs hatch in 4 to 5 days. The "red bar" stage can help distinguish European corn borer egg masses from those of the southwestern corn borer. The summer-form larva is off-white, with a regular pattern of

Armon Keaster

Southwestern corn borer moth.

Texas A&M

Red bands are unique to southwestern corn borer eggs.


Lee Jenkins


Lee Jenkins

Southwestern corn borer larvae. Summer form has black spots (top); overwintering form is immaculate, or spotless (bottom).


University of Illinois

"Windowpane" feeding by southwestern corn borer. Damage is more extensive than the same type of whorl feeding by European corn borer.

black spots that become conspicuous by the third instar. The full-grown larva loses its spots through a molt at the onset of hibernation; this uniformly pale yellow, overwintering larva is known as the immaculate form. Full-grown larvae are 1¼ inches long.

The southwestern corn borer overwinters as an immaculate larva in the lower part of the stalk, below ground level. After pupation in late May, the moths lay eggs that produce the first generation of borers. Larvae infesting young corn move to the inner whorl, where their feeding produces extensive "shot holes" and elongated lesions in the expanding leaves. Like the European corn borer, the last two instars tunnel and feed within the stalk. Full-grown larvae pupate and emerge as moths to lay the eggs of the second generation beginning in July.

Although southwestern corn borer eggs are laid mostly on the upper surfaces of leaves over the entire plant, they are concentrated near the ear on the middle seven leaves of the tasseled plant. Small larvae feed primarily on lower ear shoots (concealed by the leaf sheaths) and between husks of primary ears. Half-grown larvae tunnel within the lower half of the stalk.

Full-grown larvae typically tunnel down the stalk to the base of the plant just below the soil line beginning in late August. They girdle the inner stalk 2 to 4 inches above the base of the plant while constructing a hibernation cell. This girdling activity causes lodging and stalk breakage, resulting in direct ear losses. Corn is generally harvested before the girdling activity of the third generation begins.

Damage

Southwestern corn borer damage is primarily due to tunneling and girdling of the stalk by the robust larvae. Tunneling through the conductive tissue of the stalk interferes with the transport of nutrients and water, thus impairing the plant's ability to produce maximum yield. Yield losses are due to poor ear development and also broken or lodged stalks resulting from the girdling activity of borers preparing for winter. Stalk girdling begins during the last week in August and is largely completed by mid-September. With the exception of inner girdling of the lower stalk, damage is similar to that of European corn borer (refer to "Diagnostic tips").

Signs of first-generation southwestern corn borer infestation beginning at the whorl stage:

- Elongated stripping or "windowpane" feeding of leaves
- Buckshot appearance when leaves grow out of infested whorls
- Dead heart (death of the growing point)
- Frass at entry holes on the lower part of the stalk
- Stalks broken at one of the lower internodes

Signs of second- and third-generation southwestern corn borer infestation beginning at the tasseling stage:

- Egg masses located mostly near the ear on the middle seven leaves
- Frass or small larvae under lower leaf sheaths and on the ears
- Frass at entry holes in the lower half of the stalk
- Stalk breakage caused by girdling of the inner stalk 2 to 4 inches above the soil line

Diagnostic tips

Damage is similar to that of the European corn borer: whorl and leaf feeding followed by stalk tunneling by the last two instars. However, injury caused by the two species of borers differs in the following ways:

- Small plants under 16 inches are not "immune" to southwestern corn borer damage.
- Southwestern corn borer "windowpane" feeding is usually more extensive than that of the European corn borer: elongated strips run parallel to veins, leaving the upper or lower epidermis intact.
- Southwestern corn borer may cause dead heart in whorl stage corn by boring into the central part of the stalk, destroying the growing point.
- Second- and third-generation southwestern corn borers tunnel in the lower half of the stalk; second-generation European corn borers tunnel in the stalk within and above the ear zone.
- Overwintering southwestern corn borers girdle the inner stalk 2 to 4 inches above ground level, causing stalk breakage and lodging.

Armon Keaster

Girdling by southwestern corn borer larva preparing to overwinter. This type of damage is unique to southwestern corn borer and frequently leads to stalk breakage.

Management

- Early planting of corn often minimizes lodging losses, because the crop may be harvested beginning in early September. This is before most second-generation southwestern corn borers have matured to the prehibernation stage when they girdle the lower stalks.
- The economic threshold for first-generation borers is 20% to 25% of plants with leaf feeding and larvae in the whorls.
- The economic threshold for second-generation borers is 20% to 25% of corn plants infested with eggs or small larvae.

Control considerations

- Controls are generally aimed at second-generation southwestern corn borers (because their late-season girdling behavior may result in severe yield loss).
- The window for treatment is narrow because most larvae begin to enter the stalk 10 to 14 days after hatching.
- The extended flight of moths laying eggs of the second and third generations lasts from early July through mid-August. Full control might require two insecticide applications because of this prolonged egg-laying period.
- Consider transgenic Bt hybrids that provide season-long control of southwestern corn borer. Plant Bt hybrids with refuges of non-Bt corn to manage resistance.

Fields most likely to sustain injury

Late-planted cornfields are more susceptible to dead heart injury from whorl feeding by the first generation and also stalk girdling by the later generations of the southwestern corn borer.

Incidence

Scout for first-generation larvae from June through early July, second-generation larvae from July through August, and third-generation larvae from mid-August to harvest.

Jim Jarman

Lodged plant. Corn may grow upward in a gooseneck shape to compensate for lack of root support caused by corn rootworm pruning.

© Marlin Rice

Split the stalk to identify the pest. European corn borer is inside tunnel in stalk.

SYMPTOMS

Stalks malformed

Lodging or growing upward in a gooseneck shape

A likely cause of lodging or goosenecking in *continuous corn* is root pruning by corn rootworm larvae. Shallow rooting in wet or loose soil or misapplication of the growth regulator herbicide 2,4-D may also result in the gooseneck growth of cornstalks in any rotation system, especially following periods of high winds. Although 2,4-D injury sometimes results in malformation of the brace roots, it may still be advisable to dig up root masses of goosenecked plants to eliminate shallow rooting as a cause and confirm the presence of

- Corn rootworm larvae . . . . . page 38

Holes bored in stalk

A coil of frass may trail out from the entrance hole into the stalk. The feeding cavity may be easily seen if the stalk is split, and often the tunneling larva can be identified as

- Stalk borer 18
- European corn borer 32
- Southwestern corn borer 35
  - Southern portions of Missouri and Illinois.

Group of corn rootworm larvae.

Corn Rootworms

Corn rootworm larvae are the most serious insect pests of continuous corn in the Midwest, including Illinois, but they are not a major economic threat in Missouri because of the small amount of continuous corn acreage. There are three species of corn rootworms found in Missouri and Illinois. Although western and northern corn rootworm larvae can both cause serious damage, the western corn rootworm is the dominant species in both states.

Appearance / Life cycle

Corn rootworm larvae are white with brown heads and slender bodies. Full-grown larvae are about ½ inch long, and there is a dark "tail" plate on the top of the terminal segment. The southern corn rootworm is not considered an economic pest in midwestern corn production.

Western and northern corn rootworm beetles are ¼ inch long, and south-

ern corn rootworm beetles are ⅜ inch long. The color and markings of these beetles vary according to the species:

- Western corn rootworm females are yellow with three black stripes: one stripe on the outside of each wing cover and one in the middle where the wing covers meet. On males, the front of each wing cover is sometimes solid black so that the stripes are obscured and only the tips of the wing covers are yellow. The female beetles also tend to be larger, especially as they age and fill with eggs.
- Northern corn rootworm beetles are uniformly green to yellowish green, although newly emerged beetles are light tan.
- Southern corn rootworm beetles are yellow with 12 distinct black spots on the wing covers. They are most frequently pests of cucurbits and are also known as 12-spotted cucumber beetles.

Western and northern corn rootworms have a similar life cycle. Both have a single generation each year, and corn is the only economic host. Beginning in July, females lay eggs in the soil at a depth of 2 to 4 inches near the base of corn plants. The eggs overwinter, and the onset of hatch ranges from late May (southern and central Illinois and Missouri) to early to mid-June (northern Illinois). Peak hatch occurs approximately 7 days after the first rootworm larvae are noted. Temperature and moisture vary with soil depth and influence both overwintering survival and time of hatch.

Rootworm larvae feed on corn roots for 3 to 4 weeks, passing through three growth stages (instars). The second-instar larvae are often the first detected, because first instars are very small (only 1/16 inch long) and difficult to see. Mature larvae pupate in earthen cells. Adults begin emerging from mid-June (southwestern Missouri and southern Illinois) to early July (northern Illinois). Adults live for 75 to 85 days, feasting on foliage, pollen, and silks. Eggs are laid in the soil of cornfields, and egg laying lasts for 3 to 4 weeks.

photos by Lee Jenkins

Corn rootworm adults: southern (top), northern (left), and western (right).

Lee Jenkins

Several corn rootworm larvae feeding on roots.

Damage

The feeding of western and northern corn rootworm larvae is generally greatest on roots near the soil surface; when these are consumed, the next lower node is attacked. First and second instars leave brown feeding scars (lesions) as they tunnel from root tips to the plant base, destroying root hairs and small roots. Third instars cause the majority of root damage, and they generally feed on the larger primary roots near the stalk and the first set of brace roots. Pruning of the root tips may result in extensive "bottle-brush" lateral root regrowth.

The 1 to 6 root rating scale to assess the level of damage caused by rootworm larvae (Iowa State University):

1 = no damage or only a few visible feeding scars
2 = some roots with feeding scars, but none pruned to within 1½ inches of the stalk
3 = at least one root pruned to within 1½ inches of the stalk, but never an entire node destroyed
4 = one node of roots destroyed (or the equivalent)
5 = two nodes of roots destroyed (or the equivalent)
6 = three or more nodes of roots destroyed

Kansas State University

Comparison of normal and pruned root systems. Damaged roots (on right) would be rated as a "6" on the Iowa State University scale.

University of Illinois

Row of goosenecked corn.

Generally, economic yield loss occurs when root ratings (see the Iowa State University scale) exceed 3.0 to 3.5; lodging may occur at ratings of 4.0 or more. The first indication of rootworm injury may be in late June or early July when plants fall over after strong winds and heavy rainfall. Yield losses depend on the number of larvae per plant and on plant maturity, soil fertility, and amount of moisture following peak injury, as well as the ability of the hybrid to regenerate root tissue. Drought stress worsens the effects of root pruning. Conversely, infested plants may severely lodge (because they lack root support) when wind and rain storms occur near the time of peak larval injury.

Corn rootworm injury results in yield losses in the following ways:

- Root pruning and tunneling disrupt the transport of nutrients and water from the root system.
- Lack of root support causes gooseneck lodging, which may complicate harvesting.
- Root feeding promotes invasion by secondary pathogens such as bacteria and fungi, increasing the incidence of root rots.

Adult feeding rarely has an impact on yield and consists of

- Stripping of the upper layer of tissue from the leaves; more likely to occur if tassels have not emerged and pollen is not available
- Silk clipping

Management

Annual crop rotation is the most reliable and economical means of managing rootworm populations throughout most of the Corn Belt. Certain populations of northern corn rootworms in more northern states may undergo extended diapause, in which the eggs remain dormant in the soil for two winters before hatching. However, extended egg diapause does not currently occur in Missouri. In addition, western corn rootworm injury to first-year corn planted after soybeans has been reported in areas of intense corn/soybean rotation in east-central Illinois, northern Indiana, southern Michigan, and western Ohio. Research suggests that a genetic variant of the western corn rootworm is selecting soybean fields as another egg-laying site (in addition to corn). Despite these exceptions, crop rotation still provides the most consistent control of rootworm infestations.

Western and northern corn rootworm adults can be counted in cornfields in July and August to assess the need for an insecticide application the next spring in fields where corn will be planted. An average population of 0.75 or more beetles per plant in late summer is likely to lay enough eggs to cause an economic larval infestation the following season in continuous corn.

In areas of the Corn Belt where western corn rootworm adults lay eggs in soybean fields, scouting for adults in soybeans is possible by using sweep nets, visual observations, or yellow sticky cards. However, established thresholds have not been verified with extensive field testing, so scouting for western corn rootworms in soybeans usually reveals only presence or absence of the beetles. Decision-making thresholds are under development and can be obtained from extension specialists in the affected states (Illinois, Indiana, Michigan, Ohio).

In some areas of Nebraska, the focus of corn rootworm management has

been the control of adults to prevent egg laying. However, insecticide control failures for adult western corn rootworms have been on the rise since the mid-1990s. Resistance to methyl parathion and carbaryl in the western corn rootworm beetle population has occurred where "adulticides" have been applied over wide areas for many years.

Control of adults for silk clipping is rarely necessary unless green silks are being clipped back to ½ inch or less before 50% pollen shed.

There are no consistently reliable scouting methods to monitor corn rootworm larvae. However, an insecticide treatment during cultivation may be justified if two or more larvae per root mass are counted in a 7-inch cube of soil sampled from untreated fields in early June. Although such "rescue" treatments are generally equal to, or more effective than, planting-time insecticide applications, timing is critical.

Fields most likely to sustain injury

Corn planted after corn is most susceptible to injury by corn rootworms, with two exceptions:

- areas in east-central Illinois, northern Indiana, southern Michigan, and western Ohio where western corn rootworms lay eggs in soybeans
- areas where extended diapause in northern corn rootworms occurs

In addition, the performance of soil insecticides is reduced when corn planting in early to mid-April is followed by cool, wet weather that delays rootworm egg hatch.

The chances for adult silk feeding and egg laying are increased in late-planted corn because such fields are likely to pollinate later and attract more migrating rootworm beetles.

Incidence

Early June through July (larvae) and late June through August (adults).

Tasseling to corn maturity (VT to R6)

OVERVIEW

At this growth stage look for:

Leaf tissue removed . . . . . pages 42, 43
- chunks of leaf tissue removed
- small circular holes or elongated lesions

Stalks malformed or broken 43
- lodging (goosenecking)
- stalk breakage

Tassels damaged 43
- tassel broken
- tassel eaten in whorl
- tassel discolored

Silks clipped 45

Ear damage 47
- chunks of kernels removed
- tunneling or chewing damage
- ear drop

Lee Jenkins

Grasshopper damage. Large, irregular chunks of leaf tissue are removed to the midrib as grasshoppers feed.

SYMPTOMS

Leaf tissue removed

Chunks of plant tissue removed from leaf margins, or ragged holes in leaves

- Armyworm . . . . . page 26
  – Late-season damage not common.
- Fall armyworm 29
  – Damage seen more frequently in late whorl stage corn.
- Grasshoppers 31
  – Serious only if large amounts of foliage are consumed above the ear leaf.

(More leaf tissue removed symptoms on page 43)

(Leaf tissue removed symptoms continued from page 42)

SYMPTOMS

Small, circular holes or elongated lesions in leaves

- European corn borer . . . . . page 32
  - – Feeding of young, second-generation larvae may produce holes (and occasionally lesions) in the collar area of leaves in the ear zone.
- Southwestern corn borer 35
  - – Southern portions of Missouri and Illinois.
- Corn rootworm beetles (especially western) 38
  - – Beetles may occasionally strip the upper, green tissue from leaves when pollen is unavailable.

Stalks malformed or broken

Lodging or growing upward in a gooseneck shape

- Corn rootworm larvae 38

Stalks broken

- European corn borer 32
- Southwestern corn borer 35
  - – Stalks mainly broken at the base of the plant.
  - – Southern portions of Missouri and Illinois.

Tassels damaged

Tassels broken

- European corn borer 32

Tassels eaten (in whorl)

- Fall armyworm 29

Tassels discolored

- Corn leaf aphid 44

University of Nebraska

Damage to leaves in the ear zone by European corn borer.

Jim Jarman

Goosenecking caused by corn rootworm feeding.

Lee Jenkins

Stalk breakage due to girdling near ground by southwestern corn borer.

University of Nebraska

Tassel eaten in whorl by fall armyworm. Reddish pellets are frass.

Brian Christine

Corn leaf aphids. Refer to diagnostic tips for help in distinguishing them from other aphids in corn.

Lee Jenkins

Large colony of corn leaf aphids. Tan ones are aphid mummies; white cast skins are also visible.

Corn Leaf Aphid

Appearance / Life cycle

Small, blue-green, soft-bodied corn leaf aphids may colonize the tassels and upper leaves of the corn plant. These globular insects are about 1/16 inch long with black antennae, legs, and "tail pipes" (cornicles). Female aphids do not lay eggs during the growing season as other insects do, but give birth to live young. Therefore, populations can quickly reach economically damaging levels. Individuals found in the spring are wingless females. However, as populations increase during the growing season, winged females are produced; these mobile females disperse to less crowded sites and begin new colonies. Except for their smaller size, the nymphs are similar to the wingless adults.

Aphids migrate from the south and produce as many as 10 generations each year in Missouri and Illinois. Corn leaf aphids suck plant nutrients from the phloem tissue, and excess fluid consumed by the aphids is excreted as a sugary, sticky substance called honeydew. Corn leaf aphid populations may reach a peak in the whorl just before the tasseling stage and later infest the tassel, upper leaves, and ear.

Diagnostic tips

Corn leaf aphids sometimes coexist on the same plant as greenbugs. Greenbugs are light, dusty-green aphids with a darker green stripe on the back, and only the tips of the cornicles and legs are black. Bird cherry-oat aphids, occasionally found in cornfields, are a darker olive-green with a rusty-red area between the cornicles.

Damage

Heavy infestations of corn leaf aphids cause yellow mottling, wilting, and curling of leaves. The most serious injury to corn occurs before pollination is complete. Incomplete kernel formation, smaller ears, and sometimes even barren plants may result from heavy whorl feeding 2 to 3 weeks before tassel emergence. Later, corn leaf aphids may swarm over the tassel and upper leaves, coating the surface with honeydew and numerous white cast skins shed from molting. In rare cases, tassels and sometimes silks become so heavily coated with honeydew that pollination is disrupted. Honeydew may eventually turn dark, as the high sugar content creates a favorable substrate for sooty molds. Injury symptoms are more pronounced when corn is moisture-stressed. The corn leaf aphid can transmit barley yellow dwarf virus and is also a suspected carrier of maize dwarf mosaic virus (expressed as marginal corn leaf necrosis).

Management

An insecticide application may be justified if the following conditions are met:

- At least 50% of the tassels are coated with more than 50 aphids
- Infestation occurs during pollen shed before pollination is half completed
- Corn is under drought stress

Moisture-stressed plants may still suffer yield loss after pollination if the

upper leaves and tassels remain heavily infested with corn leaf aphids. Insecticidal control may be unnecessary, however, if light brown, parasitized aphid mummies and numerous predators (lady beetles and lacewing) are present.

Fields most likely to sustain injury

Late-planted cornfields are most susceptible to corn leaf aphid damage.

Incidence

Mid-June through mid-August

SYMPTOMS

Silks clipped

Several insects feed on green silks and clip them off before pollination is complete, causing some ears to fill only partially. However, control of insects for silk clipping is rarely necessary unless green silks are continuously clipped back to ½ inch or less before pollination is half complete. (Pollination has occurred when silks are turning brown and curling at the tips.)

- Grasshoppers. . . . . page 31
  - Although grasshoppers readily consume foliage, they prefer to clip silks and chew on kernels during the early reproductive stages of corn.
- Corn rootworm beetles 38
  - Look for clipped green silks.
- Corn earworm. 46
  - Look for moist, light brown frass lodged in silks near the ear tip.
- Japanese beetle
  - In eastern Illinois, large numbers of Japanese beetles (five or more per plant) may clip enough silks to prevent proper pollination.
- Yellow woollybear
  - Larvae clip silks, especially if flowering is delayed. However, yellow woollybears tend to move readily from plant to plant, reducing their impact on pollination.

Ohio State University

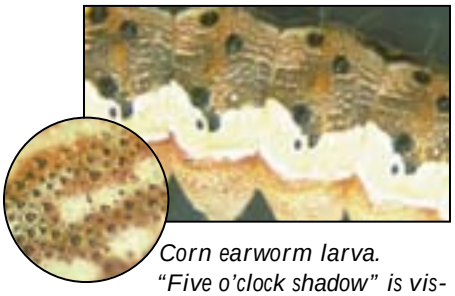
Missing kernels due to incomplete pollination, caused by clipped silks.

Lee Jenkins

Corn earworm eggs on corn silk.

Lee Jenkins

Two color variations of corn earworm larvae.



photos by Laura Kabrick

Corn earworm larva. "Five o'clock shadow" is visible above white band. Close-up (right) reveals black microspines.

Corn earworm damage. Generally, feeding is concentrated near the ear tip.

Lee Jenkins

Corn Earworm

Although the corn earworm (also known as cotton bollworm, sorghum headworm, and soybean podworm) infests more than 100 species of plants, corn is the preferred host.

Appearance / Life cycle

Moths have buff-colored wings with irregular markings and a wingspan of 1½ inches. Eggs are ribbed and hemispherical and approximately the same color and diameter as an individual silk. Larvae are extremely variable in color, ranging from light green to pink, but all larvae have a tan head and alternating dark and light stripes on the body. The larvae have numerous dark spots (tubercles) with long spines. Corn earworm can be distinguished from other larvae by tiny, thornlike projections called microspines that give a bristly appearance when viewed under 10x magnification. Larvae pass through five growth stages and are 1½ inches long when full-grown.

Corn earworm populations in the Midwest mostly arise from spring migration from southern states, although pupae may successfully overwinter in southeastern Missouri and southern Illinois. Although migratory flights trickle in as early as mid-April in the Missouri Bootheel, the corn earworm arrives in force by mid-June. There are two or three generations in Missouri and Illinois.

The first-generation larvae sometimes infest the whorls if silking corn is unavailable. Moths that lay the eggs of the second generation are highly attracted to fresh, green silks. Eggs are deposited individually, and the newly hatched, pale-yellow larvae tunnel through the silk channel to the developing ear. Larvae feed for about 2 to 3 weeks, consuming kernels at the tip and along the side of the ear. Unlike the fall armyworm, corn earworm does not bore an entrance hole through the husk, but does sometimes leave an emergence hole as the full-grown larva prepares to pupate in the soil. Third-generation larvae may attack very late-planted corn but are more likely to develop on sorghum, soybeans, or cotton (depending on the location) as corn silks turn brown and dry. Because the species is cannibalistic, only one corn earworm typically develops in each infested ear or whorl.

Diagnostic tips

Use a 10x hand lens to distinguish corn earworms from other striped larvae infesting corn. The dense covering of microspines along the back and sides of the corn earworm is unique to this species. Microspines show up under magnification as dark, short bristles that resemble a "five o'clock shadow." In addition, the corn earworm usually feeds at the ear tip; fall armyworm and European corn borer typically feed on the sides of the ear below the tip.

Damage

Whorl feeding appears as ragged holes in the leaves as they unfurl; moist, tan frass is found inside the whorl. Corn earworm prefers the developing ears during the silking period, and damage is mostly confined to the ear tip. Moist, light tan frass is also lodged in the silks at the ear tip. Silks are often clipped as larvae tunnel into the ear. The ear will have an incomplete kernel set if the silks are destroyed before pollination is complete. Ear molds developing in the damaged kernels may cause toxicity problems in livestock.

Management

Although a majority of the ears may contain an earworm, insecticide application is impractical for field corn. Control is difficult because eggs are laid on emerging silks, on which a protective insecticide coating cannot be maintained unless sprays are applied every 2 to 3 days. Control may be economically justified in sweet corn or in late-maturing seed production fields while fresh silks are present.

Fields most likely to sustain injury

Any cornfield with fresh silks acts as a magnet for egg-laying corn earworm moths, especially during strong migratory flights. Early-planted corn is more likely to escape injury if silking is completed before corn earworm populations peak. However, in most years, corn earworm larvae consistently remove their 2% to 3% "tax" from the majority of the ear tips, regardless of planting date.

Incidence

Mid-June through August

SYMPTOMS

Ear damage

Large chunks of kernels removed, often at blister and milk stages

- Grasshoppers. . . . . page 31
  - Often damage ear tips and shucks

Tunneling or chewing damage

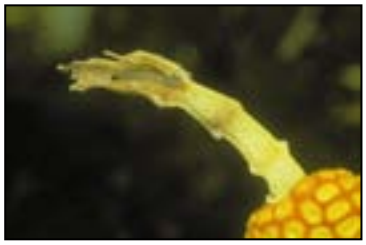
- Fall armyworm 29
- European corn borer 32
- Corn earworm. 46

Ear drop

- European corn borer 32
  - Ear loss due to shank tunneling.

Lee Jenkins

Lee Jenkins



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Wayne Bailey

Ear damage by grasshoppers (top), European corn borer (above), and fall armyworm (left). European corn borer tunneling inside shank (far left) can lead to ear loss before harvest.

Appendix

Management of the European Corn Borer

Management

The following information is required when deciding whether it will be profitable to treat a field infested with European corn borer larvae:

- Corn stage
- Expected yield
- Expected market price
- Cost of control (insecticide plus application costs)
- Estimated percent control
- Average number of larvae per plant (first generation)
- Average number of egg masses per plant (second generation)

Jim Jarman

Scouting whorl-stage corn for first-generation European corn borer.

Scouting for first-generation European corn borer

Scouting should begin 200 degree-days (typically 11 to 12 days) after the first spring moth has been detected in blacklight or pheromone traps. Plan to scout cornfields at least once a week for 3 to 4 weeks after peak moth flight (often early June in mid-Missouri to mid-June in northern Illinois). Concentrate first on the earliest planted (tallest) fields in the area.

Scouting procedure

1) Examine a minimum of 50 plants (10 plants at each of five field stops) for the presence of larvae.
2) Pull whorls from plants and unroll leaves to count live borers. Randomly select plants to avoid sampling *only* plants that show larval damage.
3) Divide total number of larvae found by number of whorls examined to determine average number of borers per plant. (Do not count larvae that have bored into plants.)
4) Refer to the management worksheet for first-generation European corn borer.

Scouting for second-generation European corn borer

Start checking for egg masses, not feeding damage, when moth flight begins (usually mid-July in central Missouri and Illinois). Assume that egg laying has begun when the first moths are either collected in pheromone or blacklight traps or flushed from dense areas of vegetation surrounding cornfields. Scout fields at least once a week and continue scouting throughout the egg-laying period, which can extend for 3 to 6 weeks. Concentrate initial scouting efforts in late-planted corn where the probability of an economic infestation is greatest.

European corn borer egg mass.

Scouting procedure

1) Examine a minimum of 100 plants (20 plants in five locations).
2) Check undersides of leaves in the ear zone (i.e., middle seven leaves of the plant) for egg masses.
3) If only the ear zone was examined, divide the egg count by 0.91 to adjust for egg masses laid elsewhere.
4) Refer to the management worksheet for second-generation European corn borer.

Control considerations

- Consider transgenic Bt hybrids (planted with refuges of non-Bt corn to manage resistance).
- If moth capture data is available, a single treatment is best applied just after peak moth flight.
- If possible, avoid making a treatment decision until the majority of larvae have reached the second instar (3/16 inch long, or 4 to 5 days after most eggs have hatched).
- Larvae cannot be controlled by insecticides once they begin to bore into the stalks (about 10 to 13 days after hatching).

Second generation

Egg laying of the second-flight moths occurs over approximately 3 to 6 weeks, so good control of second-generation borers may require two treatments:

- First insecticide treatment at 10% pollen shed
- Second insecticide treatment 7 to 10 days after first treatment

Use the management worksheet to determine whether multiple insecticide treatments are expected to yield an economic return.

First-generation European corn borer management worksheet

	Larvae found	×		expected survival [1,2]	=		surviving larvae
	Surviving larvae	÷		plants examined	=		larvae/plant
	Larvae/plant	×		yield loss/larva [3]	=		yield loss
	Yield loss	×		expected yield (bu/A)	=		loss (bu/A)
	Loss (bu/A)	×	$	price/bu	=	$	loss/A
$	Loss/A	×		control [4]	=	$	preventable loss/A
$	Preventable loss/A	–	$	cost of control/A	=	$	gain (+) or loss (-) per acre if control applied

Notes:

[1] Record all percentages as decimals (e.g., 20% = 0.2).

[2] If larvae are newly hatched (first instar), it is likely that only about 20% will survive to maturity, depending on environmental stresses. If larvae are second instar (about 3/16 inch) or larger, the survival rate may increase to 50%. Adjust this number accordingly.

[3] Use 0.06 for V10 corn, or 0.05 for V16 (green tassel) corn. When borer numbers reach or exceed three per plant, the loss caused by each additional borer will decrease. Therefore, use 0.035 loss per borer for each additional borer above three per plant.

[4] 80% control with granules (aerial or ground application) and with sprays directed over the whorls (ground application); the more effective insecticides provide comparable control when applied as broadcast sprays (aerial application).

Sample worksheet completed for first-generation European corn borer

225	Larvae found	×	0.4	expected survival [1,2]	=	90	surviving larvae
90	Surviving larvae	÷	50	plants examined	=	1.8	larvae/plant
1.8	Larvae/plant	×	0.06	yield loss/larva [3]	=	0.108	yield loss
0.108	Yield loss	×	140	expected yield (bu/A)	=	15.12	loss (bu/A)
15.12	Loss (bu/A)	×	$ 2.50	price/bu	=	$ 37.80	loss/A
$ 37.80	Loss/A	×	0.8	control [4]	=	$ 30.24	preventable loss/A
$ 30.24	Preventable loss/A	–	$ 14.00	cost of control/A	=	$ 16.24	gain (+) or loss (-) per acre if control applied

Second-generation European corn borer management worksheet

	Egg masses found [1]	÷	0.91	(if only ear zone sampled)	=		adjusted egg masses
	Adjusted egg masses	÷		plants examined	=		egg masses/plant
	Egg masses/plant	×	4	larvae/egg mass [2]	=		larvae/plant
	Larvae/plant	×		yield loss/larva [3,4]	=		yield loss
	Yield loss	×		expected yield (bu/A)	=		loss (bu/A)
	Loss (bu/A)	−	$	price/bu	=	$	loss/A
$	Loss/A	×	0.75	control	=	$	preventable loss/A
$	Preventable loss/A	−	$	cost of control/A	=	$	gain (+) or loss (-) per acre if control applied

Notes:

[1] Counts may be cumulative if taken a few days apart.

[2] Four larvae/egg mass assumes 20% survival of 20 eggs/mass; increase if environmental conditions are favorable for borer survival.

[3] Record all percentages as decimals (e.g., 20% = 0.2).

[4] Yield loss per borer per plant at two corn stages:

Average number of egg masses	Pollen shed	Blister stage
Two or fewer per plant	0.04	0.03
More than two per plant	0.03	0.02

As plants mature beyond the blister stage, the economic benefits of treatment rapidly decrease.

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Corn growth stages

Vegetative growth stages

VE	Emergence (coleoptile above soil)
V1	First leaf fully emerged (collar visible) from the whorl
V2	Second leaf fully emerged (collar visible) from the whorl
V3	Third leaf fully emerged (collar visible) from the whorl
V(n)	n^{th} leaf fully emerged (collar visible) from the whorl
VT	Tasseling

Reproductive growth stages

R1	Silking; fresh green silks
R2	Blister; visible blisters with abundant fluid
R3	Milk; kernels with milky white fluid
R4	Dough; semisolid kernels with no visible denting
R5	Dent; majority of kernels dented or denting
R6	Physiological maturity; black layer formed

Symbols used in this guide

Planting to full emergence (up to V2)

Emergence to knee-high corn (VE to V8)

Knee-high to tasseling corn (V8 to VT)

Tasseling to corn maturity (VT to R6)

Glossary

Coleoptile: The first "spiking" corn leaf, forming a protective sheath around the embryonic plant.

Cornicles: A pair of tubular structures located on the top side of the posterior end of aphids.

Diapause: A period of suspended growth and development that occurs at one stage in the life cycle of some insects (e.g., European corn borer larvae overwinter as diapausing fifth instars).

Economic injury level: Lowest pest density that can cause enough economic damage to justify the cost of control.

Economic threshold: Pest density at which control action should be taken to prevent a pest population from reaching the economic injury level.

Frass: Solid waste excreted by insects, often containing plant fragments.

Instar: The insect between successive molts, the first instar being between egg hatch and the first molt.

Raster: An area of definitely arranged hairs and spines on the bottom surface of the last abdominal segment of the larvae of scarab beetles (white grubs).

Suture: A groove or seam in the body wall of insects, indicating the division of distinct parts.

Tiller: A shoot or sucker arising from the base of the stalk of a corn plant.

Transgenic Bt hybrid: Corn hybrid genetically altered by insertion of DNA from *Bacillus thuringiensis* (Bt), a naturally occurring soil bacterium that produces a protein toxic to lepidopterous larvae (e.g., European corn borer and southwestern corn borer).

Tubercles: Small rounded and knoblike protuberances on the bodies of caterpillars; patterns useful for identification (e.g., of cutworm species).

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