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Texas CORN Production

Emphasizing Pest Management & Irrigation

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Texas Corn Production
Emphasizing Pest Management and Irrigation

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Introduction

This guide contains practical, science-based information to help Texas corn producers make economically sound management decisions. Much of the information is specific to the state and may be inaccurate outside of Texas.

Irrigation is a major cost of corn production in much of the state, so the water use and irrigation information should be very useful. It covers crop water demand, irrigation timing, pre-season watering, evapotranspiration calculation, water quality, salinity and groundwater protection.

While this is not a manual on corn diseases, it does address specific diseases as they relate to pest management. *Fusarium* and *Aspergillus,* which cause stalk and ear rots, are often related to insect and water management and can greatly affect the profitability of corn production in Texas. Dealing with corn diseases can be a major production expense; in extreme cases, diseases may make a crop unmarketable. This was the case in 1998 when a large amount of Texas corn was disposed of in landfills because it exceeded federal standards for aflatoxins.

The insect section includes information on the biology, damage, scouting procedures and economic thresholds of each pest as it occurs in Texas. This guide should be used in conjunction with the Texas Cooperative Extension publication "Managing Insect and Mite Pests of Texas Corn" (B-1366), available at your county Extension office or on the Web at *http://tcebookstore.org/.* B-1366 contains specific insecticide recommendations and is updated frequently.

Additional information can be found at this manual's companion Web site, *http://lubbock.tamu.edu/cornIPM.* The site includes every electronic publication referred to in this manual as well as instructional videos and links to more information. The Web site will be updated with new corn pest management resources after this book has been printed.

County Extension personnel are available to make field visits and help growers with management decisions, as are private consultants. In addition, the Web has a rich offering of local, state and regional newsletters and insect control guides from Texas and nearby states.

This manual was made possible by financial support from the U.S. Department of Agriculture Cooperative States Research and Extension Service (Southern Region) and the Texas Department of Agriculture Integrated Pest Management Grants Program.

Corn Growth and Development

Insect pests, diseases and water requirements change throughout the season and are closely related to the developmental stage of corn. Agronomists have devised a standardized method (called the leaf collar method) for describing corn development. This method is easy to use because you simply count leaf collars on individual plants to determine vegetative stages. The collar is a light-colored band at the base of a leaf. It attaches the leaf blade to the leaf sheath. The back of the collar is usually the first part that is visible. Do not count leaf sheaths, which are the columns of leaf that grow around the stalk and attach the leaf to the stalk.

Vegetative (V) stages begin at emergence (VE) and end at tasseling (VT). The first leaf to emerge (V1) has a rounded tip and never grows as large as later leaves. Each new visible leaf collar adds one to the V number. A plant with four leaf collars visible is a V4, regardless of other leaves that may still be in the whorl. V numbers are added until the final collar appears before tasseling. Because the number of leaves varies with the hybrid and environment, the final V number is represented in Table 1 as simply V(n), where n represents whatever the final number really is for a particular field. Early leaves start to fall off plants by V5, and there are ways to determine development by splitting stalks and counting nodes. This is not usually necessary for making insect and disease control and irrigation decisions.

Insurance adjusters use a different method that tends to score plants as one to two leaves higher than the leaf collar method. Also, the instructions for some herbicides that can be applied during specific growth stages may use different ways of determining corn growth. Always consult the product label to be sure you determine growth stage by the manufacturer's method.

Table 1. The leaf collar method for assessing field corn development.*

	Vegetative stages		Reproductive stages
VE	Emergence	R1	Silking
V1	First leaf	R2	Blister
V2	Second leaf	R3	Milk
V3	Third leaf	R4	Dough
V(n)	n^{th}-node	R5	Dent
VT	Tasseling**	R6	Physiological maturity

*Modified from Bulletin 472, The Ohio State University. A field is considered to be at a particular growth stage when 50 percent of the plants reach that stage.

**Technically, the VT stage is considered a reproductive stage.

Corn Development, Temperature and Growing Degree Days

There are weather station data on the Internet for most parts of Texas. These data are routinely used to calculate crop water demand (ET), but can also be used to calculate corn development based on heat accumulation, sometimes referred to as "heat units." Growing degree days for corn are calculated by the simple formula:

$$((\text{daily high} + \text{daily low}) \div 2) - 50$$

If the daily high temperature is greater than 86 degrees F, use 86 as the high value for the day. If the daily low temperature is less than 50 degrees F, use 50 as the daily low. (These values are substituted for actual highs and lows because corn grows very little below 50 degrees F or above 86 degrees F.) Adhering to these low and high value cutoff limits makes it possible to calculate corn development with the "Modified 86/50 Cutoff Method," which is quite accurate.

Knowing the number of growing degree days required to reach a certain growth stage can help in predicting irrigation needs.

Table 2. Approximate number of growing degree days (base 50) required to reach each corn developmental stage*

Growth stage	Growth stage	Cumulative degree days	Significant events
VE	Emergence	100	
V3	3 leaves	280	
V6	6 leaves	460	Growing point is above soil
V9	9 leaves	640	Rapid growth, number of kernel rows being established
V12	12 leaves	820	Kernel number and ear size being determined here through V17
V18	18 leaves	1180	Moisture stress can delay silk
V19	19 leaves	1240	Moisture stress can delay silk
VT	Tassel	1300	
R1	Silking	1360	
R2	Blister	1660	
R3	Milk	1860	
R4	Dough	2000	
R5	Dent	2300	
R5.5	Half milkline	2520	
R6	Black layer	2720	Physiological maturity

*Modified from Bulletin 472, The Ohio State University.

Uniform Germination

Uniform germination and stand establishment are critical to getting the best return on a crop. Even with adequate water and no pests, a nearly 7 percent yield loss will occur when 25 percent of the plants emerge 7 to 10 days late. This is because the older, larger plants will prevent the later, younger plants from reaching their full yield potential. Also, some insect problems can be made worse in fields with uneven growth stages. The three requirements for uniform germination are

- adequate and uniform moisture in the seed zone,
- adequate and uniform temperature in the seed zone, and
- adequate and uniform seed-to-soil contact.

Low Temperatures

The growing point of corn remains below ground level until the fifth or sixth leaf collar stage, when corn is usually about 10 inches tall. When the growing point is below ground level, above-ground leaves may be lost to frost. This may delay plant growth but does not generally reduce yield directly. Freezing temperatures after the growing point is above ground level can kill plants. In fact, radiative heat loss can lower leaf temperature to below the air temperature on a cold night, causing frost injury even when the thermometer does not indicate a freeze. To determine the effect of freezing on yield, see Texas Cooperative Extension publication B-6014, "Assessing Hail and Freeze Damage to Field Corn and Sorghum," at *http://tcebookstore.org.*

The effects of low temperatures during early corn development are usually not overcome by the hot temperatures of summer. This is because corn growth is severely retarded when the temperature is above 86 degrees F and heat units do not accumulate above this temperature.

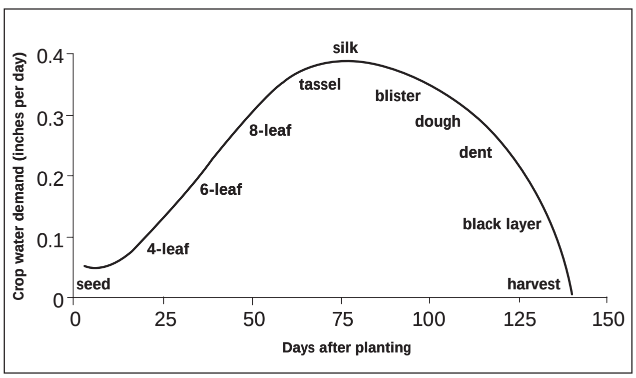
High Temperatures

Corn growth plateaus at temperatures above 86 degrees F and decreases when temperatures exceed 95 degrees F. If water is adequate, a few days of temperatures above 100 degrees F during ear formation, reproduction and grain fill will not affect yield significantly. However, yields will suffer if temperatures remain that high for several days. At high temperatures, plants cannot take up enough water to stay cool. Once the cooling mechanism is disabled, plant cells are damaged by the heat. For example, parts of the High Plains had more than 14 consecutive days of temperatures above 100 degrees F in 2003, and the heat damage caused widespread yield reductions.

Water Demand and Irrigation Management

Corn uses a relatively large amount of water and is highly sensitive to drought. In the Texas High Plains, corn uses approximately 28 to 32 inches per season. Peak water use occurs a few days before tasseling (concurrent with maximum leaf area index). Water demand begins to decline about midway through the grain-fill period (dent stage). The most critical period—when water stress has the greatest effect on yield—occurs about 2 weeks before and after silking. The general trend of crop water demand during the season is shown in Figure 1.

Figure 1. Approximate corn water demand (inches per day) in the Texas High Plains.



According to research in the Texas High Plains, the yield return per water input (Water Use Efficiency, or WUE) is 250 to 450 pounds of grain per acre-inch of water (4.5 to 8 bushels per acre-inch). Under deficit irrigation management, the WUE may be as high as 10 to 15 bushels per acre-inch. WUE depends on factors such as crop variety, irrigation method, irrigation management, pest pressures, fertility management, and field and climate conditions.

Soil Moisture Management

The **root zone** of corn can be as deep as 5 to 6 feet if soil conditions allow. Roots usually develop early in the season and grow best in moist soil. They will not grow in saturated or extremely dry soil. Like most crops, corn will extract 70 to 85 percent of the water it requires from the top 2 feet of soil, and almost all of its water from the top 3 feet if water is available. Deep soil moisture is beneficial primarily when the shallow moisture is depleted during periods of peak water demand.

The soil moisture profile, plow pans, caliche layers, etc. often limit the depth of the root zone. A shallow-rooted crop is more susceptible to drought injury.

The properties and condition of soil affect how much water can be retained in the root zone and at what rate water can enter the soil.

Permeability is the ability of the soil to take in water through infiltration. A soil with low permeability cannot take in water as fast as a soil with high permeability. Therefore, the permeability of the soil affects how quickly applied water will run off the surface. Permeability is affected by soil texture, soil structure and surface condition. Generally, fine-textured soils (clays, clay loams) have lower permeability than coarse soils (sand). Surface sealing, compaction and poor structure (particularly at or near the surface) limit permeability.

Soil moisture storage capacity describes how much water can be retained in the soil between the two extremes of field capacity and permanent wilting point. Once soil reaches field capacity, excess water applied will run off or be lost through deep percolation. When the soil moisture is below the permanent wilting point, water is held too tightly to soil particles for the plants to extract it. The only water available to plants is that stored between those two critical levels. Some soils can store more water than others. At field capacity, a sandy soil may hold 0.6 to 1.25 inches and a clay loam 1.5 to 2.3 inches of water per foot of soil. Table 3 shows representative soil properties of selected soils. Note the ranges and changes of permeability, available water storage capacity and soil textures between soil layers (depths).

Producers should manage soil moisture so that the crop's water demand is met without allowing soil to become waterlogged. Soil moisture can be monitored in a number of ways, including

- physical sampling and monitoring by feel and appearance (summarized in Table 4),
- resistance-based sensors (gypsum blocks and granular matrix sensors),
- tensiometers, and
- capacitance probes.

The goal is to monitor soil moisture in the effective root zone so that irrigation can be better matched to crop water demand.

Example: Given the following conditions, estimate the available soil moisture storage capacity in the effective root zone.

Estimated effective root zone depth: 4 feet

Soil properties:

Soil layer depth from surface, inches	Permeability inches/hour	Soil water storage capacity (inches H_2O/ inches soil)	Potential available soil water storage in the layer
0 – 14	2.0 – 6.0	0.08	1.12
14 – 46	0.6 – 2.0	0.15	4.8
46 – 80	0.6 – 2.0	0.13	4.4

In the top 4 feet (48 inches) of soil, water holding capacity = (14 x 0.08) + ((46-14) x 0.15) + ((48-46) x 0.13) = 1.12 + 4.8 + 0.26 = **6.18 inches of water.**

Table 3. Representative soil properties of selected soils in Texas.

Soil series	Depth from surface (inches)	Soil texture	Permeability (inches/hour)	Available water capacity (in H_2O per inch soil)	Available H_2O per foot soil (inches)	Available H_2O per 3-foot root zone (inches)	Available H_2O per 5-foot root zone (inches)
Acuff	0 - 10	Loam	0.63 - 2.0	0.14 - 0.17	1.86	5.7	9.1
	10 - 36	Sandy clay loam	0.63 - 2.0	0.15 - 0.17	1.92		
	36 - 80	Sandy clay loam	0.63 - 2.0	0.13 - 0.15	1.68		
Amarillo	0 - 9	Fine sandy loam	2.0 - 6.0	0.11 - 0.15	1.56	5.5	8.9
	9 - 44	Sandy clay loam	0.6 - 2.0	0.15 - 0.17	1.92		
	44 - 102	Sandy clay loam	0.6 - 2.0	0.11 - 0.15	1.56		
Estacado	0 - 15	Clay loam	0.63 - 2.0	0.13 - 0.15	1.68	5.0	8.4
	15 -25	Clay loam	0.63 - 2.0	0.13 - 0.15	1.68		
	25 - 80	Clay loam	0.63 - 2.0	0.13 - 0.15	1.68		
Houston Black Clay	0 - 6	Clay	< 0.06	0.15 - 0.20	2.1	5.5	8.7
	6 - 35	Clay	< 0.06	0.12 - 0.18	1.8		
	35 - 80	Clay	< 0.06	0.10 - 0.16	1.56		
Olton	0 - 13	Clay loam	0.63 - 2.0	0.16 - 0.18	2.04	6.1	9.6
	13 - 39	Clay loam	0.20 - 0.63	0.16 -0.18	2.04		
	39 - 80	Clay loam	0.20 - 0.63	0.14 - 0.15	1.74		
Pullman	0 - 8	Clay loam	0.20 - 0.63	0.15 - 0.18	1.98	5.7	9.0
	8 - 46	Clay	< 0.06	0.15 - 0.16	1.86		
	46 - 84	Silty clay loam	0.06 - 0.20	0.14 - 0.16	1.80		

(Source: USDA Natural Resources Conservation Service Soil Surveys.)

Table 4. Estimating soil moisture by feel and appearance.				
Soil moisture level	**Fine sand, loamy fine sand**	**Sandy loam, fine sandy loam**	**Sandy clay loam, loam, silt loam**	**Clay loam, clay, silty clay loam**
0 - 25% available soil moisture	Appears dry. Will not retain shape when disturbed or squeezed in hand.	Appears dry. May make a cast when squeezed in hand but seldom holds together.	Appears dry. Aggregates crumble with applied pressure.	Appears dry. Soil aggregates separate easily but clods are hard to crumble with applied pressure.
25 - 50% available soil moisture	Slightly moist appearance. Soil may stick together in very weak cast or ball.	Slightly moist. Soil forms weak ball or cast under pressure. Slight staining on finger.	Slightly moist. Forms a weak ball with rough surface. No water staining on fingers.	Slightly moist. Forms weak ball when squeezed but no water stains. Clods break with applied pressure.
50 - 75% available soil moisture	Appears and feels moist. Darkened color. May form weak cast or ball. Leaves wet outline or slight smear on hand.	Appears and feels moist. Color is dark. Forms cast or ball with finger marks. Will leave a smear or stain and leaves wet outline on hand.	Appears and feels moist and pliable. Color is dark. Forms ball and ribbons when squeezed.	Appears moist. Forms smooth ball with defined finger marks and ribbons when squeezed between thumb and forefinger.
75 - 100% available soil moisture	Appears and feels wet. Color is dark. May form weak cast or ball. Leaves wet outline or smear on hand.	Appears and feels wet. Color is dark. Forms cast or ball. Will smear or stain and leaves wet outline on hand. Will make weak ribbon.	Appears and feels wet. Color is dark. Forms ball and ribbons when squeezed. Stains and smears. Leaves wet outline on hand.	Appears and feels wet; may feel sticky. Ribbons easily. Smears and leaves wet outline on hand. Forms good ball.

Irrigation Efficiency

Irrigation efficiency suffers when there are transmission losses (seepage from ditches, leaks from pipelines, etc.) or application losses (deep percolation below the crop root zone; evaporation and drift, especially in hot, windy conditions; run-off). Low-pressure, advanced irrigation technologies (described below) are generally more efficient than surface irrigation and high-pressure sprinkler irrigation systems. However, the water source, farm layout and lack of operational resources may prevent a grower from fully adopting these technologies.

Management and maintenance are critical to optimizing any irrigation system. At the same time, soil moisture storage must be maximized and runoff minimized to improve overall water use efficiency.

Surface irrigation systems (furrow and flood irrigation) can be improved by

- leveling and grading the land,
- using high-flow turnouts (from ditch irrigation systems),
- using surge irrigation (for furrow irrigation systems),
- alternating furrow irrigation, and
- recovering and reusing tailwater, as appropriate to the individual farming operation.

High-pressure, overhead sprinkler systems (center pivot or linear move) should be designed, maintained and managed to ensure uniform applications with minimal losses from runoff or deep percolation. Selecting the right applicators and nozzles for the specific system (considering soil intake rate, flow, pressure, etc.) is important. Because high winds can cause excessive evaporation and drift, converting to a lower pressure, lower elevation applicator may be advisable, especially where the amount of irrigation water available is a concern.

Advanced technologies have made irrigation more manageable, more efficient and more uniform. Newer systems also are more automated, easier to control, and require less labor. Low-Energy Precision Application (LEPA) and Low-Elevation Spray Application (LESA) are considered experimental in much of the U.S. (and the world, for that matter), but are common in the Texas High Plains and Texas Southern High Plains. LEPA and LESA systems use less energy and apply water more efficiently. They are especially beneficial in dry areas with relatively deep aquifers and, therefore, high pumping costs. Variations on LESA technology, such as Mid-Elevation Spray Application (MESA) and Low-Pressure In-Canopy (LPIC) systems, are other efficient alternatives. Recently, subsurface drip irrigation has been gaining ground. It is highly efficient and increases crop yield and quality noticeably in deficit irrigation situations.

Deficit irrigation generally returns more yield per water input (WUE) than full irrigation.

Tillage and Other Conservation Practices

Furrow diking is an integral part of a LEPA irrigation system and is recommended for other overhead sprinkler systems. This tillage method forms small embankments within furrows to hold irrigation and rain water until it can infiltrate into the soil. Furrow dikes can even be used in dryland and alternate furrow irrigation systems to increase the retention of precipitation. Furrow impoundments reduce run-off, improve water use efficiency, and distribute water uniformly in the field.

Conservation tillage practices (strip till, reduced till, no till, etc.) can increase off-season soil moisture storage by reducing rainfall run-off.

Irrigation Management

Pre-plant and Early-season Irrigation

Where crop acreage and yield are limited by irrigation capacity, it is common practice to irrigate before planting. The objectives are to provide adequate moisture for seed germination and crop establishment and to store enough water in the soil profile to meet peak water demand (which is often greater than the irrigation system capacity) later in the season. Research indicates that pre-plant irrigation can be very inefficient, regardless of the method used. Any irrigation applied or precipitation received in excess of the soil moisture storage capacity will be lost through run-off and/or deep percolation. Evaporation from the surface of moist, bare soil and losses during irrigation also can be significant. Therefore, pre-plant and early-season irrigation should be targeted to achieve crop establishment and promote early root development, while reserving some soil moisture storage capacity (15 to 25 percent) for rainfall that may be received. The crop needs less water early in the season, so there may be time before the peak water demand period to fill the soil profile after the crop is established. The irrigation system capacity, crop rotations used and other issues will affect decisions about early-season irrigation.

Example: Given the following conditions, how long will it take to achieve the desired soil moisture (80 percent field capacity)?

Estimated effective root zone depth: 3 feet

Approximate soil water at field capacity: 1.7 inches of water per foot of soil

Target soil moisture: 80 percent field capacity

Estimated soil moisture before irrigation: 40 percent

Irrigation capacity: 5 gpm/acre (1.86 inches per week, Table 3)

Irrigation efficiency: 80 percent (estimated)

Water to be applied: 3 ft x 1.7 in/ft x (0.80 – 0.40) = 2.0 inches

Adjust for irrigation application efficiency: 2.0 ÷ 0.8 = 2.5 inches

Time to apply 2.5 inches: 2.5 inches ÷ 1.86 inches per week = 1.34 weeks

It will take between 1 and 2 weeks to apply 2.5 inches of water at a rate of 5 gpm per acre.

Late-season Irrigation

The amount of moisture stored in the root zone, the flexibility of the irrigation system, the amount of water being lost to evapotranspiration (ET), and the probability of rainfall will determine whether corn should be irrigated late in the season. Water demand decreases from the dent stage to harvest, although some moisture will be required as the crop matures. Long-term and real-time crop ET estimates, explained below, can be very useful in projecting how much water will be needed to complete the crop season. Advanced irrigation technologies (subsurface drip irrigation and center pivot methods) make it possible to apply water at reduced rates as the end of the season nears.

Irrigation Capacity to Meet Peak Water Demand

Where the capacity of the irrigation system is limiting, a grower may be able to plant only the acreage that can be supplied by that capacity and the moisture stored in the soil. Peak water demand for corn can exceed 0.35 inches per day (6.4 gpm per acre) in some areas of the state. Because soil moisture storage (3 to 6 inches of water in the top 3 feet of soil) can help meet demand during the peak period, irrigation capacities of 5 to 6 gpm per acre are generally adequate for corn production, provided the irrigation equipment and management are very efficient.

Table 5. Irrigation capacities and equivalent irrigation depths.

Gallons per minute to acre-inches per day		Gallons per minute per acre to inches per day or inches per week		
gpm	ac-in/day	gpm/ac	in/day	in/week
100	5.3	1	0.053	0.37
200	10.6	2	0.11	0.74
300	15.9	3	0.16	1.11
400	21.2	4	0.21	1.48
500	26.5	5	0.27	1.86
600	31.8	6	0.32	2.23
700	37.1	7	0.37	2.60
800	42.4	8	0.42	2.97

Estimating Crop Water Demand with Evapotranspiration Data

Evapotranspiration (ET) is the loss of water from a combination of evaporation (water vaporized from moist surfaces) and transpiration (water in plants removed through stomata on the leaves).

Reference ET, also known as Potential Evapotranspiration (PET), is an estimate of the water required by a well-watered reference crop. This reference crop (grass or alfalfa) is an idealized crop used as a basis for the ET model. Reference ET is calculated by applying climate data (temperature, solar radiation, wind, humidity) in an equation.

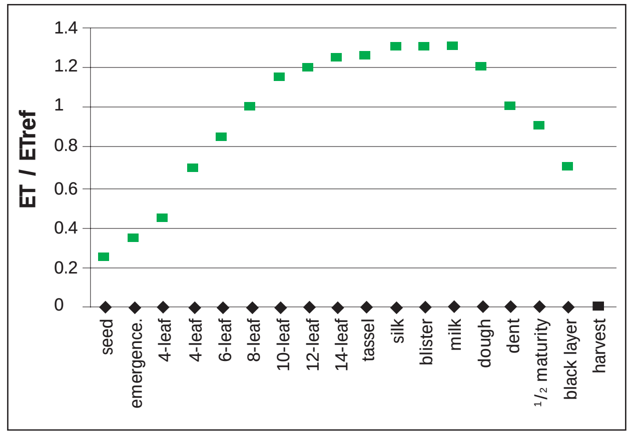
Reference ET is only an estimate of the water demand for this idealized crop, based on weather data at a given location.

The ET of a specific crop is estimated by multiplying the Reference ET by a crop coefficient.

Crop ET = Reference ET x Crop Coefficient

The crop coefficient takes into account the crop's water use (at a given growth stage) compared to that of the reference crop. For instance, seedling corn does not use as much water as the idealized grass reference crop, but during silking corn can use more water than the grass reference crop. The crop coefficient follows a pattern (curve) of the general shape shown in Figure 2.

Figure 2. Crop coefficients for corn grown in the Texas High Plains.

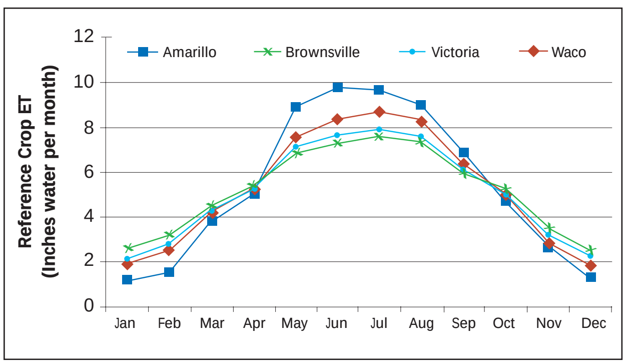


The reference crop ET model and the crop coefficient curves were developed from long-term research at various locations. Actual crop water demand can be affected by many factors, including soil moisture, crop health, and probably by plant populations and variety traits. These factors are not taken into account by the models. Hence, ET data provided by online networks are best used as guidelines for irrigation scheduling and (where applicable) for integrated pest management and integrated crop management. The growth stage and water use predicted by the data should be verified with field observations. The actual crop water use is likely to be somewhat less than the predicted value.

There are a variety of irrigation scheduling methods, models and tools that use ET data. Many are essentially based upon a "checkbook" approach: Water stored in the soil (in the crop's root zone) is withdrawn by evapotranspiration and deposited back into the soil through precipitation and irrigation. When soil moisture falls below a given threshold, the crop should be irrigated to restore the moisture. The threshold may be determined by the crop's drought sensitivity, by irrigation system capabilities, or by other criteria.

There are several ET weather station networks in Texas, each serving a particular region. The Texas High Plains is served by two networks—the North Plains ET Network (*http://amarillo2.tamu.edu/petnet1.htm* based at Amarillo) and the South Plains ET Network (*http://lubbock.tamu.edu/irrigate/* based at Lubbock). The South Plains and North Plains ET networks have merged most of their operations to form the Texas High Plains ET Network. South and central Texas are served by the Texas ET Network (*http://texaset.tamu.edu* based at College Station). There are other local networks from which data are available. Long-term average monthly reference crop ET values for selected locations are summarized in Figure 3.

Figure 3. Long-term average monthly reference crop evapotranspiration demand (inches water per month).



Water Quality

Salinity

Corn is moderately sensitive to salinity in soil and irrigation water. Grain yield is reduced if the salinity of irrigation water is greater than 1.1 dS/m electrical conductivity (EC), or the salinity of the soil is greater than 1.7 dS/m EC. A 50 percent reduction in yield can be expected with irrigation water EC of 3.9 dS/m.

Corn is also moderately sensitive to foliar injury from sodium (tolerance between 230 and 460 ppm) and chloride (tolerance between 350 and 700 ppm) in irrigation water. If water quality is marginal, spray irrigation is more likely to injure foliage than other irrigation methods. If the crop receives excess water periodically (by irrigation and/or rainfall) some accumulated salts will be leached from the root zone. Learn more about salinity management in Texas Cooperative Extension publication B-1667, "Irrigation Water Quality Standards and Salinity Management Strategies," available at *http://tcebookstore.org.*

Protecting Water from Contamination

Agricultural chemicals, including fertilizers and pesticides such as atrazine, have been detected in wells and surface waters in Texas. The herbicide atrazine is a special concern because it is widely used, it persists in the environment, and it can move readily into surface and ground waters. Farmers can prevent the contamination of surface and groundwater resources by using the following best management practices.

Storing and handling agricultural chemicals. Storage facilities should protect chemicals from extreme temperatures, sunlight, moisture, etc., to preserve their efficacy. Storage should be organized, with materials segregated to prevent cross-contamination and make access easy. Handling facilities must be able to contain all spills and rinsate. Farms should have written emergency response plans and the equipment required for responding to fires, spills, and exposure to hazardous conditions. Personnel must be trained to respond correctly to emergencies.

Protecting wellheads. Groundwater can be contaminated through wells if chemicals are not stored and handled correctly, if wells are not maintained, and if abandoned wells are not properly closed. Chemicals should not be stored in a well house or mixed, handled or applied near a well. Abandoned wells and those with cracked well casings should not be left open.

Applying pesticides. To reduce the risk of agricultural chemicals entering water resources, all personnel involved with pesticide application should read the product labels and understand the instructions, restrictions, application rates, and other critical information they contain.

Other best management practices are

- preventing back-siphoning,
- containing and cleaning spills,
- maintaining and calibrating application equipment properly,
- reducing run-off and erosion losses from fields, and
- minimizing deep percolation losses of irrigation water that can carry dissolved chemicals below the root zone.

Managing nutrients. Good nutrient management practices will maximize the benefits of fertilizers and other crop amendments while preventing water contamination. Before fertilizing, soil and/or plants should be tested to determine the need for nutrients. Fertigation (fertilizer application through irrigation water) can be used to optimize the rates and timeliness of fertilizer applications. Of course, using a check valve to prevent backflow is essential for keeping the water source safe from possible contamination.

For additional information, refer to these publications from Texas Cooperative Extension, available at *http://tcebookstore.org.*

B-1667, "Irrigation Water Quality Standards and Salinity Management"

B-6096, "Center Pivot Irrigation"

L-6023 – L-6032, "Tex-A-Syst Rural Well Water Assessment" series

Also see:

Natural Resources Conservation Service, United States Department of Agriculture. Soil Surveys. *http://soils.usda.gov/survey*

Corn Diseases

Corn diseases affect not only the quality and quantity of the crop, but also human and animal health. Some diseases produce metabolites that cause cancer or allergic reactions.

Diseases are difficult to deal with because they may go undetected until it is too late to prevent damage. It is important for farmers to understand how pathogenic organisms infect plants and cause diseases so that they can predict when diseases might develop and be ready to control them. Plant pathologists often talk about the disease triangle—the three things that must be present before a disease outbreak can occur. These three things are

- a susceptible host,
- a disease-causing pathogen, and
- an environment that is favorable to the pathogen.

A susceptible host is a plant that has little or no resistance to a disease and is likely to suffer significant damage. Some plants are very resistant to disease, but no plant is completely immune. Disease tolerance means that a plant may get a disease but that growth and yield are not affected as much as in susceptible varieties. Most of the time we rely on host plant resistance (which includes tolerance) to help reduce plant disease damage. However, corn varieties are not equally susceptible to all diseases. Plant breeders have incorporated some disease resistance into modern hybrids. Some hybrids have excellent to fair resistance to some diseases, and little if any resistance to other diseases. Given the differences among hybrids, growers should consult seed companies to find varieties with the traits they desire.

The second part of the disease triangle is the pathogen, which must be present before the susceptible crop is planted or arrive during the growing season while the plant is susceptible.

Disease does not always develop, even if a pathogen is present with a susceptible host. The environmental conditions must be right. These conditions include temperature, relative humidity, pH, organic matter, or some combination of these. Usually the appropriate environmental conditions must occur together; for example, both high temperature and high relative humidity may be required for a disease to begin. With just one of those conditions, disease will not occur.

The goal of any disease management program is to prevent the disease from occurring. If this is not possible, the grower tries to limit the damage. The problem is that by the time symptoms are observed, the disease-causing organism is already infecting the crop. At that point, protective methods must be shelved and more aggressive action taken.

Scouting for corn disease should be done weekly beginning at the whorl stage. As you scout for insects, observe any abnormal lesion or leaf discoloration. Check at least two rows (ten consecutive plants) at several locations throughout the field. Record the percentage of plants infected (incidence = percentage of plants infected within a population) and the damage observed (severity = the degree of damage done by a plant disease).

The five basic principles of plant disease control are avoidance, exclusion, eradication, protection and resistance. Avoidance involves altering factors such as the planting time to avoid conditions that are favorable to the disease. Exclusion means preventing a disease organism from being introduced into or becoming established in an area. Eradication is the elimination of a pathogen or the reduction of the pathogen population. Protection is the placement of a protective barrier, usually a chemical, on the plant to prevent infection. Resistance is the selection and planting of resistant hybrids.

A good disease management plan incorporates cultural and chemical control practices.

The goal of cultural control is to reduce pathogens mechanically or physically. Cultural control includes planting seed that is certified to be free of pathogens. This will ensure that plants are healthy initially and will form uniform stands. Seed can be infected with a pathogen internally, within the embryo, and/or externally, on the seed coat. Corn seedling diseases reduce plant population and yield and lower the health of plants, making them more susceptible to other diseases.

Another cultural method is crop rotation, which can sometimes eliminate soil-borne pathogens. However, rotating out of corn for 3 or 4 years is not always practical or economical. Plowing under or burning crop debris destroys disease pathogens and speeds up the rotting of debris. These methods do not eliminate pathogens completely, but they often reduce the amount of inoculum to acceptable levels.

Chemicals can be an effective means of controlling diseases. Fungicides kill or control fungi that cause diseases without harming the plant host. Fungicides are described as protectants, curatives or eradicants. Protectant fungicides are applied to healthy plants before a pathogen attacks to prevent infection. They prevent spore germination and fungal penetration. Curatives help control diseases after plants are infected and symptoms have appeared. Eradicants are applied to eliminate a pathogen.

Fungicides are classified according to their specific mode of action. Fungicides that inhibit the electron transport chain include sulfur, organotins, oxathiins and dinitrophenols. Those that are enzyme inhibitors include copper, mercury, dithiocarbamates, thiazoles, substituted aromatics, dicarboximides and quinines. The inhibitors of nucleic acid metabolism and protein synthesis include the benzimidozoles, antibiotics, aliphatic nitrogens, triazines and phenylamides. Inhibitors of sterol synthesis include imiazoles, triazoles, pyrimidines, piperazines and morpholines.

Fungicides with these modes of action are systemic products, meaning that they enter the corn plant itself. There are advantages and disadvantages of using systemics. Advantages are:

- The plant can be continuously protected throughout the growing season.
- The fungicide may be taken up by the roots and transported to newly formed tissues.
- The fungicide is not subject to weathering.
- There is minimal toxic effect to people because the toxicant is in the plant.

The main disadvantage of systemic fungicides is that because they are always present in the plants, disease pathogens can develop resistance to them. This is a particular problem with the more selective organic fungicides that have only a single mode of action.

Seedling Diseases

Seedling diseases affect germination and cause seed rot. Seeds may germinate but die prematurely, or they may germinate, emerge and then die. The coleoptile and meocotyl are affected early in the infection process, followed by poor root development. Symptoms of damage are brown discoloration and a wet, rotting appearance. Common fungal organisms that cause seedling diseases include *Pythium*, *Fusarium* and *Penicillum*. One or more of the pathogens may occur at the same time. Seed rots are most severe in wet, cool (50 to 55 degrees F) soils. The best way to prevent them is to plant good quality seed that has been treated with fungicide and plant when soil temperature is above 55 degrees F.

Rusts

Common rust – *Puccinia sorghi*

Southern rust – *Puccinia polysora*

Rusts, which are caused by fungi, are the most destructive corn diseases. Two major corn rusts occur in the U.S. Common rust appears after silking and causes chlorotic flecks on the plants. These flecks later develop into powdery pustules. The oval, bright red pustules are randomly scattered on both upper and lower surfaces of the leaves. They rupture the leaf epidermis so it appears as if the leaf has been torn. Spores of common rust are wind-borne. This disease develops best when the temperature ranges from 60 to 70 degrees F and the relative humidity is higher than 95 percent for about 6 hours.

Common rust can be managed by planting resistant hybrids (although very few corn hybrids have rust resistance) and applying foliar fungicides. Spores do not survive on crop residue from the previous crop. Foliar fungicides are recommended for seed corn, popcorn and sweet corn. In Texas there are no fungicidal recommendations for field corn. According to the literature, field corn has suffered less than 3 percent yield loss, even with heavy disease pressure. However, other states recommend application of fungicides when disease pressure is low (less than 1 percent per plant) in seed corn, popcorn and sweet corn.

Southern rust causes damage similar to that of common rust; however, the distinctive color of the pustules can be used to distinguish the two diseases. The spores of southern rust are small, circular to oval, and light brownish orange to brick red. They are found on the upper leaf surface only. Both common rust and southern rust cause tearing, but leaves affected by common rust begin to tear sooner. Spores are disseminated by wind or on infected plant material. Southern rust is favored by high humidity and warm temperatures (80 degrees F and higher). Management practices are similar to those for common rust.

Smuts

Head smut – *Sphacelotheca reiliana* (*Sporisorium holci-sorghi*)

Common smut – *Ustilago zeae* (*Ustilago maydis*)

Head smut can be a devastating disease, but the resistant hybrids developed recently have kept the incidence of head smut low. The fungus overwinters in the soil and on seed. Seedling corn plants are infected early, which allows the fungus to develop systemically within the host. Low temperature (70 to 80 degrees F) and wet soils create optimum conditions for infection.

Most corn producers become aware of a heavy infection when they observe galls on the tassels and/or developing ears. These galls are full of black spores that can be seen when they are released into the air during harvest. Ears infected early in the growing season develop in a “teardrop” shape. Not every tassel or every ear will be infected. However, by the time damage is noticed there will be some yield loss, as high as 70 percent in severe cases.

The most economical management strategy for head smut is the use of resistant hybrids. If they are not available, corn should be rotated with other crops. Rotation reduces the amount of inoculum over time, but if the disease pressure is heavy, it might be wise to keep corn out of the rotation for several years. Smut spores are resilient and can survive for several years in the soil. Treating seed with a protective fungicide is only partially effective. Systemic fungicides appear to give better protection. Removing and burning smutted tassels and ears can help reduce the level of inoculum for the following year.

Common smut occurs throughout Texas. The disease can be observed on all above-ground plant parts, including the stalks, ears, leaves and tassels. This particular smut disease is favored by extreme drought; heavy damage from hail, sand, insects or herbicide; or the application of excessive fertilizer. The disease develops most readily during drought conditions when temperatures average 78 to 93 degrees F. Infection can occur anywhere there is a wound or opening in actively growing or embryonic tissue. Infected plants develop galls on leaves and stalks. As galls enlarge, they are covered by a glistening, greenish to silvery-white membrane. Later, the inner tissue darkens as powdery black spores develop. These spores persist as inoculum in the soil and infect plants the following year.

Neither rotation nor tillage will completely eliminate common smut. The best management practice is avoidance, which means protecting plants from the stress caused by mechanical injury, insect damage, herbicide damage and drought. Hybrids with different levels of resistance are available. Ask your seed representative for the ratings of common smut tolerance or resistance.

Blights

Southern leaf blight – *Cochliobolus heterstrophus* (anamorph: *Bipolaris maydis*) syn. *Helminthosporium maydis*

Northern leaf blight – *Setosphaeria turcicia* (anamorph: *Excerohilum turcicum*) syn. *Helminthosporium turcicum*

Anthracnose leaf blight – *Colletotrichum graminicola* (teleomorph: *Glomerella graminicola*)

Foliar fungal blights kill foliage rapidly. **Southern leaf blight** can be particularly severe in fields with reduced tillage and corn-following-corn production systems. Spores and mycelium overwinter on crop residue and infect plants the following year when the crop canopy closes. There are two races of southern leaf blight—Race O and Race T. (A race is a subgroup within a species or variety that has some differences in virulence, symptoms and/or hosts.) Race O and Race T can be easily distinguished in the field by the symptoms they cause. Race O infects mainly leaves and causes short, rectangular lesions that are tan with reddish-brown outer margins. Race T infects the entire plant with short, rectangular lesions that are reddish brown with chlorotic halos.

Southern leaf blight develops most readily at temperatures of 59 to 79 degrees F. There must be moisture (from heavy dews or early-morning rainfall or irrigation) for spores to germinate and infect plants. Cultural control, such as plowing under crop residue and using resistant hybrids, is the most economical way of controlling either race.

Northern leaf blight first appears as lesions on lower leaves soon after temperatures reach 64 to 80 degrees F when conditions have been moist for some time. The leaves develop elliptical, grayish lesions that turn tan during the disease cycle. The spores overwinter in plant residue and are dispersed by wind. The disease is most severe in no-till systems. Rotating crops, destroying crop debris and planting resistant hybrids are recommended cultural control methods.

Anthracnose leaf blight causes small, oval to elongated, water-soaked lesions that, over time, become brown to tan with reddish-brown borders/halos. Spores overwinter in crop residue; during warm, wet weather they are disbursed by splashing rainfall or irrigation water or by wind. The continuous planting of corn with reduced or minimum tillage creates ideal conditions for the development of anthracnose leaf blight. Large amounts of corn residue, insect injury, and/or environmental stress favor both foliar diseases and anthracnose stalk rot. Anthracnose leaf blight can cause plant dieback and stalk rot. Symptoms of this stalk rot are a uniform, shiny black color observed on the lower internodes. These internodes rot and collapse easily in windy weather. Stalk lodging frequently results from anthracnose leaf blight infection. The best way to manage this disease is to plant resistant hybrids, reduce the damage caused by corn borers, and keep the crop properly irrigated.

Downy Mildews

Sorghum downy mildew – *Peronosclerospora sorghi* (syn. *Sclerospora sorghi*)

Crazy top downy mildew – *Sclerophthora macrospora* (syn. *Sclerospora macrospora*)

The downy mildews are unique fungal diseases in that the spores can survive in crop residue and soil for several years and can infect seedlings through the roots. **Sorghum downy mildew** occurs all over the world. Systemic infection can occur when the temperature is 70 to 80 degrees F and the humidity is high. Spores are disseminated by wind and germinate at temperatures of 63 to 84 degrees F. There are two types of symptoms observed with sorghum downy mildew, depending on which stage of the crop was initially infected. Systemic infection causes chlorotic, whitish steaks along the midrib. Both systemic and later infections produce spores that appear as downy (slightly fluffy) growths on individual leaves. Stunting and severe yellowing follow. To manage sorghum downy mildew, use resistant hybrids and plant fungicide-treated seed. Also destroy crop residue to reduce the amount of inoculum that overwinters. If damage from this disease is severe, rotate to a crop other than corn or sorghum.

Crazy top downy mildew survives in crop residue. Overwintering spores germinate and produce secondary spores. The disease is most likely to occur if the soil is saturated soon after planting and temperatures range from 75 to 82 degrees F for 24 to 48 hours. Crazy top is a soilborne pathogen, so it is far less common in fields without a history of the disease. Symptoms vary according to the growth stage at which the plant was initially infected. When seedlings are infected, leaves will be rolled and twisted and there will be excessive tillering. The most characteristic symptom occurs when older plants are infected—a proliferation of tassels that gives rise to the term “crazy top.” There are no resistant varieties, so cultural control practices such as proper field drainage are the most effective means of managing crazy top.

Stalk Rots

Gibberella stalk rot – *Gibberella zeae* (anamorph *Fusarium graminearum*)

Fusarium stalk rot – *Fusarium moniliforme*

Bacterial stalk rot – *Erwina* spp.

Diplodia stalk rot – *Diplodia maydis, Pseudomonas spp.*

Brown spot – *Physoderma maydis*

Charcoal rot – *Macrophomina phaseolina*

Stalk rots are caused by both fungi and bacteria. These diseases can affect nutrient uptake and, ultimately, stand and yield. Annual losses (primarily because of poor ear development) are estimated at 5 to 10 percent.

Stress to the corn crop early in the growing stage increases the possibility of individual plants developing stalk rot. Stress might be caused by hail damage, drought, herbicide or insect damage, fertilizer injury, or cultivation damage. The most distinguishable symptom of stalk rots is the disintegration of the pith tissue. The interior portion of the stalk is completely shredded so the stalk is easily pushed over, which leads to lodging at harvest. Other symptoms include premature death, discoloration at the nodes, and wilting of leaves. In general, most stalk rots can be managed by reducing physical damage (cultivation, insect and herbicide damage) to the plants early in the growing season and avoiding drought stress.

Gibberella stalk rot is caused by a fungus. The pathogen survives in crop residue and in the soil and infects plants most readily in warm, moist weather. Stress, insect damage, weather and dense plant populations contribute to the development of Gibberella stalk rot. Spores are dispersed by wind and infect plants at the soil line. Eventually, the fungus grows into the crown and stalk. A characteristic symptom is pink discoloration of the pith tissue in corn stalks. Leaves turn a dull gray and plants often lodge and die prematurely. Crop rotation, which reduces inoculum in the soil, is the way to manage this disease. However, producers should not rotate into cereal crops because this same organism can cause scab or Fusarium head blight in wheat. It also helps to plow under crop residue.

Fusarium stalk rot is very similar to Gibberella stalk rot in that both cause discoloration and disintegration of stalks. This fungal organism survives in the seed as well as on crop residue. Plants stressed by heat, excessive nitrogen and dense plant populations are predisposed to infection. Spores are spread by wind or splashing water (from rain or overhead irrigation), and the infection begins easily where there is plant damage from insects, hail or sand. Symptoms are very similar to those of Gibberella stalk rot, and it is very difficult to distinguish between the two. Symptoms usually occur after pollination. Lower internodes of the stalk turn brown prematurely. The pith rots and takes on a pinkish to salmon color. To manage this disease, reduce crop stress and use resistant hybrids. Thin corn stands so that plants are not under moisture stress during hot weather.

Erwina **bacteria** live on crop residue in the soil or on seed. Bacteria are disseminated by wind or splashing water. Bacteria spread by water are most apt to infect plants when the temperature is 88 to 95 degrees F; infection can be made worse by heavy insect damage. Symptoms of this bacterial stalk rot are water-soaked lesions at or near the lowest internodes of each stalk and a foul, banana-like odor. The management of stalk rot caused by *Erwina* spp. is difficult; however, plowing under crop residue will reduce the amount of inoculum. During the growing season, avoid the excessive use of overhead irrigation to limit the spread of the bacteria and the incidence and severity of the disease.

Diplodia stalk rot is caused by a fungus. The pathogen spores survive in crop residue or on corn seed. Spores are disbursed within the corn canopy during warm (82 to 86 degrees F), wet conditions 14 to 21 days before silking. If infection occurs during the first 14 days of the 21-day period, both ear rot and stalk rot can be expected. After silking, leaves become grayish green. Black dots (fungal fruiting structures) the size of the tip of a pen will develop on the lowest internode of the stalk near the brace roots. The pith will begin to disintegrate and turn light gray. Plants may weaken, lodge and die suddenly. The most economical means of controlling Diplodia stalk rot is to use resistant hybrids. Cultural control with rotation and tillage can reduce inoculum levels.

Charcoal rot is caused by a fungus that overwinters in crop residue. Infection occurs most readily after pollination when the temperature is at least 85 degrees F and plants are stressed by drought. The infection begins at the root tips and moves into the lower internodes of the stalk. Early symptoms of damage are premature ripening followed by the disintegration of stalk pith. Stalk breakage at the crown will be observed near the end of the growing season. On close inspection, small black dots (fungal fruiting structures) can be observed along the stalk rind. Expect severe damage during extended hot, dry growing conditions. The best management strategy for charcoal rot is to use resistant hybrids and reduce crop stress with proper irrigation. Because this organism infects sorghum and soybeans, rotation to these other crops is not recommended.

Viral Diseases

Maize dwarf mosaic virus

Maize chlorotic dwarf virus

High Plains virus

Plant viruses are usually transmitted by insects, but viruses also can be carried from plant to plant by mechanical injury, humans and animals. Aphids and leafhoppers are the most common insect viral vectors in all crops. In corn, mites also can be vectors. Most viruses can remain year-round on plants known as "alternate hosts"; these plants bridge the gaps between the corn crops each year.

Losses from **maize dwarf mosaic virus** vary from year to year but may be more than 30 to 40 percent under favorable conditions. At least 15 aphid species can transmit this disease, including the greenbug, the English grain aphid and the corn leaf aphid. Plant symptoms include dark green "islands" on a light green to yellow background and mottling on leaf tissue. Mottling can be observed easily when a leaf is held up to the sun. The shortening of the upper internodes may cause some plants to be stunted. This virus is managed by planting resistant hybrids. Johnsongrass is an alternate host and should be controlled near corn fields.

Maize chlorotic dwarf virus was once known as corn stunt because the disease shortens internodes and causes extremely stunted plants. The disease also causes chlorotic striping along leaf veins, but there are no mosaic patterns. Leaves become reddish over time. Leafhoppers are the primary vectors of this disease. Alternate hosts include johnsongrass, crabgrass, foxtail and sudan grass. Planting resistant hybrids is the most effective and economical way to reduce maize chlorotic dwarf infection.

High Plains virus is a relatively new virus. It was first seen in sweet corn, where plants were killed by early-season infection. In field corn, stunting and poor corn development are commonly observed. The wheat curl mite vectors High Plains virus. This mite travels long distances with the wind but dies within 24 hours without adequate food. These mites feed on a number of alternate hosts, many of which can serve as reservoirs for the virus. The symptoms of High Plains virus depend on the host crop and the age at which infection begins. Chlorotic spots and mosaic patterns occur randomly on the leaf surface. A purple discoloration develops first on the tips of the lower leaves and then spreads along the leaf margins. This is followed by tissue death. Symptoms progress up the plant rapidly, and plants become stunted and die. Host resistance and cultural controls are effective at preventing High Plains virus. Miticides are not effective. Good grass control around fields before the corn crop emerges will reduce the chances that wheat curl mites will survive until the corn is up.

Plant Parasitic Nematodes

Root-lesion nematode – *Pratylenchus* spp.

Root-knot nematode – *Meloidogyne* spp.

Stubby-root nematode -- *Trichodorus* spp.

Sting nematode – *Belonolaimus* spp.

Several nematode species attack corn. With knowledge of the different species and the ways they infect plants, proper identification can be made and correct control strategies selected. Most nematodes are found in sandier soils, though there are exceptions. The symptoms of root damage caused by nematodes can be confused with nutrient deficiencies or herbicide damage. Usually, symptoms of nematode damage are observed in random parts of a field and not over the entire field.

Nematodes are classified according to their method of feeding. There are ectoparasites, which feed on the outer root surface, and endoparasites, which feed within the root tissue. Controlling endoparasitic nematodes is difficult and very costly.

Nematodes have a unique means of reproduction. They go through four juvenile, metamorphic stages from egg to adult. It is the juvenile stage 2 (J2) that causes root damage. The best ways to control nematodes that attack corn are to apply nematicides, rotate crops and destroy crop residue.

The lesion nematodes, such as the **root-lesion nematode,** are endoparasites that feed on the root cortex. They can be found in both sandy and heavy-textured soils. On corn they reproduce most readily at 75 degrees F, and they can complete a life cycle in 3 to 4 weeks. The lesion nematodes are associated with the fungus *Fusarium moniliforme*. Their feeding wounds the root cortex, which allows the fungus to infect the plant. Stunted roots and chlorotic leaves usually occur at the seedling stage. The nematodes may cause the pruning of fibrous roots and the shedding of cortical tissue. *Fusarium* infections cause brown lesions and root decay.

Root knot nematodes are very common in Texas. They prefer sandy soils but can be found in most soils. Many species affect several crops, including corn, cotton, soybeans and many vegetables. Crop rotation is not a very effective control for root-knot nematodes. The most obvious symptoms above ground are stunting and chlorosis. Characteristic root galls form as their feeding damages roots, so roots should be inspected to confirm infection. Yields in heavily infected fields may be reduced by 30 percent.

The **stubby-root nematode** is found in sandy soils and feeds on the growing root tips. This ectoparasitic nematode causes poor root development that results in severe stunting and chlorosis of above-ground plant parts. The roots appear stubby, shortened and thicker, which may resemble herbicide damage.

The **sting nematodes** are ectoparasites and do not enter the root. Their feeding causes blackened, sunken, dead lesions along root tips. Heavy feeding damage may girdle the roots and stunt the plants. This group of nematodes prefers sandy soils.

Ear and Kernel Rots

Aspergillus ear and kernel rot – *Aspergillus flavus*, *Aspergillus parasiticus*

Fusarium ear and kernel rot – *Fusarium moniliforme*

Diplodia ear rot – *Diplodia maydis* (*D. zeae*, *D. zeae-maydis* and *Stenocarpella maydis*)

Gibberella ear rot – *Gibberella zeae* (anamorph *Fusarium graminearum*)

Ear and kernel rots are caused by the same fungi that cause stalk rots. These diseases affect yield and, more importantly, grain quality. The fungi *Aspergillus flavus*, *Aspergillus parasiticus* and *Fusarium moniliforme* produce byproducts that are toxic to humans and animals.

The most important fungal ear rot pathogens are *Aspergillus flavus* and *Aspergillus parasiticus* because of the health issues associated with their by-products. These organisms spread by sclerotia (spores) that survive in crop residue and on stored grain and are disbursed by wind and insects. Waste corn around storage bins also can be a source of spores. Conditions that favor Aspergillus infection are drought, high temperatures (90 to 100 degrees F) with high humidity (greater than 85 percent), and grain moisture at 18 percent. The fungi grow poorly at temperatures below 55 degrees F and at moisture levels lower than 12 to 13 percent. Corn plants usually are infected after silking when the moisture level in kernels is high. The spores germinate and grow down the silk channel around the developing ear. Yellow-brown silks that are still moist are most susceptible to infection. Heavy insect damage can increase the incidence and severity of the disease. The fungus easily colonizes kernels injured by insects or birds. Insects can carry spores of *A. flavus* to senescing silks and into wounded kernels. Insect damage, especially during pollination in drought-stressed corn, increases the occurrence of Aspergillus ear and kernel rot and the levels of its byproduct, aflatoxin.

A symptom of Aspergillus infection is patches of greenish-yellow spores on ears; these often follow the path of insect feeding. Even if kernels are uninfected at harvest, spores on kernel surfaces can, with the right temperature and moisture conditions, germinate and infect injured or broken kernels within a day or two of harvest.

The byproduct of Asperigllus infections is aflatoxin. When fed to livestock, this substance causes reduced weight gain and liver damage. It causes cancer in humans. At slaughter facilities, animal carcasses with necrotic or abscessed livers are condemned and disposed of as not edible or saleable.

Grain elevators are responsible for detecting corn contaminated with aflatoxin before it is processed for feed or for human consumption. The Food and Drug Administration (FDA) establishes guidelines for acceptable levels of aflatoxin, and these levels vary depending on the end use of the grain. The maximum level of aflatoxin if corn will be fed to dairy cattle is 0.5 parts per billion. (Aflatoxin can be secreted into milk after animals consume contaminated grain.) For human consumption, grain can have no more than 20 parts per billion of aflatoxin. Feed for confined beef cattle can have no more than 300 parts per billion, although most feedyards do not accept grain with more than 150 parts per billion. Corn that contains unacceptable levels of aflatoxin must be discarded or used for another purpose. The best sampling method is to take a composite sample of at least 10 pounds from a moving grain stream, or to take multiple probes in a grain cart or truck, for a composite 10-pound sample. Samples can be sent to the Office of the Texas State Chemist for analysis.

There are no *A. flavus*-resistant hybrids commercially available, although the Texas A&M corn breeding program at Lubbock has developed new hybrids that are drought tolerant, insect resistant, and produce less aflatoxin. These hybrids are in the final stages of experimentation. Cultural control practices that help reduce Aspergillus infection include proper irrigation and fertilization to reduce drought stress and prevent excessive growth cracks that allow the fungus to infect kernels. Good insect management practices will reduce the production of aflatoxin. Growers who suspect an aflatoxin problem during the growing season should harvest early and dry corn to 15 percent, the moisture level at which aflatoxin production is stopped. This does not get rid of any aflatoxin that may already have been produced, but it will stop the production of any additional aflatoxin.

Fusarium ear and kernel rot occurs across the corn belt. There are several fungi in the genus *Fusarium*; however, *F. moniliforme* is the most prevalent. It produces a metabolite byproduct known as fumonosin. The fungus overwinters primarily on crop residue, especially on corn kernels left in the field after harvest. Dry weather early in the season, followed by insect infestation and wet weather during silking, increase the amount of fungal infection on corn kernels. During silking, spores are released and become airborne, infecting silks as they develop. In some instances, insects and their damage assist in the infection process. After infection, kernels begin to show a symptom referred to as "starburst," or a white streaking of the kernel. Later fungal development occurs in much the same manner as with Fusarium stalk rots. There are usually patches of pink to salmon-colored cottony mold scattered throughout the ear. Infection by *F. moniliforme* will not greatly affect corn yield.

No corn hybrids are totally resistant to the Fusarium fungus, although some may be more resistant than others. Avoid the most susceptible corn hybrids, harvest early, and dry the corn rapidly to less than 15 percent moisture.

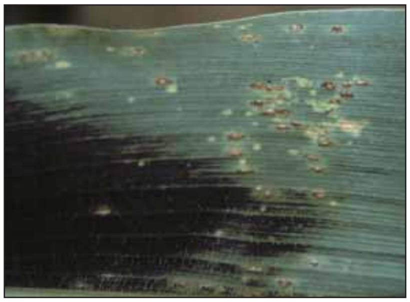
In humans, fumonosin, which is produced by the *F. moniliforme* fungus, may damage the liver over time. It may also play a role in esophageal cancer. When fed to horses, fumonosin causes leukoencephalomalacia ("blindstaggers"), and in swine it causes pulmonary edemia.

In 2002, the Office of the Texas State Chemist and the Texas Feed and Fertilizer Control Service analyzed 53 samples of new crop corn for fumonisin and found that 49 percent of the corn contained more than the recommended levels of fumonosin for the safe feeding of horses and rabbits. The maximum levels considered by the FDA Center of Veterinary Medicine to be safe are 5 parts per million for horses and dairy cattlew and 60 parts per million for beef cattle sheep and other ruminants older than 3 months being fed for slaughter.

Diplodia ear rot causes white fungal growth on corn kernels. The organism can overwinter on infested corn stubble or debris. Heavy insect damage when the weather is warm and moist increases infection. Infection starts at the base of the ear or from the stalk into the shank. Husks appear bleached or straw colored. The raised black bumps (fruiting structures) that appear on the husk late in the season can help in making a diagnosis. Diplodia ear rot does not normally affect grain quality, but it can be a problem in storage when grain moisture is not properly maintained at 20 percent or less. If corn is harvested early, it must be dried to 15 percent moisture to reduce further infection. To manage this disease, choose less susceptible hybrids and rotate out of corn for at least 2 years. Plowing under residue will reduce the inoculum.

Gibberella zea overwinters in infected crop residue and is dispersed by airborne spores. Cool, wet conditions soon after silking favor this pathogen. Infection can increase when heavy rainfall dampens silks. Gibberella ear rot can be easily distinguished from most other ear rots by the red to pink fungal mold at the tip of the ear. However, it is very difficult to distinguish Gibberella from Fusarium because both produce pink to reddish mold. Laboratory diagnosis is the only way to distinguish between the two. *Gibberella zea* produces mycotoxins that can be harmful to humans. Some corn hybrids are less susceptible than others, but there are no resistant hybrids. Research indicates that in the hybrids with tight husks, fewer spores enter the ears, which in turn can reduce infection.

Common rust




Southern rust

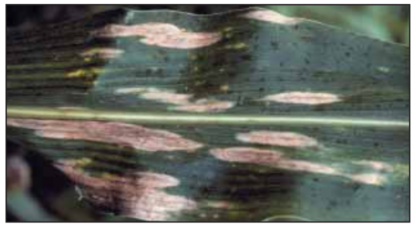


Head smut


Common smut

Southern leaf blight


Northern leaf blight



Anthracnose leaf blight

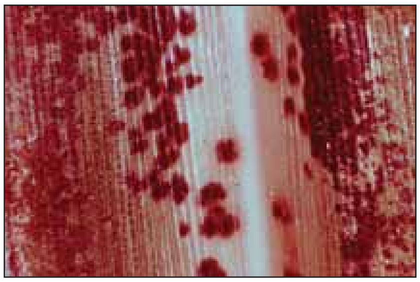
Sorghum downy mildew

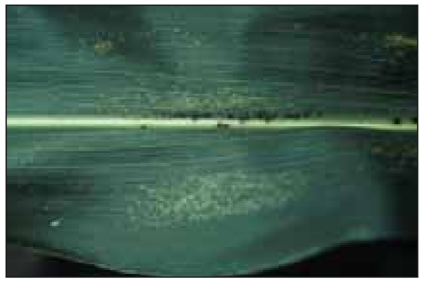
Crazy top downy mildew

Gibberella stalk rot

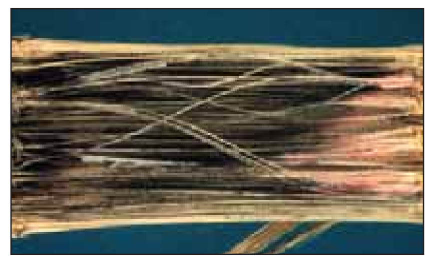
Bacterial stalk rot

Brown spot





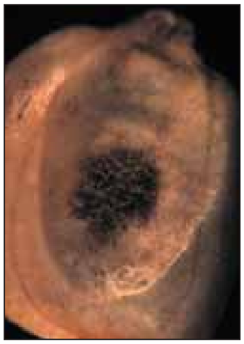
Charcoal rot

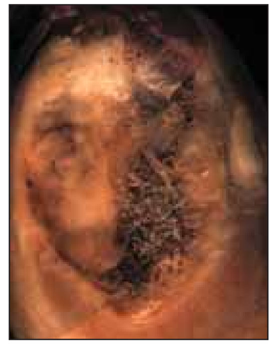


Maize dwarf mosaic virus

Maize chlorotic dwarf virus

Aspergillus





Fusarium ear rot

Diplodia ear rot

Gibberella ear rot

Corn Insects

Integrated Pest Management

Integrated Pest Management (IPM) is a strategy that blends science, art and experience. Its goal is to prevent pest populations from building to a point where they cause unacceptable economic losses, so that the producer's yield goals can be achieved in the most economically and environmentally sound manner possible. There are many tools for achieving this goal, and pesticides have a role. However, pesticides should be used only when pest populations reach the economic threshold level and other options have failed.

A pest management strategy that includes more than one tactic is generally more stable and cost-effective than one that relies on a single tactic.

There are four components to an IPM plan—prediction, prevention, detection (scouting) and remedial action. Carrying out the first three properly often eliminates the need for remedial action.

Prediction involves anticipating problems before they occur. Experienced producers often can predict pest problems based on weather, the cropping system used (such as no-till or conventional tillage), and past pest problems. There are also computer models for predicting pest outbreaks. Irrigation requirements can be predicted to some extent by using ET (evapotranspiration) data for the current year and past years.

Prevention is often the least expensive and most effective way to save money on pest management. Producers who rotate crops, alter planting dates to avoid peak pest outbreaks, practice proper sanitation to destroy insects and sources of disease innoculum, plant resistant varieties and/or transgenic varieties, preserve beneficial insects, fertilize properly, and prevent undue water stress at critical corn growth stages usually have the lowest pest management costs.

Detection of pests involves scouting fields regularly—at least once a week. Scouts should check for pest insects, beneficial insects, diseases, weeds, plant nutrition problems, and water stress. Scouting after a pesticide application (insecticide, miticide, fungicide, herbicide) is important to determine whether the pesticide is providing good control.

A number of Extension agents and specialists publish weekly pest management newsletters to help producers keep current on what is happening in area crops. Many of these newsletters have insect trap capture and actual field scouting information that can serve as an early warning of pending problems. These newsletters can be found on the county Extension Web site (*http://county-tx.tamu.edu/*). Contact your county Extension office to subscribe. Private industry also provides newsletters and pest updates.

Remedial action (often thought of as "control") is an intervention to lower the number of pests in a field. All remedial actions cost something to implement, so it follows that they should not be used until the cost of the pest damage equals or exceeds the cost of the intervention. This concept is at the core of "threshold" theory. The "economic injury level" is the point at which the dollar value of the pest damage equals the cost of control. Because it may take several days to implement a control measure and see its effect, it may not be a good idea to wait until the economic injury level is reached before taking remedial action. Rather, control decisions should be made before the economic injury level is reached. The "economic threshold" is the pest density that justifies control, factoring in the amount of damage pests will continue to do in the time it takes to implement that control. In terms of pest numbers, the economic threshold is a little lower than the economic injury level. The economic threshold signals the need for pest control at precisely the right moment to prevent the economic injury level from being exceeded.

Economic Thresholds

Economic thresholds are guidelines based on research. They are not perfect, but they are usually fairly accurate. A perfect economic threshold would change as the price of control measures changed and/or the per bushel value of corn changed. In reality, many published thresholds do not change as corn prices and control costs fluctuate. These types of thresholds are called "static" because they do not change to reflect actual values and costs. Are they bad thresholds? No, they are just not as good as they could be. Growers and consultants often adjust static thresholds to reflect current market prices for corn. There is nothing wrong with this. Most static thresholds assume that corn is valued at $2.50 per bushel or more. If corn is worth less, the economic threshold is higher. In a simplified example, if an insecticide application to control a grain-feeding insect costs $10.00 per acre, the economic injury level would be $10.00, or a yield loss of 4 bushels of $2.50 corn per acre. If corn were valued at $2.00 per bushel, the economic injury level would still be $10.00, but this would be 5 bushels lost. It takes more insects to eat 5 bushels of grain than to eat 4 bushels of grain, so the economic threshold is adjusted upward as the price of the corn decreases.

While thresholds are simple to determine if a pest feeds directly on the grain, they are harder to determine if a pest damages other plant parts and the damage has an indirect effect on yield.

"Dynamic economic thresholds" are more accurate than static thresholds in estimating economic injury levels because they change to account for different values of the crop, cost of control, and sometimes the growth stage of the crop or life stage of the pest. The Texas spider mite threshold is one example; the economic threshold changes with the value of corn and the cost of control. Dynamic thresholds take a little more effort to apply, but usually give better economic results than do static thresholds.

In the end, economic thresholds are guidelines. They are reasonably good indicators of when control measures should be implemented. There are few hard and fast rules in Integrated Pest Management, and that is why we acknowledge that it is a blend of science, art and experience. This manual can be a valuable resource, but please use the companion Web site at *http://lubbock.tamu.edu/cornIPM* for the most current updates. Also remember that county Extension agents, agricultural consultants, agribusinesses, and other Web sites can provide excellent information.

Scouting

To make sound pest management decisions you must have accurate and timely information about what is happening in the crop. Corn should be scouted at least weekly, and more often when pest numbers are building. It should also be scouted as soon as possible (based on reentry interval) after an insecticide application, because it can't be assumed that the application was effective. There are no hard and fast scouting rules that must be followed, but there are guidelines based on experience. Crop consultants become very familiar with the fields in their areas and have a solid idea of what is happening in those fields. Their constant familiarity with the emerging pest profile lets them concentrate on developing problems rather than spending time on pests they know are not important at the current time.

For people not so devoted to keeping tabs on the pest profile, the task may be a bit more difficult. An Extension newsletter about pest management in your county will help you fill in the picture every week. Extension pest management agents can train you to scout your fields, identify insects, and make control decisions. They are there to help producers, so don't hesitate to call them.

It does take time to accurately estimate the pest situation in a field, and time is a resource that must be managed wisely. The amount of time devoted to scouting depends in part upon the type of information you are trying to collect and what you intend to do with that information. Scouting to determine pest numbers in relation to economic thresholds is rather straightforward. That is why this manual was written—as a practical aid to making pest control decisions based on current and projected pest populations. However, if you are attempting to determine the dispersion of a pest within a field, track changes over time, or determine the ratio of beneficial insects to pests, be prepared to spend more time in the scouting process. Sampling techniques for such needs can be quite involved and are not addressed in this manual.

The job of a scout is to determine the "average" infestation in the field and provide information on the amount of variability associated with that average. This is where scouting and statistical theory collide. Statistically valid sampling procedures that allow very accurate estimates of the average infestation level of a pest generally require that many locations and plants be checked. Scouts often cannot devote enough time per field to satisfy the strict requirements of statistically valid sampling. In the end, a scout falls short of perfect counting, but must still generate an acceptably accurate picture of what is happening in the field. **The scout must always protect against unjustified economic loss, and if a field is approaching an economic threshold, he or she must devote the time required to estimate pest numbers fairly accurately. Scouting takes more time when a field infestation is nearing the economic threshold level.** More time is also required when counts vary widely in different parts of the field. However, if the field is well below or well above the economic threshold, the scout can make a "no treatment needed" or "remedial action needed" decision rather quickly.

Variations in pest counts may result from plant differences caused by soil type or fertility, drainage, organic matter, weediness, plant variety, or other factors. Many insects lay eggs only in areas that meet certain criteria, avoiding areas that don't match those criteria. For example, many cutworm species lay eggs on weeds before corn is planted. A weedy area of the field is more likely to have a cutworm infestation than a weed-free part of the field. Another example is the European corn borer's preference for laying first-generation eggs in taller corn. A good scout will choose some locations with taller corn and some with shorter corn when determining the average infestation.

Other differences in pest counts between locations may be a function of the pests themselves. Some pests tend to remain "clumped" in areas of the field rather than being evenly distributed. This is particularly true at low levels of infestation. A scout may walk into a "hot spot" in one place, but would have recorded very low pest numbers just a few yards away. Other pests may vary according to a "gradient," or become more or less numerous as one moves through the field. For example, spider mite infestations often begin on the side of the field from which the prevailing wind blows and then spread downwind through the field. A good scout will spend more time in the areas where problems are likely to occur first and then track the pests as they move into the interior of the field. Nonrandom pest distribution makes scouting more difficult and generally requires that more locations be checked per field.

The "edge" is the outside 75 feet on each side of a field. Pest counts in the edge are often higher and more variable than in the rest of the field. Therefore, sampling in an edge is discouraged except where insects are moving in from an edge and a spot treatment may be needed. A small field has lots of "edge" or border in relation to the total number of acres in the field. A square 40-acre field is 1,320 feet long on each side. A 75-foot edge around all four sides equals 8.6 acres, or 21 percent of the area in the field! In contrast, a square 120-acre field is 2,286 feet long on each side. A 75-foot edge around all four sides equals 11.6 acres, or only 9.7 percent of the entire field. Thus, the smaller the field, the larger the percentage that is occupied by the "edge." It would seem, then, that smaller fields would have more variability in insect counts than large fields. But large fields often have lots of variability in pest numbers also.

Some corn scouting guides recommend that every 40-acre block of corn be scouted in five locations, which implies that a 120-acre field should be scouted at 15 locations and a 320-acre field at 40 locations. In reality, the number of locations to scout depends on how much variation there is in the field, whether the field is large or small, whether the pests are evenly distributed in the field, and what is growing outside that field to influence pests moving into the field.

A scout who walks a square grid pattern in a 40-acre field and takes samples at four locations separated by 400 yards on each side covers about 83 percent of the field. The same scouting route would cover only 28 percent of a 120-acre field and 10 percent of a 320-acre field. The field estimate "average" reported by a scout becomes less and less reliable as less of the field is examined. It is imperative that the "average" be accurate. Larger fields usually must be sampled at more locations than smaller fields, although there is a minimum number of samples needed no matter how small the field.

Scouting is meant to determine the average pest density in a field. Because there is less edge effect in larger fields, scouts often take fewer samples per unit of area (but the total number of locations sampled is higher). A 40-acre field should be scouted at a minimum of five locations. Five locations might be enough for a 120-acre field if the pests are evenly distributed, but there is a significant risk of missing something important. It is best to scout in more than five locations in larger fields. Scouting too few locations will increase the risk of error. Scouting too many locations will not appreciably improve the accuracy or precision of the pest count, and it will take more time.

Do not ignore low spots, weedy areas, or any other unusual part of the field. By the same token, be certain that the pest counts from these areas are not disproportionately represented in the "average" count for the field.

The sampling locations should be widely separated. Taken as a whole, they should represent the field. Don't sample the same locations of a field week after week unless you have a good reason to do so, such as determining if pest numbers have changed in a specific location. Mix sampling locations up and move around. It could be that by returning to the same general place each week you are missing something important in the areas that are ignored.

Never sample fewer than ten plants per location. These plants can be consecutive in one row, but the first plant should be chosen at random. There is a natural tendency to choose as the first plant one that is strange. We notice the exception to the normal and give it special attention. A good field scout will make sure the first plant is chosen at random by either taking a certain number of predetermined steps and choosing the plant that is closest to his or her foot, or throwing an object a few feet ahead and choosing the plant nearest to the object.

Look for anything that is unusual. Take samples of diseases and insects if you are not certain what they are. Note soil compaction, plant water status, nutrient deficiencies, weed species, plant growth stage, and the general number of beneficial insects and spiders.

Don't cut corners. A scout is the eyes of the grower and is responsible for accurately assessing the situation each week. A scout is never criticized for providing too much information to a grower. Be sure of what you say. Spend the time it takes to do a thorough job; your diligence will be appreciated.

Finally, all individuals make mistakes. If you discover that you missed something important, go to the grower or your supervisor immediately and explain the situation. There may still be time to correct the problem. Identify why you made the mistake and then correct your practices so as to avoid the same error in the future. Scouting is hard work, but when done properly it can be very rewarding. When done poorly, it can be very costly.

Submitting Samples for Identification

County Extension agents and Extension entomologists can identify insect samples. This service is generally provided for free. No appointment is necessary, but it is best to call ahead to make sure your county agent will be in the office.

Samples also can be submitted through the mail if prepared properly. With the exception of moths, the best way to prepare insect samples for identification is to put them in 70% alcohol—the type sold at grocery and drug stores. Alcohol will kill the insects and preserve them for a time. To prepare larvae for shipping, first place them in boiling water for 1 minute and then transfer them to alcohol. The heat will stop the enzymes in the body and prevent the specimens from turning black in a day or so. Bring the water to a boil, remove it from the heat source, and then add the larvae. Do not add the larvae while the water is being heated.

Be sure the container of alcohol does not leak. Mason jars, baby food jars, and other containers with gaskets work best. Do not use pill bottles and other containers without gaskets. Always include a note with information about the affected crop, the growth stage of the crop, the damage being done, how severe and widespread the damage seems to be, and your address and telephone number. Write your note in pencil. Most pen ink will dissolve in alcohol, and poorly sealed jars of alcohol will obliterate your note.

Insect specimens can be shipped dry in plastic Ziploc®-type bags, along with a sample of a damaged plant. It is best to put some paper toweling in the bag to absorb moisture. However, if the mail is delayed or is not opened for some time, the samples will usually be rotten and beyond recognition. Do not mail dry samples in envelopes. The canceling machinery at the post office will squash the insect. Always mail samples in a box. When submitting a dry specimen (one not preserved in alcohol), mail it for delivery on Tuesday through Friday. Avoid Monday delivery because the sample will sit in the post office over the weekend.

Digital images are replacing actual insect specimens for identification purposes. The advantage of a digital image is that it can be "delivered" instantly. Get the best image possible, and get as close to the specimen as you can. Digital images work well for common and abundant pests, but they are very poor substitutes for a real specimen when the insect is uncommon or unusual. When submitting a digital image via e-mail, always include all relevant information and be sure to send a telephone number. If the specialist is unable to identify the pest from its image, he or she will either call you back or notify you by e-mail.

Practical Entomology

Entomology can be baffling for most people, in part because entomologists use Latin words and complicated terms to describe insect species, body parts and insect development. This section explains a few important principles of entomology in words that make sense.

Insect Development

With the exception of aphids that bear live young, all insect pests found in corn start from eggs laid by the females in the soil or on the plant. After hatching, immature insects go through several growth stages, shedding their skin at the end of each stage. They need to do this because the "skin" we see is actually a skeleton on the outside of the insect's body. The immature insect can't continue to grow while encased in a skeleton that is too small. Each immature stage is called an "instar" and is given a number. The first stage is called a "first instar," the next, larger stage is called a "second instar," and so forth until the last immature stage is reached. The number of immature stages varies with the species and sometimes with the environment and the quality of food available.

This process of change through the life stages is called **metamorphosis.** There are two types of metamorphosis in insects. In **simple** metamorphosis, the immature stages closely resemble the adults except that they are smaller and their wings and reproductive organs are not fully developed. In the U.S. we often use the term nymph to describe these immature insects, but European entomologists call them larvae. Grasshoppers, crickets, aphids and the true bugs are examples of insects with simple metamorphosis.

The second and more complicated type of metamorphosis is **complete.** In these species the adult looks completely different from the immature stages. Examples of insect species that undergo complete metamorphosis are moths, butterflies, beetles, flies, bees and wasps. The immature stages of insects with complete metamorphosis are called larvae. This type of metamorphosis has some advantages. For example, when larvae and adults have different mouthparts and can feed on different types of food, they don't have to compete with each other. A disadvantage of complete metamorphosis is that the insect must have a forced resting stage while it undergoes the radical changes from the larval to the adult form. This resting stage is called the pupal stage. Most insects go through the pupal stage in a secluded location such as in soil or inside a plant, which helps protect them from predators while they are immobile and helpless. The pupal stage also explains in part why insects with complete metamorphosis seem to disappear for a week or more before they emerge as adults.

Identifying Insects by Plant Damage

The type of damage you observe on a corn plant helps you identify the insect culprit because the damage indicates the type of mouthpart the pest has.

There are two types of mouthparts in insects– **teeth** or **piercing and sucking straws.** Insects with teeth (mandibles) eat by chewing holes in tissue. Insects with piercing and sucking mouthparts never chew their food, but they suck out the contents of plant cells and often inject saliva that can kill tissue. Some piercing and sucking mouthparts are elongated, tube-like structures similar to sharp soda straws. Other insects do not have such straws, but rasp or stick cell surfaces and drink the contents.

Table 6 shows the main groups of corn insect pests, the types of mouthparts they have, and the damage they cause. When you find insect damage in a field, use this table to help you identify the pest that is causing it. For example, if whorl stage corn has leaves that are ragged with tissue missing, you can assume the damage was not done by insects with piercing/sucking mouthparts (aphids, true bugs, flies or spider mites). These pests suck juices but don't have the teeth to eat tissue. You would then concentrate on caterpillars or the adults or immatures of beetles or grasshoppers. If you found oval areas of dead but intact leaf tissue, you could eliminate the insects that have chewing mouthparts, such as caterpillars, most beetles (except very small ones that can't eat through the whole leaf) and grasshoppers.

Table 6. Insect pests, type of metamorphosis, and the appearance of plant damage.

Pest group	Metamorphosis	Insect order	Stage	Mouthpart type	Damage
Caterpillars	Complete	Lepidoptera	Larva	Chewing	Tissue removed
			Adult	Siphon–sucking	None
Beetles	Complete	Coleoptera	Larva	Chewing	Tissue removed
			Adult	Chewing	Tissue removed
Grasshoppers	Simple	Orthoptera	Nymph	Chewing	Tissue removed
			Adult	Chewing	Tissue removed
Aphids	Simple	Homoptera	Nymph	Piercing–sucking	Cells disrupted, tissue intact
			Adult	Piercing–sucking	Cells disrupted, tissue intact
True Bugs	Simple	Hemiptera	Nymph	Piercing–sucking	Cells disrupted, tissue intact
			Adult	Piercing-sucking	Cells disrupted, tissue intact
Flies	Complete	Diptera	Larva	Sucking	Tissue damaged, some removed
			Adult	Sponging or piercing	None
Spider mites	Simple	Acarina (not insects)	Nymph	Sticking	Cells disrupted, tissue intact
			Adult	Sticking	Cells disrupted, tissue intact

Overwintering and Cultural Control Practices

Insects are coldblooded, which means that the temperature of their bodies tends to be near the temperature in the environment. Below a certain temperature, an insect does not move about and slows down its metabolic processes to stay alive. Some insects freeze and die at temperatures below freezing; others can withstand very low temperatures by moving to a protected location, creating an anti-freeze-like substance in their blood, or freezing with little cell damage. The difference in their ability to withstand cold temperatures explains why some insects are able to overwinter in parts of Texas and others are not. Northern pests such as the European corn borer are not challenged even by the most severe winter in Dalhart, but southern pests such as the fall armyworm cannot overwinter there. Depending upon the species, an insect may overwinter as an egg, immature or adult. Pests that can overwinter successfully begin moving into the corn crop in the spring. Pests that cannot overwinter usually arrive later through migration. Cultural control practices such as stalk destruction, deep tillage, crop rotation, and delayed planting are usually directed at pests that can overwinter. Almost all corn pests can overwinter in Texas.

Temperature and the Rate of Insect Development

The time it takes for an insect to complete a generation depends on temperature. Insects develop more rapidly as the temperature increases. This is why a pest that takes 4 weeks to complete development in May might take only 3 weeks to complete development in July. As strange as it may seem, it is unusual for insects to die from high temperatures. They do suffer heat stress, but they can get water from the plants on which they are feeding and are cooled by the plants themselves. High temperature sometimes kills insect eggs, but usually it is because the eggs are also dehydrated.

Insect Development and Insecticide Efficacy

Most insects are easier to kill when they are small, and there are two reasons why this is so. First, a toxin is lethal only at a certain weight of active ingredient per unit weight of insect. This relationship is often expressed as milligrams of insecticide per kilogram of body weight. A fifth-instar larva that is 50 times heavier than a first-instar larva will require 50 times more insecticide to kill it. Another advantage of older larvae is that they often have detoxification systems that break down insecticides to nontoxic or less toxic substances. An insect's detoxification system usually becomes more efficient as the insect gets older. Thus, an older larva has both a larger size and a better detoxification system to reduce its susceptibility to insecticides.

Integrated pest management stresses the importance of detecting pests early, although acceptable control often can be achieved even if pests are detected late. However, the behavior of the insect involved and the insect's stage of growth must be considered when deciding whether or not to apply insecticide. Some insects, such as the corn borer species, move inside the plant soon after hatching from the egg stage. Non-systemic insecticides (those not taken up in the plant) cannot reach them once they are inside the plant, so insecticide applications would be wasted. There is also a point at which there would be no economic gain from using insecticide, even though it might kill a large percentage of the insects. This point is reached when most of the insects are in their last larval stage and have done about all of the damage they are going to do. They will soon stop feeding and enter the pupal stage, so what is the point of spending money for an insecticide application that might, at best, prevent a day or two of feeding? The choice to use an insecticide is really a choice to incur a cost, and IPM is based in part on the principle that the benefits of insecticide use should outweigh the costs incurred.

Insect Naming Conventions

Most of us know insects by their common names, which often reflect the plant on which the insect feeds. For example, the corn earworm is the larva commonly found in ears of sweet corn and field corn. However, the same pest is known as the cotton bollworm and the tomato fruitworm when it attacks those plants. There is nothing wrong with using common names for pests, but in scientific circles names must be clear. Having too many names for the same insect causes confusion. Therefore, scientists have devised a rather strict system for classifying living things and for assigning a name to each species.

In this system, insects are grouped according to

- order (the most broad and inclusive group),
- family,
- genus, and
- species.

Butterflies and moths, grasshoppers, bugs, flies, and bees and wasps are in different insect orders. An order contains one to many families. A family contains one to many genera. A genus is a rather small group within a family that usually contains one to many species. A species is specific and unique.

For example, the corn earworm's scientific name is *Helicoverpa zea.* It belongs to the genus *Helicoverpa* and is the species *zea.* Other species in the genus include *Helicoverpa armigera* (the old world bollworm) and *Helicoverpa punctigera* (the native budworm). Insects in the genus *Helicoverpa* belong to the family Noctuidae and the order Lepidoptera. When an entomologist hears the family name Noctuidae, he or she immediately knows that the insect being described has a larval immature stage and the adult is a moth in the large group of insects called Lepidoptera (moths and butterflies). Scientific names provide a lot of information about an insect and are, therefore, quite helpful to people who deal with insects on a daily basis.

Another important aspect of scientific names has to do with the endings of singular and plural words, which derive from Latin. In general, plural words end in "ae" and singular words end in "a." Examples are "larvae" and "larva," "pupae" and "pupa."

Infestation Timeline

This manual describes most insect pests of corn in Texas. Many pests cause economic damage for only a short time during the growing season, while some remain a threat for much longer periods of time. Table 7 is a quick reference to the pests that may be of economic consequence at a particular stage of corn growth. These pests are discussed on the following pages in the same order as presented in Table 7.

Table 7. Seasonal progression of insect pests.

Pest	Seed/ Seedling	Whorl to pretassel	Tassel/ Silk	Grain filling
Wireworms	Yes			
White grubs	Yes			
Red imported fire ants	Yes			
Seedcorn beetles	Yes			
Seedcorn maggot	Yes			
Flea beetle	Yes			
Cutworms	Yes			
Lesser cornstalk borer	Yes	Yes		
Chinch bugs	Yes	Yes		
Southern corn rootworm	Yes	Yes		
Western corn rootworm	Yes	Yes	Yes	
Mexican corn rootworm	Yes	Yes	Yes	
Corn leaf aphid	Yes	Yes	Yes	
English grain aphid	Yes	Yes	Yes	
Fall armyworm	Yes	Yes	Yes	Yes
Armyworm	Yes	Yes	Yes	Yes
Spider mites	Yes	Yes	Yes	Yes
Southwestern corn borer		Yes	Yes	Yes
European corn borer		Yes	Yes	Yes
Mexican rice borer		Yes	Yes	Yes
Sugarcane borer		Yes	Yes	Yes
Neotropical borer		Yes	Yes	Yes
Western bean cutworm		Yes	Yes	Yes
Corn earworm		Yes	Yes	Yes
Grasshoppers		Yes	Yes	Yes

Corn is susceptible to insect damage as soon as it is planted. Fortunately, most early-season, soil-dwelling insects can be detected before planting and corrective measures taken before significant damage is done. Insects that might damage very young corn include wireworms, white grubs, fire ants, seedcorn beetles and seedcorn maggots. Of these, only the seedcorn maggot can infest a field after it is planted; the other pests are already there. Cutworms also can be a threat, especially in weedy fields.

Wireworms

Several genera and species in the beetle family Elateridae.

False wireworm larva

Biology

Wireworm larva

Wireworms are the larvae of a click beetle, not the "caterpillar" type larva we normally associate with the term "worm." They are $^{1}/_{2}$ to 2 inches long and tan to reddish brown. They have three pairs of legs on the thorax just behind the head and no legs on the abdomen. The last abdominal segment has a flattened plate on the top side. Differences in this plate are used to differentiate between species. The name "wireworm" describes their overall appearance—long and narrow. Larvae are usually hardened and have an armored appearance.

Wireworms overwinter as larvae or adults in the ground. Larvae move through the soil and change depth with soil temperature and moisture. As soil temperature warms in the spring, larvae move up in the soil profile to feed. They move downward in the profile in hot summer weather or when there is little soil moisture near the surface. Larvae may remain in the soil for 1 to 6 years.

Damage

They often feed on seeds and leave only an empty hull (pericarp). They also prune seedling roots and may burrow into the underground part of the stem. This may kill the growing point of the corn plant or cause stunting. Above-ground symptoms of wireworm damage include wilting and distinct yellow streaking of the leaves. Damaged plants often die or do not produce ears.

Scouting

Intense wireworm scouting should be done when corn follows pasture, sod, forage or fallow. Scouting can be done after land preparation and before planting. Wireworms are difficult to find because they can go as deep as 5 feet in the soil. Solar bait stations can be used in the fall, or at least 3 weeks before planting, to check for wireworms.

There is no formal treatment threshold for wireworms based on solar bait station captures, but Midwestern recommendations suggest insecticides will be justified if there are one or more wireworms captured per bait station. Some researchers suggest placing one to four bait stations per acre, but this seems highly impractical. A good compromise might be to use eight bait stations per field of 80 acres or less.

Bait stations are made by digging a hole 4 inches deep and 9 inches wide. Place a cup of whole kernel, untreated, corn-wheat mixture in the bottom of the hole. The corn-wheat mixture can be presoaked the day before to make the bait more attractive. Fill the baited hole with loose dirt and cover it with an 18-inch square of black plastic. Cover the black plastic with a 3-foot square sheet of clear plastic. Then place soil on the edges of the plastic to protect it from the wind. Plastic increases the soil temperature and decomposition of the bait. Be sure to mark the station location. After 2 weeks, check each station for wireworm larvae, which are attracted to the gases produced by the decomposition of the corn-wheat mixture.

High Plains growers occasionally have very large numbers of wireworms from the genus *Conoderus*, including *C. vespertinus* (the tobacco wireworm) and *C. lividus*, which does not have a common name. The best bait for monitoring these species is about 1/2 pound of rolled oats (not seed oats). Several fields were lost to *Conoderus* species in 2004.

Wireworm damage is usually detected while scouting for cutworms or making stand counts. To confirm wireworm damage, examine 50 plants in each of five areas of the field. When a damaged plant is found, dig 4 to 6 inches of soil around the damaged plant and check for wireworms. Wireworms may be found around roots, in the underground portion of the stem, or in the seed. If plants are completely missing from an area, search for the presence of seeds and wireworms. An absence of seeds may indicate a planter skip. The presence of empty seed hulls may indicate wireworm damage. In some areas, ants, especially fire ants, may cause similar damage.

Control

Cultural control methods include crop rotation and delayed planting. Rotation from cotton, soybeans or some other nongrass crop can be effective because wireworms do not develop well on these plants. Late planting with adequate soil moisture will not lower the number of wireworms in the field, but because the soil is warmer later in the season, corn will be able to germinate and grow faster to possibly compensate for the damage. Late plowing will kill some of the wireworms in a field, but it has several detrimental effects, including drying the soil in the root zone.

Wireworms are difficult to control. When wireworms are a threat or bait station captures equal one or more larva per trap, apply a soil insecticide at planting time to protect seeds and seedling corn plants. Certain seed treatments also may protect the crop. Seed treatments may be considered when bait station captures average fewer than one wireworm per station. In general, seed treatments are less effective than soil-applied insecticides, but newer seed treatments show some promise. Chemical rescue treatments have not been successful for wireworm control.

White Grubs

Phyllophaga species

Biology

White grub larvae

The larval stages of the Scarab beetle family are called white grubs. Our most common species are May and June beetles, but other species also can be pests of corn. White grubs tend to build up in fields planted to sod, wheat or other grasses. May and June beetles have one generation per year, and because the eggs are laid in midsummer, the larvae are fairly large by the time corn is planted the next year. Larvae move downward in the soil profile as temperatures fall and may escape notice in the spring.

Larvae are whitish, plump, and have three pairs of legs on the thorax just behind the head and no legs on the abdomen. Larvae curl into a “C” shape. (Cutworms do this too, but are not white and do have prolegs on the abdomen.)

Damage

White grubs feed on roots and can kill plants or cause stunting.

Scouting

Scouting should begin before planting, and fields that were in a grass crop the previous year should be very carefully examined. Examine the top 6 inches of a 1-foot-square area in each 5- to 10-acre section of a field. Birds like to eat white grubs, so large numbers of birds in a field during soil preparation might indicate high grub numbers. An average of one white grub per square foot is enough to cause stand loss.

Control

Use an insecticide if there are two or more white grubs per square foot. Newer seed treatments may help reduce white grub feeding, but as of this writing there are not enough data to make a recommendation.

Red Imported Fire Ant

Solenopsis invicta

Fire ants can be found in Texas from Abilene southward. They feed on seeds and germinating seedlings. Seed treatments (including lindane treatments) suppress fire ants, and applying insecticide to the soil over open furrows has been shown to be effective. Fire ant management is a complex topic, and readers are referred to Texas Cooperative Extension publication B-6076, "Managing Red Imported Fire Ants in Agriculture."

Seedcorn Beetles

Slender seedcorn beetle – *Clivina impressifrons*

Seedcorn beetle – *Stenolophus lecontei*

Seedcorn beetles only rarely reach pest status. The adults are brown to reddish brown and $^1/_4$ to $^1/_3$ inch long. They damage corn by feeding on the seed or germinating embryo. Damage includes partially eaten seeds, lack of germination, and stunted plants. Wireworms also cause this type of damage. If germination is poor, dig a foot of row in several locations and look for seedcorn beetles, wireworms and white grubs.

Seedcorn Maggot

Hylemya platura (Meigan)

Biology

Seedcorn maggots are fly larvae. They are small, dirty white, and have no legs. The body has 12 segments, is tapered at the front end, and has no visible head. The abdominal end is usually blunt and does not taper. The head has two dark hooks that are part of the maggot's mouth. The hooks are used to feed in the seed or on the underground portion of the stem. When mature, the larvae are about $^2/_{10}$ to $^1/_4$ inch long. Maggots develop through three larval stages. They feed in temperatures between 40 and 75 degrees F, but do not feed when soil temperatures are warmer than 75 degrees F. Feeding continues for 1 to 3 weeks and then larvae pupate in soil at depths up to 18 inches.

Seedcorn maggots overwinter as pupae. During the spring, adults emerge at night or early in the morning. Seedcorn maggot adults are flies that resemble the common house fly but are smaller, more slender, and have longer legs than house flies. The adults are grey with three black stripes on the thorax and, like all flies, one pair of wings. Adults grow to about $^2/_{10}$ inches. Adults prefer to lay eggs in newly tilled soil, manured fields, or fields with decaying seed or crop debris. The white, $^4/_{100}$-inch (1-mm) long, elongated eggs are laid singly or in clusters. Larvae hatch in 1 to 9 days, depending on temperature. Most areas of Texas have one to two generations of seedcorn maggots per year.

Damage

Seedcorn maggots feed on organic matter or tunnel through the corn seed coat and feed on the seed germ. Most damaged seed will not germinate. Damaged seed that does germinate usually does not survive. Maggots may also feed on the underground stems of newly sprouted corn, which weakens seedlings so that they rarely survive. Feeding allows plant pathogens to enter the plant.

Serious problems are relatively rare and are usually confined to fields that contain lots of manure or crop debris.

Scouting

Scouting for seedcorn maggots is not difficult. Generally, eggs are laid throughout a field on organic matter or plant debris, so expect to see damage over a large area. This differs from the damage of cutworms, wireworms and white grubs, which is usually more isolated or "patchy" in a field. When corn is in the seedling stage, look for gaps or skips in the stand, or yellowed or stunted plants. Seedcorn maggot infestations do not "follow the row," so if stand damage is confined to rows, suspect planter problems or possibly wireworms. Dig up suspect plants and look for maggots in or near the seed. Maggots can occasionally be found in tunnels within seedling stems.

Control

Cultural controls include early fall plowing of fields that contain lots of manure or other organic matter. This will make the field less attractive to seedcorn maggot flies at egg-laying time in the spring. Do not plant these fields early. Wait until soil temperatures are warm enough to promote rapid germination and growth.

Texas has no established economic threshold for seedcorn maggot. Seed treatments or soil insecticides applied at planting may be needed if conditions are favorable for infestation and cultural controls cannot be used.

Corn Flea Beetle

Chaetocnema pulicaria Melsheimer

Flea beetles and leaf damage.

Biology

Flea beetles and seedling damage.

Flea beetles are small, black insects that feed on the leaves of young corn plants. Corn flea beetle adults overwinter near the soil level sheltered by grasses. Mild winters promote their survival. Wheat and many other grasses can sustain the adults in the early spring before corn is available. Adults mate after leaving their overwintering sites. Females lay eggs in the ground near corn seedlings. Larvae hatch in 6 to 10 days and feed on corn roots for about 2 weeks before pupating in the soil. Pupation lasts about 7 to 10 days. Several generations of corn flea beetles may occur each year.

Corn flea beetle larvae look much like the larvae of corn rootworms but are more slender. They are milky white and cylindrical with dark heads. They have three pairs of tiny legs just behind the head. Flea beetle larvae are about $^1/_6$ inch long when fully grown. Pupae are white, soft bodied, and resemble the adult in size and somewhat in shape.

Adult flea beetles are about $^1/_{16}$ inch long and shiny black tinged with bronze or bluish green. The first segment of the hind legs that is visible without magnification (the femur) is greatly enlarged, which makes the beetles exceptional jumpers. In fact, it is this trait that gives the corn flea beetle its name—it can jump like a flea.

Damage

Both adult and larval corn flea beetles damage plants, but only rarely is this of economic importance. The damage caused by adults is easy to recognize. They feed on the foliage and cause streaks or “windowpane” feeding patches. This is an area where one surface of the corn leaf has been eaten, leaving only a translucent layer of leaf tissue. Flea beetles can damage corn from emergence until it is about 18 inches tall. Leaves may take on a whitish, bleached appearance. Large numbers of adults have been known to kill large areas of corn in fields. Larvae feed on roots and may reduce plant vigor.

While corn flea beetles usually do little damage themselves, they transmit the bacterium that causes Stewart’s bacterial wilt. Symptoms of this wilt include stunting, wilting, and linear lesions and wavy edges on leaves. Leaf yellowing progresses up the plant in time. Drought or water stress can make the disease more severe. The injury caused by Stewart’s bacterial wilt is usually worse in cool growing seasons. When the weather is most favorable for plant growth, field corn usually outgrows the injury. Sweet corn or inbred corn grown for seed is less likely to outgrow the disease.

Scouting

Start scouting for flea beetles at plant emergence and continue through the 5-leaf stage. Expect to find more adults after a mild winter and cool spring and where corn fields are adjacent to grass hosts and other overwintering sites. Adults are easy to recognize.

Control

Although flea beetle management is rarely required, there are a few ways to reduce beetle numbers. First, fields and adjacent areas should be kept free of weeds. Also avoid early planting dates that may slow seedling development and increase seedling susceptibility to damage. Plowing under crop residue also may prevent damaging corn flea beetle populations.

Most commercial field corn varieties are resistant to Stewart's bacterial wilt, and Texas has no economic threshold for treatment. Chemical control may be justified if more than five beetles are found per plant before the 4-leaf stage. Corn breeding lines may require a rescue treatment if they are infested before the 5-leaf stage, two to three adult corn flea beetles are found per plant, and 10 percent of the plants are white from flea beetle injury.

Cutworms (excluding western bean cutworm)

Biology


Cutworm in characteristic "C" shape.

With the exception of western bean cutworm (see page 66), all cutworms are pests of corn from the seedling stage through about the 7-leaf stage. They have a broad host range, and moths often lay eggs on weeds in and around fields before corn is planted or in winter crops preceding corn. The larvae move to corn as it emerges and grows.

"Cutworm" is a generic term for any one of several different caterpillar species that feed on corn. All cutworm larvae have four sets of prolegs on the third to sixth abdominal segments and one set of prolegs on the last abdominal segment. Most larger cutworm larvae curl into a "C" shape when disturbed. (White grubs also curl into a "C" shape, but they do not have any prolegs on the abdomen.) Many species are active at night and hide in the soil during the day. Detection often requires digging around damaged plants. Cutworms pupate in the soil, and their pupae are difficult to distinguish from those of other moths.

Adult cutworms are moths with wingspans of 1 to 2 inches. Most of them are black, brown, grey or tan. Moths do not damage corn and are not a concern, except for the eggs that they might lay. Cutworm moths often fly in large numbers and contribute to our late spring "Miller Moth" populations.

There are several species of cutworms that can infest Texas corn. Of these, only the black cut-

Table 8. Identifying cutworm larvae.

Species	Body color	Head markings	Body markings
Black cutworm	light gray to black skin with a rough, pebbled, greasy appearance	brown with two black stripes	top of body has pale stripe; each body segment has two sets of paired spots unequal in size
Bristly cutworm	dull grayish brown		stripes along sides of body; pale diamond-shaped markings and stiff hairs on top of body
Variegated cutworm	pale gray or brown with dark brown splotches and an orange stripe		row of white or pale yellow dots along the middle of the back; eighth segment has a black and yellow spot
Army cutworm	greenish brown or gray with white splotches	pale brown with dark brown freckles	brown stripe on top of body and dark stripe and white splotches on lower body
Pale western cutworm	grayish green or pale yellowish gray	amber to black; young larvae have a narrow-waisted **H** on the front of the head, older larvae have an inverted **V**	three pairs of greenish-gray stripes along the back and sides
Dingy cutworm	gray, sometimes with a hint of reddish brown color		each body segment has a dark **V** on the top and a dark spot on each side; dull gray stripe along the back bordered by a narrow, dark stripe on each side; each body segment has two sets of paired spots equal in size
Glassy cutworm	greenish white; appears translucent or glassy	reddish brown	no distinct markings

worm and the western bean cutworm (see page 66) commonly cause economic damage. This is not to say that other cutworms do not cause significant damage, but year in and year out they are of less importance than the two principal pest species. Because it is a mid-season pest, the western bean cutworm is discussed in a later section. The other cutworm species are early-season pests except where noted.

The **black cutworm** is especially common in weedy fields. Moths are present in the winter along the Gulf Coast and migrate north in the early spring. They lay eggs in clumps of 10 to 30 on grasses, broadleaf weeds, and crop residue before corn is planted. Eggs hatch in 3 to 16 days, depending on the temperature. The length of the larval stage also depends on temperature and other factors; it generally lasts 28 to 35 days. There are many generations per year. Fields that are free of living weeds 6 weeks before crops are planted are much less likely to have cutworms. Fields should be carefully scouted for eggs and small larvae before corn is planted, and insecticides should be considered if pre-plant populations are high. Spot treating weedy crop areas is an alternative to whole-field treatment. Through experience, many growers know which of their fields are most prone to black cutworm infestations year after year.

The **variegated cutworm** produces a new generation about every 48 days depending on temperature. The first generation of the year is a threat to corn younger than the 6-leaf stage; the next generation can infest ears and feed on silks, but this is seldom an economic problem. Eggs are white when laid but turn purple-gray as they near hatch. Eggs can be found on low-growing plants and inanimate objects. Young larvae climb plants, but older larvae burrow into the soil and may cut plants at the soil surface.

Bristly cutworms overwinter as third or fourth instar larvae and feed on weeds, alfalfa or pasture until corn emerges. There are two generations per year; first-generation adults fly in June, and second-generation adults fly in August to September. Larvae feed near the soil surface.

Army cutworm adults are migratory and move west toward the Rocky Mountains after they emerge from the pupal stage. These adults return in the fall and lay eggs that hatch a few weeks later. The larval stage overwinters and continues to feed on plants when the weather is warm enough. There is one generation per year. Army cutworms can be very destructive to wheat and alfalfa in the spring, but this species is not considered to be a corn pest because most of them have reached the nonfeeding pupal stage by the time corn plants emerge. Huge outbreaks of army cutworms occur periodically and they become nuisance pests in yards and communities. The name “army” refers to the tendency of the larvae to move *en masse* in search of good host plants.

Pale western cutworm larvae feed under ground and are usually a problem only when the soil is very dry. There is one generation per year. Adults fly in the fall and prefer to lay eggs in loose, sandy or dry soil. Some eggs may hatch during warm periods in the fall or winter; the rest hatch in spring.

Dingy cutworms overwinter as larvae and are often the first cutworms to damage corn in the spring. Larvae are most often found in corn with heavy crop residue, or in corn that follows sunflowers or a legume crop. They feed above ground on leaves or sever plants at or below ground level. Moths lay eggs from August through September on weeds and other vegetation low to the ground. There is one generation per year.

Glassy cutworms prefer sod but may be a problem in corn that follows sod or pasture. They overwinter as larvae, feed in underground burrows, and damage corn roots and basal stems. Glassy cutworm damage can be more severe during drought. There is one generation per year.

Damage

Larger cutworm larvae can cut young plants completely off near the soil, while younger larvae (instars 1 to 3) typically cause small holes or “windowpane” damage. Plants damaged below the growing point will not recover. Plants damaged above the growing point may recover but have lower yield. Such plants may not produce ears, or ears may be unusually small. Some cutworms climb plants and feed on foliage. One cutworm can damage three to six plants before it enters the pupal stage and no longer feeds.

By the 6-leaf stage, most corn cannot be seriously damaged by cutworms (except for the western bean cutworm).

Some larvae move in large groups through fields and consume almost all exposed vegetation. These are known as “army” type cutworms and may actually include the fall armyworm and the true armyworm, which are not really members of the cutworm group.

Soil moisture may affect cutworm feeding. When soil is very dry, cutworms tend to tunnel and feed underground where soil is more moist. When soil is unusually moist, more damage may occur above ground than would otherwise be the case.

Scouting

Scouting for cutworms is a little different than scouting for most pests. Usually we assume that the eggs of insect pests will be laid on the crop and that the larvae will do relatively little damage while they are small, thus giving us time to find and treat them. Cutworms are different. Most of them lay eggs on weeds, early-season crops, or even inanimate objects so that the larvae are usually quite large by the time they begin feeding on corn. So seedling damage can occur quickly. In addition, some species spend most of their time below ground, making them difficult to control with insecticides.

Fields should be scouted weekly from emergence to the 6-leaf stage. Pay particular attention to fields that are weedy, no-till, rotated from pasture or legumes, planted late, or that have low or wet spots. Look for leaf feeding, missing plants (especially several consecutive plants in the same row), unexplained wilting and discoloration. Cutworm infestations are usually not evenly distributed in a field. Pay particular attention to borders, low spots, weedy sites, and areas with lots of crop residue. Check at least 50 plants in at least five locations per field. If cut, wilted or damaged plants are found, examine the top 2 to 3 inches of soil between plants and in an 8-inch circle around individual plants. Because small larvae may be difficult to see, some scouts use fine mesh screen to sift the soil from the insects.

Cool, wet weather for an extended period in the spring slows corn development and may prolong a cutworm problem.

Control

The more crop residue or weeds in or near a field, the greater the probability of cutworm eggs being laid in the field. Clean fields minimize cutworm problems. Fields should be tilled and treated with herbicide at least 6 weeks before corn is planted so that adults are deprived of favorable egg-laying sites and larvae will be without food.

If corn is planted into another crop, be sure to carefully check that crop for cutworms and other pests before applying the burn-down herbicide. If significant numbers of cutworms are present, an insecticide application probably will be justified on either the crop to be destroyed or on the corn crop soon after emergence. An alternative would be to burn the crop down at least 1 week before planting corn. Cutworms in the burned down crop will be without food for almost 2 weeks before corn seedlings emerge, and most of them will die.

Texas does not have an economic threshold for cutworms. The recommendation in some Midwestern states is to consider control if more than 5 to 10 percent of seedlings are cut and if larvae are present. Yet, significant damage can sometimes occur with just 2 to 3 percent of plants cut initially. If a field seems to need treatment, scout it carefully to estimate the extent and location of the problem. It is likely that only parts of the field will have an economically damaging infestation, and a spot or partial field treatment may be in order.

Before using insecticides, consider these points.

- Corn is relatively safe from cutworms after it reaches the 6-leaf stage.
- If a cutworm population is made up of mostly large, last instar (the final larval stage) larvae, the nonfeeding pupal stage is only a few days away and the insecticide cost might not be recovered.

- Large larvae are less susceptible to insecticides than small larvae.
- Consider spraying only the parts of the field that have damaging infestations (if these regions can be identified).
- If the damage is already severe, it might be best to wait 2 weeks until the larvae finish feeding and then replant.

Insecticides may be applied before, during or after planting. Because cutworms are only an occasional problem in most fields, it makes sense to spray only after scouting has identified a significant problem. Exceptions to this are fields rotated out of crops with active cutworm infestations and fields that have significant infestations every year.

A post-emergence insecticide applied to a dry, crusted soil should be tilled in to improve contact with cutworms. A spray directed at the bases of plants with a high volume of water can be quite effective.

Lesser Cornstalk Borer

Elasmopalpus lignosellus

Lesser cornstalk borer larva.

Biology

Lesser cornstalk borer larvae feed in the stalk or below or near the soil surface in silken tubes usually interwoven with soil particles. They are the only caterpillar pest of Texas corn that is found in the soil and feeds in a silken tube. Older larvae are $^3/_4$ inch long and iridescent blue-green to purple with brown bands around the body. They shake vigorously when disturbed. Larvae or pupae overwinter, and females lay eggs on plants or in soil near plants. Small larvae feed on leaves and roots and then build the silken feeding tubes and bore into plants near the soil surface. Pupation occurs in a silken tube under debris on the soil surface. There are two to four generations per year.

Damage

Corn is most vulnerable to attack in the 2- to 8-leaf stage. Larvae may destroy the plant growing tip and/or the vascular tissue of the plant. Symptoms of injury can include stunting, water stress, dead heart and abnormal growth.

Scouting

Larvae often move down the row and injure several adjacent plants. Look for affected plants and dig them up with the soil around their roots. Sift through the soil and look for the larvae and/or silken tubes near the roots or within the plant. Lesser cornstalk borer also feeds on peanuts, beans, peas, cowpeas, johnsongrass, crabgrass, sorghum, sugarcane, wheat and other crops.

Control

The lesser cornstalk borer is an occasional and sporadic pest that is most damaging on seedlings and causes little problem on older plants. It is most common in sandy soils and is favored by dry weather. Rainfall or irrigation will kill many larvae. Because this pest is so sporadic, few producers use soil-applied insecticides at planting to control it, although such products can help. Liquid insecticides can be applied post-emergence.

Chinch Bugs

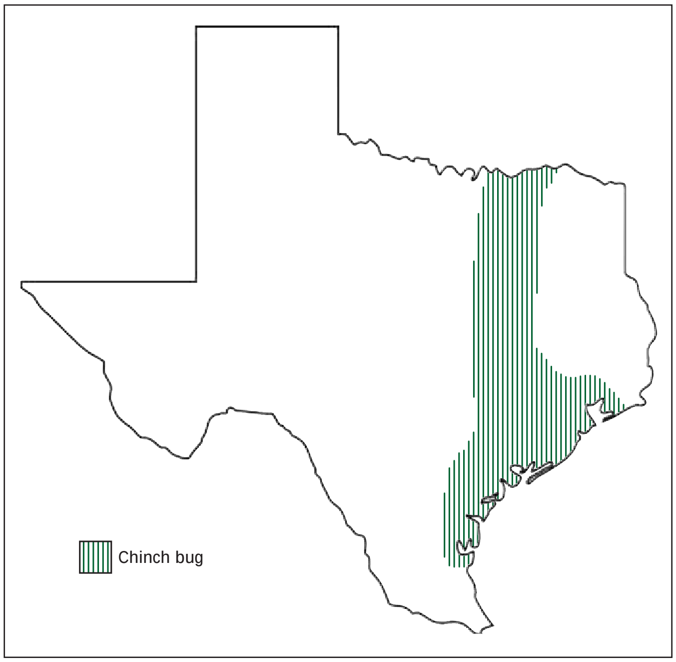
Blissus leucopterus

Chinch bug.

False chinch bug.

Biology

Chinch bugs are an occasional pest throughout the state but reach serious status far more frequently on the Gulf Coast. They can be confused with false chinch bugs (*Nysius raphanus*). Both insects have simple metamorphosis; the immatures closely resemble the adults but the



wings are not fully developed. The wings of adults may reach only partway down the length of the abdomen.

Small chinch bug nymphs are orange, whereas older nymphs are dark grey with a white stripe across the back. Adult chinch bugs are about 1/6 inch long and have black or dark grey bodies with reddish-yellow legs. When fully developed, wings are white and marked with a triangular black spot on each outer side near the center of the body. When viewed from above, the chinch bug appears to have a white hourglass shape on its back, the narrow part of which is formed by the black triangles at the outer edges of the wing.

False chinch bug adults can be as large as 1/8 inch and are dark grey to brown to black. The front part of their hindwings (which are on top of the first pair of wings) is fairly uniform in color, and the back half of the hindwings is clear. They are easy to differentiate from the true chinch bug because they do not have the hourglass shape when viewed from above.

Damage

Chinch bugs develop on small grains and weeds outside cultivated corn and sorghum fields. False chinch bugs also develop on weeds, but generally do not prefer small grains. When these early-season food sources begin to decline in quality, chinch bugs move into corn and sorghum. Huge numbers of both species can be found at the margins of fields and in pockets deeper in the field. They congregate and feed in the whorl behind leaf sheaths and are often found below the soil surface feeding on the stem and roots. Chinch bugs have straw-like piercing and sucking mouthparts that are inserted into plant cells to suck juices. The injection of saliva may cause reddening of the leaves.

Scouting

Begin scouting at corn emergence and continue until plants are at least 18 inches tall. At that time plants become less susceptible to chinch bug damage. Scout at five random locations and examine individual plants. Control should be considered when two or more adult chinch bugs are present on 20 percent of seedlings less than 6 inches tall. On taller plants consider applying insecticides when immature and adult chinch bugs are found on 75 percent of plants. If the plants are growing vigorously and have adequate water, this threshold can probably be increased. In areas with abundant weed and grass hosts, field margins may be heavily infested. If so, an edge treatment may be warranted before the bugs move farther into the field. There is no established action threshold for false chinch bugs.

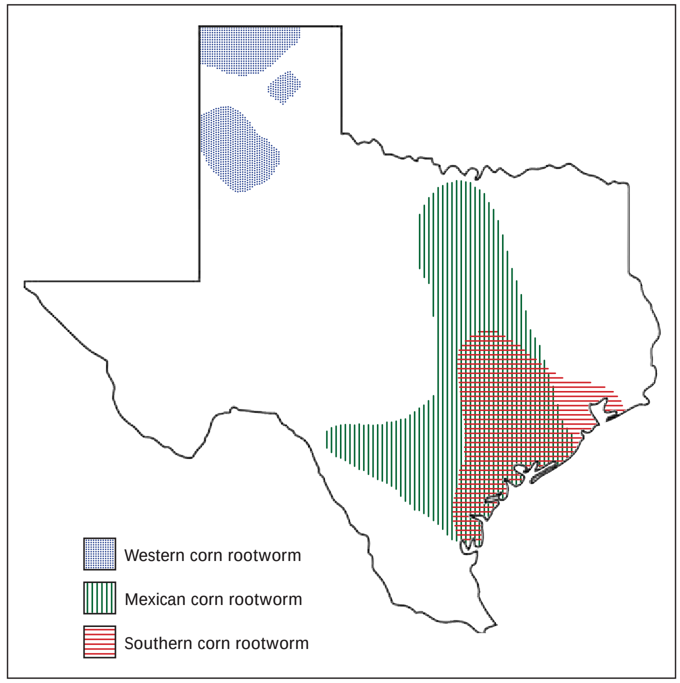
Control

Certain seed and granular insecticide treatments are very effective at controlling chinch bugs, and such treatments can offer early-season protection from other pests. Rescue treatments of foliar insecticide are often less effective. Chinch bugs often congregate around corn roots in loose soil, and foliar applications may not be effective if the soil has not been sealed by rainfall or irrigation. If a foliar or directed spray is to be applied, use ground equipment that delivers at least 20 to 40 gallons of water per acre (depending on the insecticide label) and direct the spray toward the base of the plant. In loose soil, use two nozzles per row directed at the base of plants from both sides, and use at least the amount of water suggested on the label. Cost-effective control can be achieved in loose soil only by following this procedure.

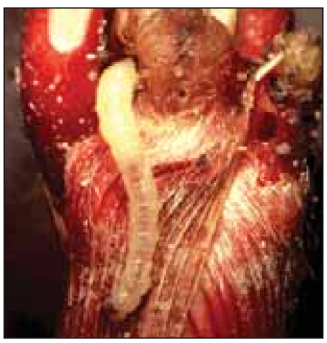
Vigorously growing plants with adequate water may outgrow some chinch bug damage.

Corn Rootworms

All Texas corn production regions are threatened by corn rootworms, but different species are found in different areas. The predominant species in South Texas and the Gulf Coast are Mexican corn rootworms (MCR) and southern corn rootworms (SCR). The western corn rootworm (WCR) is the dominant species on the High Plains, but Mexican and southern corn rootworms are present in low numbers. The Mexican corn rootworm and the western corn rootworm are very closely related. These two species have only one generation per year, and crop rotation is the best defense against them. This is not true for southern corn rootworms, especially on the Gulf Coast, because this species has several generations per year.



Southern corn rootworm – *Diabrotica undecimpunctata howardi* Barber


Southern corn rootworm larva.


Southern corn rootworm adult.

Biology

The southern corn rootworm adult deposits eggs in the field after corn emerges, which means that crop rotation provides little protection. The adult is also known as the 12-spotted cucumber beetle. This pest can develop on many plant species other than corn and also attacks peanuts and many vegetable crops. The larvae look almost identical to the Mexican and western corn rootworm larvae. The adult is green with 12 spots on the back. Neither western nor Mexican corn rootworm adults have spots, although western corn rootworm adults have black stripes.

Damage

The southern corn rootworm is a major pest along the Gulf Coast and in the Central Texas Blacklands. It is only an incidental pest on the High Plains, where it is usually confined to extremely weedy fields. Both rotated and non-rotated fields on the Gulf Coast can be heavily damaged. Adults lay eggs in the soil. Larvae burrow into germinating seeds, crowns and roots of small plants. Symptoms of damage include reduced stands and "dead heart" that discolors and kills the innermost leaves in the whorl. This insect is regarded as a "seedling pest" because it reduces stands and yields and delays maturity. A poor plant stand can cause excessive weed growth later. Second-generation larvae are not a concern because corn root systems are large enough to withstand the damage.

Scouting

All corn in the Gulf Coast region should be scouted for southern corn rootworm larvae from emergence through late May. When scouting, look for signs of water stress and dead heart. Dig several feet of row in a few areas of the field and examine seeds and developing plants for larvae and damage. A field's history of infestation and damage is also important when deciding whether to use an insecticide.

Control

Since the southern corn rootworm is a seedling pest, with nearly all of the damage occurring before plants are 6 inches tall, insecticides do not need to remain active as long as for western and Mexican corn rootworm. Granular, liquid and seed treatment insecticides are all effective at about half the rate needed for control of the other two rootworm species. However, use the higher rates in fields where heavy infestations occur each year. Lindane-based planter box treatments are not effective in reducing southern corn rootworm damage.

Western corn rootworm – *Diabrotica virgifera virgifera* LeConte

Mexican corn rootworm – *Diabrotica virgifera zeae* Krysan & Smith

Western corn rootworm larva.

Western corn rootworm adult.

Mexican corn rootworm adult.

Mexican corn rootworm adult.

Biology

Mexican and western corn rootworms are quite similar in their biology and the type of damage they do. Both species have one generation per year, prune roots as larvae, clip silks as adults, and lay eggs in the soil of corn fields in mid-season, with eggs hatching the following spring. Because there is only one generation per year, the number of larvae will not increase as the season progresses. The eggs in a field at the beginning of the season will be the only source of larvae. The adults from these larvae emerge in mid-season and can move from field to field. Some fields, especially those at green silk, can attract adults from more mature fields.

Crop rotation, the cornerstone of corn rootworm management, exploits the fact that Mexican and western corn rootworms prefer to lay eggs in corn and have only one generation per year. If corn is planted in the same field the following year, rootworm larvae will be present to damage roots. However, if another crop is planted where corn grew the previous year, the hatching larvae will die because they generally do not feed on crops other than corn. Likewise, if corn is planted in a field where nongrass crops grew the previous year, there will be few or no rootworm larvae present because adults will not have laid eggs in the preceding crop. In Texas, crop rotation is the cheapest and best way to avoid Mexican and western corn rootworm damage. (Unlike the Midwest, Texas does not have the western corn rootworm variant that also lays eggs in soybeans.)

Eggs are tiny, yellowish white, and laid in the upper 2 to 8 inches of the soil during mid- to late summer. Egg laying begins shortly after silking and continues for several weeks. Eggs remain in diapause during the winter and begin to develop when soil temperature reaches 52 degrees F. Noticeable egg hatch begins in early April on the Gulf Coast and in mid-May on the High Plains, usually 3 or 4 weeks after corn is planted.

The larvae of all corn rootworm species look very similar. There are three larval instars. First-instar larvae are white and $^1/_8$ inch long. Third-instar larvae have a wrinkled, cream to yellowish body and a dark brown head and dark terminal abdominal segment. Mature larvae are $^3/_{10}$ to $^4/_{10}$ inch.

Adults of the Mexican corn rootworm are about ¼ inch long and pale to bright green. Wing covers may match the body color or may have slightly contrasting yellowish- or orangish-green stripes. Western corn rootworm adults are yellowish tan to greenish (more rare) and almost always have a black area or black stripes on the wings. The width, intensity and definition of the black area vary, and males tend to have larger dark areas than females.

Damage

Corn rootworm larvae feed on all root parts, including brace roots. Mexican and western corn rootworm larvae begin to hatch a few weeks after corn emerges, and hatch may continue for several weeks. Mexican corn rootworm damage on the Gulf Coast usually peaks around May 10. Western corn rootworm damage peaks on the High Plains in June.

Root pruning caused by corn rootworms.

Adult western corn rootworm leaf feeding.

Larvae begin feeding on the outer parts of the roots and move toward the center as they mature. Larval feeding lasts 30 to 40 days and results in root pruning, which can be quite minor or can result in the loss of much or all of the root system if larval numbers are high. Although it may sound strange, a small amount of root pruning can be a good thing. A little pruning stimulates root regrowth, and the regrowth may provide a better root system than if pruning had not occurred. However, plants must have adequate nutrition and water for the regrowth to occur. If root damage is severe, the first symptoms noticed may look like drought stress because plants are not getting enough water and nutrients. If the soil contains little phosphorus, plants may show the purple coloration of phosphorus deficiency. Symptoms of nitrogen deficiency also are common.

Damaged plants may be stunted or die. Severe damage results in the loss of brace roots, which causes lodging. As new brace roots grow, the plant grows more upright, causing a curve at the base of the plant known as "goosenecking." Goosenecked plants can complicate harvest and increase harvest losses.

Adult corn rootworms feed on leaves before pollination, and then on pollen and silks as they become available. If silks are continually pruned to within 1/2 inch of the shuck, little pollination will occur.

Scouting

In nonrotated corn there is a reasonable chance that an economic infestation of rootworms will occur. Nonrotated corn grown in heavy clay soils in the Coastal Bend area is especially at risk for Mexican corn rootworm damage. There is no practical way to determine how many rootworm eggs are in the soil before planting. The best way to determine whether corn following corn is at significant risk is to have counted adult rootworm beetles in the field during the previous year. Unlike moths, which frequently fly from field to field at night, rootworm beetles generally mate, feed and lay eggs in the fields from which they originated. If there were one or more adults per stalk of corn the previous year, applying insecticide or planting a rootworm-active transgenic hybrid the next year might be warranted. The exception to this threshold is first-year corn, for which the threshold for next year's action is one adult rootworm beetle for every two plants. This is because first-year corn produces more females than males.

Adult rootworm counts should begin at green silk and continue weekly for 3 weeks or until the threshold is exceeded. Yellow sticky traps or plastic traps also can be used to help make control decisions for the following year. Place several traps in each field.

It is much harder to make in-season control decisions for young corn. If soil-applied insecticides were not used at planting, post-emergence treatments may be needed. It is almost impossible to count corn rootworm eggs to determine infestation levels before egg hatch. There are laboratories in the Midwest that will wash soil samples and report the number of rootworm eggs present, but this may be cost prohibitive. Small first-instar larvae are difficult to see. A good method of finding small larvae is to dig up several plants at several locations at least 50 feet inside a field. Place each plant and all the soil surrounding it for 7 inches (to a depth of 5 inches) in a plastic pail. Slowly dump the contents of the pail onto a dark colored drop cloth or plastic sheet and look for larvae. Then put water in the pail and wash the root system of the plant. Count the number of larvae floating on the water and tunneled inside the roots and add this number to those found in the soil. Using this technique, Midwestern researchers suggest that a crude threshold is one to two larvae per plant with larval damage present. They also warn that this threshold is highly dependent on the experience of the scout.

A student at Colorado State University has developed a method of rootworm sampling that uses only small plants and plastic cups. Plants and soil are dug in the field. Indoors, the soil is gently but thoroughly shaken from the root system and discarded. Each plant is then placed in a 24-ounce plastic cup from which the bottom 1 inch has been cut. The open bottom of the cup is then covered with a 6-inch square piece of window screen mesh and placed inside a second similar cup. The second cup, which is pre-filled with 3/4 inch of water, captures the larvae as they leave the plant when it dries down. All larvae in the plants are recovered after 48 hours. As yet there is no economic threshold established for this method. Details may be found at *http://www.colostate.edu/Depts/Entomology/posters/fromm981108/fromm981108.html*

Adult control in field corn should be considered if the beetles are eating silks faster than they are emerging from the husks and if pollen is present. A generally accepted threshold is eight to 20 beetles per plant, or five or more beetles actually on the ear. Good pollination depends on factors such as drought stress, plant vigor and hybrid selection. To check for pollination, gently remove the corn husks to see how many silks have dislodged. Dislodging indicates that pollination has taken place. The ear pollinates first in the middle, then at the base, and finally at the tip. About 1/2 inch of silk must extend beyond the shuck for pollination to occur.

Control in seed corn should be considered when the silk in 20 percent of the ears is clipped to within 3/4 inch of the husk, beetles are present, and pollination is still taking place. It is very important that plants have adequate soil moisture during pollination, and irrigation (if available) should be scheduled to eliminate water stress at this time.

Control

Crop rotation is the best way to avoid Mexican and western corn rootworm problems. Plant corn in fields where corn was not grown the previous year. If rotation is not possible, be prepared to use one of four insecticidal methods for rootworm control: seed treatments, at-plant soil insecticides, post-emergence insecticides, or transgenic hybrids. Scouting for adult beetles will give you a better idea of whether these control methods will be necessary the following year.

Seed treatments and insecticides applied to the soil at planting need to protect the plant for 6 to 10 weeks or until most larvae have stopped feeding and entered the pupal stage. Treated seed are easy to use, but most seed treatments use neonicotinoid insecticides (clothianidin or thiamethoxam), which provide less consistent control than soil-applied insecticides if a large number of larvae are present. In fields with light or moderate populations it may be possible to use only seed treatments and then scout for larvae and apply a post-emergence insecticide if needed.

Soil-applied insecticides begin to break down as soon as they are applied. If corn is planted early, well before rootworm eggs hatch, the insecticide may not protect roots at the crucial time. In general, soil-applied insecticides work best when they are applied close to the beginning of rootworm egg hatch. As with most insects, it takes more insecticide to kill older, larger larvae than to kill newly hatched, smaller larvae. A rule of thumb for corn rootworms is that two to four times more insecticide is needed to kill a third-instar larva than a first-instar larva. That is why soil moisture status and the timing and placement of soil-applied insecticides is so important.

When soil moisture is optimal, insecticide granules release insecticide gradually over a period of about 10 days. In very dry soils the insecticide may not move far off the granule into the soil solution, thus reducing its effectiveness. On the other hand, heavy rainfall may wash insecticide so far down into the soil profile that the roots are unprotected. This leaching effect is more pronounced in sandy soils or soils with little organic matter. Soil insecticides tend to break down faster in alkaline soils than in neutral or acidic soils, but this is also influenced by temperature and moisture.

A few growers are experimenting with applying granular insecticides in a band in front of the cultivator at first cultivation. This technique closely times insecticide application with egg hatch, but runs the risk of delaying application if fields are too wet to work. More common methods of granule application include the T-band and direct application into the seed furrow. A T-band application creates a 5- to 8-inch protected zone around the roots, but once the root system enlarges it may outgrow the zone of protection. In-furrow treatments create a narrower zone of protection. Some insecticides are not labeled for in-furrow application.

While some liquid insecticides can be broadcast or banded at the time of planting, research shows they are less effective than granular products. However, liquids can be effective after plant emergence. Liquids are sometimes used as "rescue treatments" in fields where outbreaks were not expected.

Growers can now plant transgenic corn that is toxic to corn rootworm larvae. Texas trials show that growers can expect control equal to, or in some cases better than, the best soil-applied insecticides. Transgenic technology offers a few important advantages over traditional insecticides. Transgenic hybrids perform far more consistently. The toxin in a transgenic plant is expressed in the plant tissue and thus is not affected by soil moisture, pH and other conditions. Another advantage is that people and the environment are not exposed to insecticides.

There are two transgenic toxin systems on or near the market now: Monsanto's Bt Cry3Bb1 toxin, which is moderately toxic to corn rootworm larvae, and a binary (two-part) toxin from Dow/Mycogen/Pioneer. The latter toxin is very toxic to larvae and is expected to receive EPA approval for use in the near future.

Transgenic corn is not immune to corn rootworm larvae, and the concentration of toxin in the root system declines as the growing season progresses. A weedy field may reduce the protection offered by transgenic hybrids because corn rootworms can survive, at least for a time, on certain grass species. It is currently thought that uncontrolled grass weeds provide a food source that allows larvae to develop past the point where they would be killed by transgenic hybrids, and these larvae can later move into and damage corn. This phenomenon is still under investigation, but grassy weeds may be involved in the recent failures of transgenic corn in the Midwest.

Expect to see surviving adults in fields of Cry3Bb1 Bt toxin transgenic corn because, while it provides adequate root protection, it kills only about 75 percent of larvae (depending on several other factors). These survivors are not a worry for the crop, but they may be of concern in managing resistance to the Bt toxin. The more acutely toxic hybrids being developed will leave fewer larvae to survive to adulthood.

Transgenic technology needs to be protected, so growers should follow the Insect Resistance Management (IRM) guidelines for the type of transgenic corn they are growing. A good way to check on the IRM regulations is to visit the National Corn Growers Association (NCGA) Web site at *http://www.ncga.com/*. The NCGA cooperates with the seed industry to provide extensive education and training on the use of transgenic corn. We have not included current guidelines in this publication because they may change as transgenic corn moves through the registration or re-registration process.

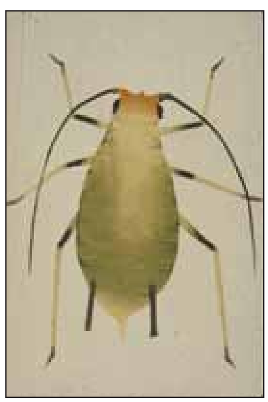
Why not just kill rootworm adults to avoid silk clipping this year and prevent an economic infestation of larvae next year? The idea is appealing, but it often causes unintended problems and may not accomplish its goals. In the late 1990s on the High Plains, many growers discovered that the synthetic pyrethroid insecticides they used to kill rootworm beetles also greatly increased spider mite populations and may have contributed to pyrethroid resistance in mites. Also, because rootworm beetles live for several weeks, they would often move from neighboring fields to treated fields after the insecticide degraded. A significant number of eggs were then laid in treated fields despite the investment in insecticide. Adult control is a very complicated matter and is outside the scope of this publication. The University of Nebraska is a good source of information on this method.

The USDA-ARS and university cooperators carried out four large trials in the late 1990s to determine whether adult rootworms could be controlled on large areas and thus eliminate the need for soil-applied insecticides. The results of this program are still being evaluated, but interest seems to be fading. The idea was to incorporate small amounts of insecticide in an adult feeding stimulant to kill beetles before they could lay many eggs. The USDA used 16- x 16-mile-square sites for the studies. While the concept had some appeal, especially in terms of reduced insecticide use, difficulties did arise. Texas growers should not attempt to control adults on individual farms when silk pruning is not a concern because beetles may become resistant and because a very large area must be treated before benefits accrue. The USDA warns that any effective program will require substantial oversight and close coordination between growers.

Corn Leaf Aphid and English Grain Aphid

Rhopalosiphum maidis and *Sitobion avenae*

Corn leaf aphids.



English grain aphid.

Parasitized aphid "mummies."

Biology

The most common aphid in corn is the corn leaf aphid, which often builds to very high numbers just after the tassel stage. The corn leaf aphid is bluish green with a darker green head. The English grain aphid is not nearly as common, but can also be quite numerous in some years. It is yellowish green to reddish brown. The antennae, cornicles and leg joints are black. Aphids are small, about $^{1}/_{8}$ inch long when mature. The immature stages look like smaller versions of the adults. Adults can be winged or wingless. Populations can increase rapidly because females are born pregnant and give birth to live young.

Several characteristics make aphids easy to identify. Most (including the two pest species on Texas corn) but not all aphid species have cornicles. These are projections arising from the rear part of the abdomen. Some people call these "stovepipes," which is not a bad description. Aphids are slow moving and very soft bodied. They have straw-like piercing and sucking mouthparts with which they extract liquids from leaves. Finally, because most aphids are flightless, they tend to form colonies and will be found clumped in groups on the plant.

Damage

Large numbers of aphids on corn can look like a serious problem, but only rarely are they anything to worry about. This is because neither of these two common corn aphids injects toxic saliva into the leaf. However, corn leaf aphid can be a vector of maize dwarf mosaic virus.

At or near tassel, aphids do two types of damage, but neither is very serious except when populations are extremely high and/or corn is under drought stress. Aphids drink a lot of plant juice and expel a sugary liquid called honeydew from their bodies. Honeydew leaves a glistening residue on leaves and is usually the first thing noticed by novice scouts. Honeydew can become moldy, turn black, and eventually block photosynthesis because sunlight does not reach leaf cells. Honeydew residue is not thought to limit yield. However, aphids can limit yield when they cover the tassel and upper two or three leaves from the time of tassel emergence through pollination. Heavy populations of aphids can increase drought stress by removing water from the plant.

Scouting and control

Texas has no economic threshold for these aphids on corn. Seedling stage plants rarely require treatment for corn leaf aphid, but high numbers can cause stand loss. Older corn can tolerate high populations.

There is some benefit to having large numbers of aphids in corn. They are excellent food for many types of beneficial insects, many of which later disperse to other crops nearby. On balance, most entomologists consider aphids to be a positive because they do not do much damage to corn and they help build populations of early- and mid-season beneficial insects.

Fall Armyworm

Spodoptera frugiperda (J. E. Smith)

Fall armyworm larva.

Fall armyworm adult.

Biology

The fall armyworm is a sporadic but serious pest of corn in Texas and can damage corn from emergence through the hard dough stage. Larval damage may increase the levels of mycotoxin in grain and reduce yield.

Fall armyworm egg mass hatching.

Eggs are laid in groups of 100 to 200 and are covered by grey scales from the female moth's body, giving the egg mass a fuzzy appearance. Eggs are pearly green when newly laid and darken to brown in about 12 hours. Just before hatching, which occurs in 3 to 7 days, the eggs turn blackish.

Newly hatched larvae are light cream but turn green after feeding. Medium-sized larvae are green or brown. To distinguish young fall armyworm larvae from those of the corn earworm and southwestern corn borer, look for a small, black spot on the side of the first abdominal segment just behind the last pair of true legs on the thorax. Fall armyworm has such a spot, and the other two species do not.

Identifying fall armyworm:

- Inverted "Y" marking on the front of the head
- Four pairs of abdominal prolegs and one pair of anal prolegs
- Four "dots" on the top of the eighth abdominal segment

Pupa and larval stages of fall armyworm.

Older larvae vary in color from light tan or green to blackish, and can change color as they mature. They have three narrow stripes down the body as viewed from above—one down the centerline and two widely separated by darker areas. The stripes vary from white to yellow-white to reddish. There is a wider dark stripe down the side of the body and a wavy, yellow-red, blotched stripe just below this.

The most helpful identifying features do not involve color. Larvae have four pairs of abdominal prolegs and a pair of anal prolegs at the tip of the abdomen. They also have four dark spots arranged in a rectangle on the top of the eighth abdominal segment near the end of the abdomen. Older fall armyworm larvae can be distinguished from larvae of the true armyworm, corn earworm, and corn borer species by the presence of a white, inverted "Y" mark on the front of the dark reddish-brown, mottled, head capsule. This mark may be absent on younger larvae.

Newly hatched larvae are about $^{1}/_{25}$ inch long. When fully grown sixth- or seventh-instar larvae, they are about $1^{4}/_{10}$ inches long. The number of larval instars varies with the time of year, temperature, and quantity and quality of food.

Adult moths have a $1^{1}/_{2}$-inch wingspan. The female's front wings are dark grey. Wings of males have both light and dark areas throughout and a whitish area near the tip.

Fall armyworm adults migrate north from overwintering sites in south Texas and northern Mexico and become established in corn and other crops in the spring. Fall armyworm does not overwinter in the northern part of Texas and does not undergo winter diapause. This species has a very broad host plant range that includes wheat, alfalfa, sorghum, corn, and other crop and noncrop plants.

Larvae feed 2 to 3 weeks. Mature larvae burrow an inch or two into the soil to pupate. Pupation lasts for about 2 weeks. Pupae are smooth and reddish brown to dark brown in color and look much like the pupae of other lepidopterous pests of corn. Adults then emerge to mate, and females can lay up to 1,100 eggs. Adults live about 2 weeks. There are several generations each year, and migratory moths may continue to arrive throughout the season.

The fall armyworm and true armyworm get their names from the behavioral trait that causes larvae to move from one field to another when they have consumed all available food. They move *en masse*, like an army.

Damage

Fall armyworms feed on a very wide range of plants from broadleaves to grasses that include corn, bermudagrass and rice. They will attack corn from the seedling stage through maturity, feeding on leaves and ears. Depending on the corn growth stage, injury may be only cosmetic or it may cause serious economic loss. If the growing point of small corn is damaged the plant will be stunted and unproductive.

The appearance of leaf damage changes as larvae mature. Early injury by small fall armyworm larvae looks like “windowpane” areas on leaves. (Other species that cause such damage are the southwestern corn borer, European corn borer, and corn rootworm adults.) Injury in the whorl stage may appear as small- to medium-sized holes or “shot-holes” evenly spaced across the width of the leaf. Feeding by larger armyworms causes elongated holes up to several inches long across the width of the leaf. One tell-tale sign of fall armyworm feeding is the large amount of light-colored, coarse frass (excrement) left on the leaves and in the whorl. Large numbers of fall armyworms will leave a field looking very ragged and “shot-up” with leaves torn and broken at the mid-ribs. This can be confused with grasshopper damage, but grasshoppers are rather obvious and their frass is less fluffy than that of fall armyworm. Later the corn may have red-streaked foliage and husks where bacteria have invaded damaged plant tissue.

Fall armyworm damage to the ear is similar to that caused by corn earworm, but while corn earworm damage is usually confined to the tip, the fall armyworm may also feed back and forth along the length of the ear and cause more grain loss. The corn earworm enters the ear from the tip; the fall armyworm larva cuts an entrance hole in the side of the ear. When mature, the larva cuts a large exit hole near the butt end of the ear. Fall armyworms also can feed on the undeveloped tassel. Heavily infested fields may not pollinate properly if much tassel damage has occurred. Larvae also feed behind leaf collars, injuring plant nodes and interfering with the transport of nutrients to leaves and ears. Fall armyworms can bore into stalks but are far less likely to do so than the corn borer species.

Fall armyworm feeding damage can lead to serious aflatoxin problems and to infection by fungal ear rots if contaminated rain or irrigation water gets into the damaged ear through entrance or exit holes. Ears affected in this way may be completely lost.

Scouting

Fall armyworms do not cause economic losses in most years, but they do occasionally require treatment, especially on the Gulf Coast. Texas does not have established thresholds for fall armyworm, but some general guidelines may be helpful.

Scouting for fall armyworms can be difficult. In very young corn, look for consecutive plants that have severe leaf feeding. Because eggs are laid in masses, it is common to find relatively large, elliptical areas that are damaged as the larvae spread out from the egg mass. Check corn leaves and grasses in the furrow for egg masses.

While the growing point is below ground level, plants can withstand quite a bit of damage. Consider treatment if leaf feeding remains severe as the growing point nears the surface of the soil.

To find larvae in whorl stage corn, pull the whorl leaf from the plant and unfold it. Look for frass (larval excrement) and leaves ragged with "shot holes." Although this may look dramatic, leaf damage usually does not reduce yields greatly so controlling larvae during the whorl stage is seldom economically justified unless the infestation is severe. Insecticide application may be justified if larval feeding reduces leaf area by more than 30 percent or is damaging the growing point.

Later in the season, check for small larvae behind leaf collars and at the bases of primary and secondary ears. If mid-season control is deemed necessary, it should be targeted at small larvae before they have entered the primary ear and can no longer be reached with insecticides. Fall armyworm ear damage can be much more serious than that caused by corn earworm.

Pheromone traps can be used to determine when large numbers of adults are flying, but they cannot be used to make treatment decisions.

Control

Late-planted corn of full-season maturity is the most susceptible to damage. Plants often recover from whorl damage without a reduction in yield. Yieldgard Bt corn does not have much resistance to fall armyworms, but the new Herculex corn shows more promise.

Early detection and proper insecticide timing are critical. Larvae in the whorl may be protected from insecticides unless a relatively large volume of water carrier is used. Ground rigs should apply at least 8 gallons of water per acre, but a higher volume is preferable. Aerial application to whorl stage corn may not be as effective. Insecticide delivered through center pivot systems can be very effective.

If control is necessary after ear formation, target young larvae before they enter the ear.

Armyworm (True armyworm)

Pseudaletia unipuncta (Haworth)

Biology

Yellowstriped armyworm.

The armyworm or "true armyworm" is a caterpillar that may be confused with fall armyworm, yellow-striped armyworm, corn earworm, or several species of cutworms. Larvae of this species range from about $^1/_{16}$ inch long at first instar to about $1^1/_2$ inches when fully grown. Small larvae are at first a dull, translucent white with an almost black head capsule. As they mature, their bodies darken to light green, dark olive-green, and finally dingy black, while their head capsules and pronotal shields become lighter in contrast to the body, turning a shiny, grayish-yellow color.

Armyworms do not have the inverted "Y" mark on the front of the head that is seen in fall armyworms. The "eye" region on the head capsule of the true armyworm usually has a net-like or mottled pattern of light and dark areas, whereas that same area in the fall armyworm is a more uniform and darker color. The true armyworm has three faint white stripes on the back; two orange stripes bordered by white are on each side down the length of the body. Each abdominal proleg has a dark, diagonal band.

The adult is a light reddish-gray moth with a wingspan of about $1^1/_2$ inches. The front wings are pointed at the tips and there is a small, white spot near the center of each forewing.

True armyworms occur from southernmost Texas through most of Minnesota and are common east of the Rocky Mountains. There are three generations per year in Texas. In the southern part of their range they can overwinter in any life stage; in the northern areas they overwinter as half-grown to full-grown larvae.

Adult females lay up to 800 eggs over several days. Eggs are laid in rows or clusters of 15 to 20, usually on grass and often at the point where the grass blade meets the sheath. Eggs hatch in

3 to 4 days and larvae develop over 3 to 4 weeks in normal weather conditions. When the temperature is a constant 80 degrees F, larvae spend an average of 3 days per instar. They pupate in the soil, usually burrowing to a depth of an inch or more before constructing the pupal cell. Pupation lasts 9 to 21 days, with an average of about 13 days.

Damage

The first visible evidence of armyworm damage is “windowpaning” of corn leaves. Small armyworm larvae in the whorl may eat through one or more layers of the rolled leaf, making several holes across the width of the leaf. Later damage will appear as small holes eaten in the leaf or small areas of the leaf edge eaten away. Late-instar larvae may eat large sections of leaf edges, leaving only the midrib. If there is excessive defoliation, yield will be reduced and stalks will dry prematurely, which can cause lodging.

Armyworm feeding damage.

Corn, small grains, forage crops, and many grass and broadleaf weed species are the preferred hosts. Armyworms are more common in corn grown in reduced tillage or no-till systems, or in cultivated fields where grass weeds are a problem. If armyworms are present when grass weeds in or near corn are killed by cultivation or herbicides, the surviving armyworms will move to the crop. Also, as cereal crops mature, or if they are defoliated by armyworms, the armyworms may migrate in large numbers to nearby corn crops. Large populations of armyworms can completely defoliate a corn crop.

Scouting

Look for armyworm larvae in grass crops and weeds outside the field, and on weeds inside the field. If corn leaves are chewed, determine whether the source of the problem is the true armyworm, fall armyworm, corn earworm, grasshoppers, or some other pest.

Control

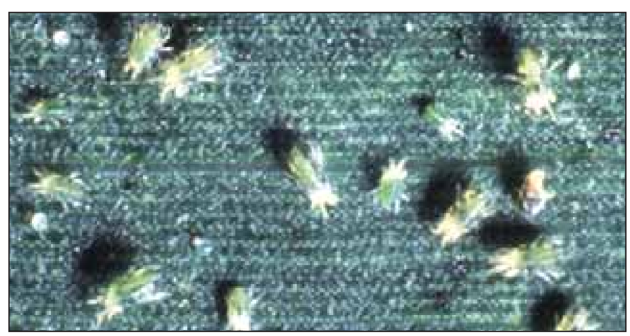
Controlling grass weeds in or around fields and in nearby small grain crops often prevents an armyworm problem. The treatment threshold is when an average of three leaves per corn plant are destroyed by larvae. It is often economical to treat the margins of a declining or devoured corn field in which large numbers of armyworms are present.

Spider Mites

Banks grass mite – *Oligonychus pratensis* (Banks)

Twospotted spider mite – *Tetranychus urticae* Koch

Banks grass mite   Twospotted spider mite



Banks grass mites.

Spider mites are a widespread and serious problem in the High Plains and Rio Grande Valley regions. Although areawide infestations may not reach damaging levels each year, there can be locally damaging infestations yearly. Populations begin to increase early in the growing season, but temperature, rainfall, drought stress, and pesticide applications for other pests affect this pest’s significance in a particular year.

Biology

Spider mites are not insects, but they are close relatives. They belong to the Acarina group that also includes ticks. Spider mites are extremely small; the eight-legged adults are barely visible without magnification. Larvae (six legs), protonymphs (eight legs) and deutonymphs (eight legs), the other life stages, are even smaller. A 10X or greater hand lens is necessary to detect spider mites and eggs.

High Plains corn is affected by four spider mite species, but the Banks grass mite (*Oligonychus pratensis* (Banks)) and the twospotted spider mite (*Tetranychus urticae* Koch) are by far the most important. Banks grass mite is usually the most abundant species throughout the season, but twospotted spider mites increase later in the season and can become serious pests, especially if insecticides eliminate beneficial insects after tasseling.

It is critical that the particular mite species be identified before miticides are applied because each may require a different miticide. A product applied to control Banks grass mites might have little or no effect on twospotted mites. The primary way to differentiate between the two species is to examine the outer edges of the body where the dark food sacks appear. In Banks grass mite adults, the food particles extend all the way down both sides of the body. In the twospotted mite, the food particles form dark areas toward the front of the body, and the mites appear to have only two spots when viewed from above.

This identification method works only with adults, and even then it is not always accurate. If a good microscope is available, the two species can be distinguished by looking at the empodium claw on the first segment of the tarsus (foot). The Banks grass mite has an extended, curved empodium claw. The empodium on the twospotted mite is not extended and not curved.

Both species of spider mites produce webbing. It is not very noticeable when colonies are small, but becomes more prominent as larger portions of the leaf are infested. Twospotted spider mites produce more webbing than Banks grass mites.


Banks grass mite colony webbing.

Both mite species move from wheat and noncrop vegetation to corn, usually assisted by wind. It takes only 6 to 10 days for a mite to develop from an egg to an adult. Adult females live an average of 23 days and lay about 45 eggs during this time. Development occurs most rapidly at temperatures of 77 to 98 degrees F and is probably favored by low humidity. Offspring generally stay near the female on the underside of a leaf, and together they form a colony. Colonies remain on lower leaves during the vegetative growth stages of corn and, under the right environmental conditions, move up the plant as the season progresses and damage on lower leaves expands.

Once corn reaches the reproductive stage, mite populations increase more rapidly, possibly because of changes in plant biochemistry at this time. Also, mites are favored by the hot, dry weather that usually coincides with the reproductive stage of corn. Mites develop more quickly on corn suffering moderate drought stress, and more slowly on fully irrigated corn or corn with severe drought stress. Cool, wet weather often reduces mite populations significantly. Fields should be rescouted for mite numbers after such weather.

Damage

Spider mites can damage and kill the leaves of young corn plants, but serious early-season infestations are usually confined to field margins exposed to prevailing winds.

Spider mites suck juices from the plant and kill the plant tissue. It is estimated that a twospotted spider mite can puncture 18 to 22 leaf cells per minute. Small colonies cause oval areas of dead tissue, generally near the midrib on the underside of a leaf. As colonies grow, they spread out on the leaf, and the area of dead plant cells enlarges. Eventually, mites can cover and kill entire leaves. Lower leaves are usually killed first. If left unchecked, mites will move up the plant killing more leaves. Severely infested plants may have dead leaves even above the ear leaf.

Spider mite feeding alters the chlorophyll content, transpiration and photosynthesis of a leaf. Yield is reduced because dead leaf cells cannot manufacture the carbohydrates needed for grain filling. Banks grass mite and twospotted spider mite do similar amounts of damage at similar densities. Yield can be reduced by as much as 20 percent, even after a producer has incurred the high costs of irrigation and insecticide applications. Heavily infested plants may develop stalk rot later in the season, which can cause harvest losses from lodging. However, studies differ as to whether spider mite damage contributes significantly to stalk rot. Spider mites do not affect yield after corn reaches the dent stage.

Scouting

When mite numbers are low, look for individual colonies near the midrib on the undersides of lower leaves. Rather than look for individual mites, look for the eliptical chlorotic areas that result from their feeding. Also scout for beneficial species that help keep low populations of mites in check. These include thrips (western flower thrips and the six-spotted thrips) at field borders during the early part of the growing season. The spider mite destroyer (*Stethorus punctum*), minute pirate bugs (*Orius* spp.), and predatory spider mite species such as *Neoseiulus fallacies* are known mite predators. Their ability to suppress mite species often declines as the mite population grows rapidly when corn enters the reproductive stage.

If an insecticide, especially a synthetic pyrethroid, is used on the field for any nonmite pest, expect it to kill most of the beneficial species present. If the insecticide is used at tasseling or silking, it will kill beneficial species at precisely the time that mite populations begin their most rapid growth. Scouting should intensify well before tasseling and continue weekly until the dent stage is reached.

With the right weather and water stress conditions, mite colonies will grow to cover more leaf area, making their webbing more apparent. Moderate mite infestations that have killed many of the lower leaves often can be seen from the road. When mites are found, identify the species; it will be important in choosing a miticide.

Texas spider mite treatment thresholds are dynamic and based on plant damage, pesticide costs, and crop value. The thresholds help determine whether a miticide should be applied as soon as possible. The thresholds do not allow one to predict mite populations at some future date based on current field counts. This is important to know because, to be effective, some miticides must be applied well before action thresholds are reached. Current thresholds are not helpful in making this decision.

To use the economic thresholds in Table 9:

Step 1. Estimate the per-acre cost of control and the expected per-acre value of the crop. Then scout several areas of the field and determine the percentage of leaves that are infested by colonies of any size. To do this, look at whole plants and divide the number of mite-infested leaves by the total number of leaves. Check Table 9 for the first number in what looks like a fraction under the

Table 9. Economic injury level for the Banks grass mite and/or twospotted spider mite on corn, based on the percentage of infested leaves per plant/percentage of leaf area damaged.

Control cost ($) per acre	Market value ($) per acre										
	200	250	300	350	400	450	500	550	600	650	700
5	15/8	12/6	10/5	8/5	7/4	7/3	6/3	5/6	5/3	5/2	4/2
10	29/16	24/13	20/10	17/9	15/8	13/7	12/6	11/6	10/5	9/5	8/4
15	44/23	35/19	29/16	25/13	22/12	20/10	18/9	16/9	15/8	14/7	13/7
20	59/31	47/25	39/21	34/18	29/16	26/14	24/13	21/11	20/10	18/10	17/9
25	74/39	59/31	49/26	42/22	37/20	33/17	29/16	27/14	25/13	23/12	21/11

appropriate row (control cost) and column (market value) heading. If your percentage of leaves infested equals or exceeds this number, go to step 2 and determine the percentage of leaf area damaged. If your percentage is lower than this number, continue to monitor the field over time.

Step 2. To determine the percentage of leaf area damaged, look at all the leaves on a plant (damaged and undamaged) and estimate the percentage of the total leaf area that is chlorotic because of mite feeding. Then refer to the second number (the one after the "/" mark) in the appropriate place in Table 9. If your percent leaf area damaged equals or exceeds that number, it is time to treat the field.

Control

It must be understood that Banks grass mites and twospotted spider mites co-exist in fields, and the suggested miticides are not necessarily the same for both species. It is usually difficult to control the more common Banks grass mite, and attempting to do so usually kills beneficial insect and mite species. This often leads to outbreaks of twospotted spider mites, which are extremely difficult to control with any miticide on the market at this time. Growers often give up on fields where twospotted spider mites are the predominant species.

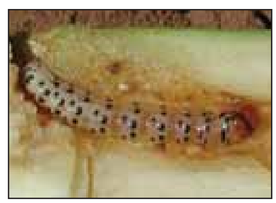
There are three miticides that can be applied early, before populations reach threshold levels. They are hexythiazox (Onager®), spiromesifen (Oberon®), and propargite (Comite®). These products "set back" the growth of colonies by killing the immature stages, but not necessarily adults, although propargite is effective on adults when spray coverage is good. The well-timed use of these products may prevent a far more serious problem later. However, if mite numbers have reached the threshold level, a rescue treatment is in order, and these miticides are not appropriate. Rescue treatments may not be effective, especially since some spider mite populations have developed resistance to organophosphate and pyrethroid insecticides. New miticides may be available soon, so contact your county Extension agent for information on available products.

Corn in the High Plains area frequently reaches the economic threshold for second-generation southwestern corn borer after silking. If an insecticide treatment is needed for southwestern corn borer and mite populations are relatively low, choose a nonpyrethroid insecticide that will not "flare" mite populations. Methoxyfenozide (Intrepid®) and spinosad (Tracer®) are two such products. If, however, mite populations are increasing rapidly, consider tank mixing a miticide with the southwestern corn borer insecticide.

As mentioned above, spider mite populations increase most rapidly when corn is moderately drought stressed and the weather is hot and dry. Corn reaches its peak water demand from silking to grain filling, precisely the time spider mite infestations begin their rapid increase. Adequate irrigation at this time is a good way to both maximize yield and minimize spider mite numbers to the extent possible.

Southwestern Corn Borer

Diatraea grandiosella Dyar



First generation southwestern corn borer larva.

Southwestern corn borer adult.

Biology

Where it occurs, the southwestern corn borer is a major pest of corn that often causes significant yield losses. The adult stage is a dull white to cream-colored moth. Newly emerged moths have faint tan lines along the wing vein margins. As moths age this feature becomes less evident. The palpi at the front of the head protrude forward to give the appearance of a snout. The wingspan is $1^{2}/_{10}$ to $1^{6}/_{10}$ inches. When at rest, the wings are folded roof-like over the abdomen, and the moths measure $^{7}/_{10}$ to $^{9}/_{10}$ inch from the snout to the rear edge of the wing. Males are usually smaller than females.

Eggs are laid singly or in masses. An individual egg is elliptical, measures $^{3}/_{100}$ inch by $^{5}/_{100}$ inch, attaches flatly to the leaf surface, and has a convex shape when viewed from the side. Most eggs are laid in masses, with each egg overlapping the next to produce a pattern that looks like fish scales or roof shingles. When first laid, the eggs are translucent to creamy white. About 24 hours later, three parallel, equally spaced, red lines appear. The head capsule of the larva becomes visible through the eggshell 24 hours before hatching. At this time the three red lines become less distinct and the egg is reddish orange. This stage is called the “black dot stage.” Eggs hatch in about 5 days, depending on the climate. The emerging larva cuts a slit at the end of the egg. The shell of the egg can remain on the plant surface for several weeks after emergence.

Newly hatched larvae are dull red with rows of small spots from front to back. As the larva develops to later instars, the dark spots become very prominent against a creamy white body. The head is reddish brown to yellowish brown. A fully developed larva enters a pre-pupal stage, during which it is immobile and molts before pupation. The pupa is dark reddish brown and measures $^{1}/_{2}$ to 1 inch. Males are typically smaller than females, and the pupal stage is the first stage at which sex can be easily determined.

Larvae overwinter in the crown of the corn stalk. They pupate in the spring and emerge from corn stubble or an alternate host. The adult leaves the pupal case behind in the crown. After mating, female moths begin to lay eggs on the leaves of whorl stage corn. Moths live 1 to 5 days and lay an average of 384 eggs. First-generation eggs are laid from late May to early June in the Texas High Plains region. Most eggs are laid on leaves, primarily on the upper leaf surface. After hatching, larvae migrate to the whorl to feed. As corn reaches the late whorl stage, usually when larvae are in the third- or fourth-instar stage, larvae move out of the whorl to feed behind leaf collars and then bore into the stalk. Once feeding is complete, the larva prepares a cell in a tunnel for pupation. Above the larva, the tunnel exits the plant, but a thin layer of stalk tissue is left to cover the exit hole. By the time pupation is complete, the plant tissue covering the exit has become brittle and the adult moth can easily push it open to emerge.

Moths emerge from early evening until about 11:00 p.m. Adults mate the night they emerge or the following night and begin laying eggs, with 76 percent of the eggs being laid the first night after mating. First-generation moths live 3 to 10 days. Each first-generation female lays an average of 498 eggs. Most eggs (more than 75 percent) are laid on the upper leaf surface, either singly or in masses averaging two to three eggs each. Masses may contain up to 15 eggs, but such a large egg mass is very uncommon.

Upon hatching, second-generation larvae move behind leaf collars to feed on secondary ears and at the base of secondary ears. After feeding for 7 to 11 days, the third- or fourth-instar larvae tunnel into the stalk. Their tunnels are usually located in a zone extending from the primary ear down to the ground. After 25 to 35 days of feeding, larvae tunnel into the lower portion of the stalk to the apex of the root (also known as the root crown), where they create hibernacula or overwintering cells. They then move up the tunnels to girdle the stalk from the inside above ground level. This leaves only a thin layer of tissue holding the stalk erect. The larvae then move back to the overwintering cell, molt a last time, and lose their spots before overwintering. Plants girdled by larvae soon lodge. Plants that have lodged appear to have been cut off with a knife, usually 2 to 6 inches above the ground.

Damage


Southwestern corn borer leaf feeding.

Both first- and second-generation southwestern corn borers can cause economic damage. First-generation infestations occur during the whorl stage of growth. Larvae produce shot holes and elongated translucent areas in leaves where the tissue is not completely eaten away. If feeding is confined to the whorl, there may be no reason for concern unless corn is planted late and is in the early whorl stage when infestation occurs. In the early whorl stage, larvae can bore down through the whorl into the growing point, which causes “dead heart” and kills the plant. Yield loss per individual larva is greater for first-generation infestations than for second-generation. Research shows that the yield of plants infested by first-generation southwestern corn borers can be reduced as much as 19 to 20 percent. However, because first-generation borers usually infest less than 5 percent of the plants in a field, most of them near field margins, damage at this time is not usually a concern.

Southwestern corn borer stalk girdling.

Second-generation damage occurs behind leaf collars, in ears, and inside the stalk. A larva feeding on the primary ear can damage the ear shank, which may cause the ear to drop when corn reaches maturity. Larvae also feed on kernels, usually near the base. But they sometimes move up a row of kernels and reduce grain yield. When larvae tunnel in the stalk they damage conductive tissue and predispose the stalk to disease pathogens. Yield losses from second-generation infestations can range from 9 to 11 percent. If both first- and second-generation infestations occur on the same plant, yield might be reduced as much as 29 to 30 percent, not including losses from lodging.

Scouting

First-generation southwestern corn borers can be very easy to detect because of the characteristic shot holes and elongated translucent areas on leaves that their feeding produces. European corn borers, corn earworms and fall armyworms also feed in the whorl, and their damage may look somewhat similar to that of southwestern corn borer. Once a scout becomes familiar with the damage caused by the various whorl-feeding larvae, it is usually possible to distinguish the species. If there is any doubt, remove the whorl from the plant and unroll the leaves to see which pest is present. Inspect 40 to 80 plants per field for first-generation infestations. If a field is large, it is best to inspect 80 plants. Inspect five consecutive plants at each stop in the field. First-generation infestations rarely reach the economic threshold, but can occasionally require treatment. The economic threshold used for the first generation is when more than 10 to 15 percent of the plants are infested. The value of the crop determines how aggressive one will be in managing first-generation larvae.

It is more difficult to detect second-generation infestations because scouts look for eggs and not larval damage. Scouting is usually done after tasseling from mid-July to mid-August in the High Plains. About 80 percent of second-generation eggs are found from four leaves below the ear leaf to two leaves above the ear leaf. In general, eggs are laid in the ear zone. Scouting time can be reduced by about half by just scouting these seven leaves on the plant. Since scouting for southwestern corn borer eggs is very time consuming, not as many plants can be inspected as during the whorl stage. A field should be divided into four quadrants and ten plants inspected per quadrant—six plants per quadrant if time is limited. Record each egg mass found and the number of plants infested. After the first week of egg lay, scouts should also look for small larvae. If hatched eggs are found on a plant, use a knife to cut down each side of the leaf collar to inspect for first-instar larvae. Also inspect the leaf collar above and below the leaf where the egg mass was found. Always inspect the base of the primary ear of plants with hatched egg masses. A clear, gelatin-like material at the base of the ear is a sign of feeding by southwestern corn borer. If this is observed, but no larva is found, then remove the ear and peel back the husk to see if a larva is feeding on the kernels. Often a hole can be seen at the base of the ear going through the husk to the kernels. The ear shank should also be inspected for tunneling because this is a site where larvae are often found. This damage is similar to that of European corn borer feeding. Record the number of plants infested with larvae and eggs so the percentage of infested plants can be determined.

A temperature-dependent model for predicting the emergence of adult southwestern corn borer in Texas was developed in the 1980s. The model uses average daily mean maximum and minimum temperatures and information on the larval instar distribution in a specific field. Larval instar distribution is determined by collecting a sample of 30 to 50 first-generation larvae from a field, using a chart to determine the head capsule width of each larva, and then assigning an instar stage to each larva based on the width of the head capsule. The instar distribution is then entered into the model along with current or historic temperatures to get a prediction of the emergence date for first-generation moths (which will lay second-generation eggs). This information helps field scouts and consultants concentrate the scouting for eggs during the emergence period.

The threshold for second-generation infestations is when 20 to 25 percent of the plants are infested with eggs or newly hatched larvae.

Control

Destroying corn stubble is one of the most effective ways of managing southwestern corn borer. A single tandem disc cultivation, or shredding the stalks close to the soil surface, kills most overwintering larvae. Knifing is also effective because it lifts the root crown from the soil. Knifing and shredding are good cultural practices to use when fields will continue to be used for grazing cattle into the early spring. Double discing and deep plowing also can be effective because they bury root crowns below the soil surface, making it difficult for adult borers to emerge. Crop residue should be destroyed before late January to kill the most larvae. These cultural practices are most effective when carried out by all producers in a region.

Other practices can help prevent losses from borers. Planting early allows corn to mature early enough to avoid excessive damage. Corn harvested before mid-September in the Texas High Plains usually has minimal lodging from borers even though considerable girdling may have occurred. Thinning corn to a moderate density is also a good idea because it allows plants to produce larger stalks. Larger stalks, combined with adequate irrigation and fertilizer, makes plants more resistant to lodging. Another effective cultural control method is crop rotation. Usually the farther corn is planted from last year's stubble, the less likely it is to become economically infested. Planting next to last year's stubble often results in an infestation in field margins adjacent to the old stubble. By the time the second generation of southwestern corn borer occurs, the infestation can be distributed over the field.

Insecticides are usually very effective in controlling southwestern corn borer. The timing of pesticide applications is very important; they are most effective at egg hatch. Some products, such as synthetic pyrethroids, are effective when applied after egg hatch but before the third-instar larvae bore into stalks. This is usually a 7- to 11-day window for treating the pest. Applications for second-generation southwestern corn borer can be made aerially or by chemigation through a center pivot. Both methods are highly effective. Aerial application should be made with 3 to 5 gallons of water per acre to help the insecticide penetrate the foliage in the lower canopy. With narrow-row corn, use 5 gallons of water per acre for best penetration. Chemigation is typically done with irrigation rates of 1/4 inch per acre to prevent the dilution of the insecticide to a less than optimal concentration. Application rates of up to 1 inch per acre have been acceptable for southwestern corn borer control, but may not be best for pests such as fall armyworms or spider mites that are being targeted with the same application. These pests are more difficult to control.

Insecticides that control southwestern corn borer often have a detrimental effect on beneficial arthropods. If spider mites are in the field, they can increase rapidly once the beneficial species that suppress them have been removed. A miticide or a combination of products that will control or suppress mites can be combined with insecticides applied for southwestern corn borers.

Transgenic corn hybrids for managing southwestern corn borer have recently become available. These hybrids contain genes of the bacterium *Bacillus thuringiensis* (Bt), which produces a toxin in the plant tissue. This toxin is toxic to the larvae of many butterfly and moth species, but has no effect on the adults. Bt hybrids developed in the late 1990s are highly effective. Hybrids currently sold in Texas with events MON810, Bt 11 and Cry 1F control both first- and second-generation southwestern corn borer. Since southwestern corn borer has a limited host range, the possibility that it will develop resistance to Bt hybrids is a concern. The EPA has mandated that corn growers plant refuges of non-Bt corn so that an adequate number of susceptible southwestern corn borer moths will be produced to mate with potentially resistant moths. The use of refuges will help delay the development of resistance.

European Corn Borer

Ostrinia nubilalis

Biology


European corn borer larva.

The European corn borer is found from the Panhandle southward to Lubbock, then eastward to about Longview, and south to near Jasper. It is not known to occur in South Texas or on the Gulf Coast, and the Texas Department of Agriculture maintains a quarantine in order to protect these areas. European corn borer is a major pest of corn in all areas east of the Rocky Mountains northward into Canada, although it has become less abundant in recent years. The reasons for the decline are not understood. Some people suggest that Bt transgenic corn has reduced populations. Others believe that the reduction of corn acreage in the Panhandle has had some effect. Still, European corn borer can sometimes reach economically damaging levels.

Young larvae are a dull white color and have dark head capsules. A larva has four sets of prolegs on the abdomen and a set of anal prolegs on the tip of the abdomen. The bottoms of the abdominal prolegs (essentially the sole of the foot) have a small, black dot in the center that can be seen with a 10X hand lens on larger larvae. The southwestern corn borer does not have a black dot on the bottom of the prolegs. Older European corn borer larvae are pale brown, pinkish or light grey; they have few if any hairs and a dark gray stripe down the center of the back. The top of each abdominal segment has two round, dark spots, but these larvae do not have the “polka dot” appearance of the southwestern corn borer.

Male and female moths are a little different in appearance, but both are rather small compared to other moths found in corn. Females have a wing span of about 1 inch and are pale yellow to yellowish brown. They have irregular, somewhat darker brown to tan bands running across the wings; these often look like waves. Males are smaller and darker than females and have darker wing markings. Both male and female moths have a pointed triangular shape when at rest.

There are two generations that affect corn. A partial third generation occurs but does not do significant damage. Full-grown larvae overwinter in corn stalks, ear shanks, cobs, weed stems or other field debris. These larvae complete development in the spring. The first flight of adult moths occurs in May or early June. Eggs are laid on vegetative stage corn, with first-generation moths preferring to lay eggs on taller (earlier planted) corn. Corn is susceptible to European corn borer infestation after the V6 growth stage, but survival is higher on V8 to V12 plants because these contain less of the toxic compound DIMBOA. Eggs are creamy white and laid in fish scale-like clusters of five to 30. They are usually laid near the midrib on the underside of a leaf, but egg clusters can be found elsewhere. Eggs hatch in 3 to 7 days and turn more yellowish as hatching nears. During the final 24 hours of egg development, the dark head capsule of the larva can be seen inside the egg shell. This is called the “blackhead” stage. European corn borer egg masses do not develop the red lines that characterize eggs of the southwestern corn borer.

First-generation larvae feed in the whorl, often boring through the rolled-up tissue. When this tissue later expands or is unrolled, there appears to be a row of “shot holes” across the leaf. It is also common to find “windowpanes,” or areas where small first- and second-instar larvae have left a layer of transparent leaf tissue. Medium-sized larvae feed on leaf sheaths and tunnel into midribs. Third-instar larvae, which are about $^{1}/_{2}$ inch long, bore into stalks and feed until they pupate approximately 2 weeks later.

Moths emerge in mid-summer, mate and begin to lay eggs. It has long been thought that moths congregate in weedy areas adjacent to fields and then move into fields during the night. Recent research at the University of Nebraska has shown that in fields irrigated with center pivots there isn't as much congregation and moths tend to follow the pivot to some extent.

The second generation of moths prefers to lay eggs on later-planted corn, and is especially attracted to fields in the early silking stage. Most egg masses are laid on the undersides of the leaves nearest to, and including, the ear leaf. Eggs hatch in 3 to 5 days and about three-quarters of the small larvae move to leaf axils to feed on pollen and leaf tissue. The remaining one-quarter feed on the ear sheath and collar tissue. After feeding externally, most fourth-instar larvae bore into the stalk in and above the ear zone. Other larvae feed longer in the ear zone before boring into the stalk, ear shank or tassel. Fifth-instar larvae prepare to enter diapause (overwintering stage), or they pupate to become adults that lay eggs for a third generation. Diapause is determined by environmental conditions such as day length and temperature, and by the genetic makeup of the larva. Partial third-generation flights do occur in the Panhandle. Any larvae these moths produce that have not reached the fifth instar and entered diapause by the time of the first freeze are killed.

Damage

The most significant damage done by the European corn borer is to plant tissues that conduct water and nutrients. This ultimately leads to poor ear development and reduced yield. Secondary losses are caused by dropped ears, broken stalks, lodging, and stalk rot diseases.

Scouting

Begin to examine whorl stage corn in late May or early June. Look for egg masses on the undersides of leaves, and watch for shot hole or "windowpane" feeding on leaves in the whorl. It is often necessary to pull damaged whorls from plants because the insect causing the problem could be a fall armyworm, beet armyworm, southwestern corn borer, European corn borer, or some other species. Look for broken midribs caused by the feeding of late second- and early third-instar larvae, and look for frass at holes in the stalk.

Many consultants use pheromone traps or blacklight traps. These traps do not help determine when fields need to be sprayed, but they do indicate when first- and second-generation flights are occurring. Many Extension IPM agents also use pheromone traps and report trap counts in their weekly newsletters.

Begin to look for second-generation European corn borer at tasseling. Look for egg masses on the undersides of leaves in and near the ear zone. Examine the sheath, collar tissue, and leaf axils for frass and small larvae. Broken midribs can indicate tunneling by third-instar larvae. Look for frass and entry holes in the stalk. Broken stalks and dropped ears appear later. Larvae might also feed lightly on the tips of kernels.

When scouting for both first- and second-generation European corn borer, examine at least 20 consecutive plants at a minimum of five locations per field. For first-generation infestations, an insecticide application is justified if 50 percent of the plants are infested with an average of at least one larva per plant. For second-generation infestations, an insecticide is justified if there are 10 to 20 egg masses, hatched and unhatched, per 100 plants. Two insecticide applications may be required to control the second generation.

Both southwestern corn borer and European corn borer damage stalks and interfere with physiological processes in the plant. They often occur at about the same time, with some difference in peak activity. When both species are present in a field as eggs or small larvae, economic thresholds should be adjusted downward. For instance, if a field is near threshold for southwestern corn borer and has a moderate (but below threshold) level of treatable European corn borers, then, in total, the field is over threshold for stalk-boring pests.

Control

Some cultural practices reduce the number of larvae that successfully overwinter. The European corn borer is far more apt to overwinter anywhere in the plant than is the southwestern corn borer, which generally builds its overwintering chamber in the crown of the plant below the soil line. Cultivation, stalk shredding, double discing, and deep plowing will reduce the survival of European corn borer. However, knifing has relatively little effect on this pest.

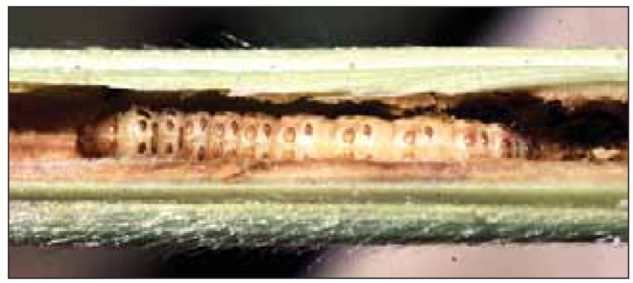
When choosing an insecticide, consider the effect an application might have on spider mites. Applications for corn borer control can cause mite populations to become far worse. Please read the section on spider mites for a discussion of proper insecticide choice in this situation. Spider mite numbers must be carefully evaluated before treating corn borers. Consider adding a miticide to the tank mix if pyrethroid insecticides are to be used. The insecticides spinosad (Tracer®) and methoxyfenozide (Intrepid®) are effective for stalk borers but do not promote spider mite outbreaks.

Transgenic corn prevents economic damage from both European corn borer and southwestern corn borer. Transgenic crops are very valuable in areas where corn borers are a perennial problem, and many growers are planting them in areas such as the South Plains of Texas. However, parts of the Panhandle are required by EPA regulation to maintain a 50 percent refuge of non-Bt corn. The northern tier of Panhandle counties must have at least a 20 percent refuge. These refuges can be sprayed for corn borers if necessary. Transgenic corn is an excellent tool for corn borer control, and refuge requirements are in place to delay the development of resistance to the Bt toxins the transgenic hybrids contain. The EPA is developing technology that will allow refuge compliance to be checked from satellite images.

Seed companies that sell transgenic corn have partnered with the National Corn Growers Association to develop and distribute educational materials about managing insect resistance. This information is available on the NCGA Web site (*http://www.ncga.com/*) and is updated to reflect the latest EPA regulations. The North Central Regional Committee number 205, a working group of scientists from many states, has an excellent publication on preventing European corn borer resistance to transgenic crops. It can be found at the University of Minnesota Extension Web site (*http://www.extension.umn.edu/distribution/cropsystems/CD7055.html*) under publication number 07055. This publication will be updated in 2006.

Sugarcane Borer and Mexican Rice Borer

Diatraea saccharalis and *Eoreuma loftini*

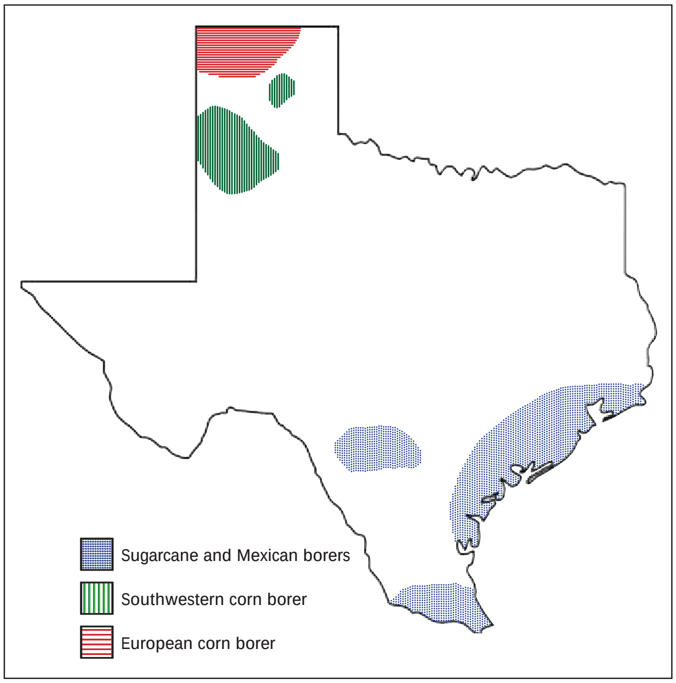


Sugarcane borer larva.

Sugarcane borer adult.

Mexican rice borer larva.

These stalk borers are a problem along the Gulf Coast and in the Lower Rio Grande Valley. The sugarcane borer is the most common species damaging corn, but the Mexican rice borer can be severe in certain years. These borers do not commonly occur on the High Plains, but their close relatives the southwestern corn borer and the European corn borer are significant pests in the north.



Biology

The sugarcane borer and Mexican rice borer (and southwestern and European corn borers) belong to the Crambidae family of moths, and the adults and larvae look very much alike. A fully grown larva is about an inch long, has four pairs of prolegs on the abdomen, a light body, and a darker head capsule. The head capsule on a sugarcane borer is dark and becomes almost black at the mouth, while the head capsule on a Mexican rice borer is orange-brown to reddish. The Mexican rice borer has relatively long hairs (setae) on the body, whereas setae on the sugarcane borer are short and difficult to see. The Mexican rice borer has four purplish lines running lengthwise down the top of the body. The sugarcane borer has two indistinct, light brown lines.

The adults of both species are shaped like a narrow, elongated triangle and are buff white to light tan in color, about the same shade as wheat straw. The Mexican rice borer moth has one prominent black spot just past halfway down the wing, while the sugarcane borer has many faint brown spots that, taken together, suggest an inverted "V" shape over the abdomen when the wings are folded and viewed from the top. As with any moth, don't rely on color patterns for identification if the wing scales are worn off or "rubbed."

The way they tunnel in corn stalks can be used to help differentiate the species. The sugarcane borer tunnel typically runs vertically inside the stalk. The Mexican rice borer also tunnels vertically, but often produces horizontal or diagonal tunnels as well. The exit holes made by adults as they leave the stalk are a little different. The Mexican rice borer leaves a clean hole and the sugarcane borer usually leaves webbing attached to the hole.

The cream-colored eggs of each species are laid in clusters and look like overlapping fish scales. The sugarcane borer usually lays 12 to 25 eggs per cluster; the Mexican rice borer lays five to 100 per cluster. As they age, eggs of the Mexican rice borer develop four purplish lines on their top surfaces. Eggs of the sugarcane borer darken as they mature but do not develop these lines.

The Mexican rice borer has four to six generations per year, and the sugarcane borer has four or five. A complete generation occurs in about 43 to 48 days depending on temperature. They overwinter as late-stage larvae and pupate in the spring. Adults become active in April and May. Because moths emerge over a fairly long period of time, and because larvae develop on many grass species, the distinct population peaks found in many other borer species do not occur. In general, though, populations increase as the season progresses.

Damage

Newly hatched larvae feed externally on leaf sheaths and soon bore into the stalk or ear shank. Corn attacked in the pre-tassel stage usually suffers minor losses unless stalks lodge. However, major damage can result when corn is infested after silking. Bored stalks most frequently fall during ear filling or ear maturation, and may lodge in high wind. The stalks may break at any point along their length, not necessarily at the soil level as with southwestern corn borer damage. Besides tunneling in stalks, larvae may also bore up the center of the ear shank and the center of the cob, which predisposes the ear to falling. Larvae eat kernels, which often produces a purplish discoloration of the grain from the growth of certain fungi.

Scouting

These borers do not overwinter in corn stubble but are present on many grasses and grass crops, including sorghum. They usually reach pest status on corn about the time of tasseling and later. Sugarcane borer lays eggs on leaves near the ear zone or on the ear. Mexican rice borer lays eggs over a much larger area of the plant, even low on the stalk. Scouts should learn to recognize the distinctive egg masses of each species (see earlier description).

Texas Cooperative Extension is developing scouting routines and economic thresholds for sugarcane borer and Mexican rice borer. It is imperative that eggs and small larvae be detected and, if necessary, controlled before borers enter stalks and ears where they are protected from insecticides. Field experience has shown that control with foliar insecticides can be unpredictable. The reasons for this are unclear, but it may be that applications were made after many of the larvae had already bored into plant tissue.

Control

Fields with heavy, uncontrollable infestations can be harvested early (at a higher moisture level) before stalk lodging becomes severe. Louisiana recommends double disking or flailing or burning stalks immediately after harvest to reduce the number of insects that overwinter. These practices have not been evaluated in Texas.

Transgenic corn with Bt toxins is highly effective on sugarcane borer and Mexican rice borer, and many growers are choosing to use this technology. Unfortunately, there is a 50 percent non-Bt corn refuge requirement in effect for areas where these pests occur, so growers will still have at least half of their acreage planted to conventional hybrids. In 2005, a researcher at Louisiana State University reported genetic resistance in sugarcane borer to some types of transgenic corn. This discovery, while alarming, needs to be investigated further.

Western Bean Cutworm

Loxagrotis albicosta (Smith)

Hatching western bean cutworm eggs.

Biology

Head and pronotum of western bean cutworm.

Only the larval stage of western bean cutworm damages corn. The small larvae have pale bodies with brown stripes lengthwise along the back. As they grow, the brown stripes become indistinct. Fully grown larvae are about $1^1/_2$ inches long and light brown to pale gray. Behind the brown head is a wide, dark brown collar with three narrow, pale stripes.

Western bean cutworm moths are distinctively marked and are larger than the moths of most cutworm species. A heavy, pale tan or cream bar extends along the front of each forewing for three-fourths of its length. A small, round, white "eyespot" touches the back of this bar midway out on the wing. Beside this spot and nearer the wing tip is a larger, kidney-shaped spot. It is tan or cream with a white outline. The rest of the forewing is marked with dark brown and black. The hind wings are entirely white except for delicate crown outlines along wing veins and margins. Moths are active at night and hide in whorls or behind loose leaf collars during the day.

Western bean cutworm egg mass.

Eggs are laid on leaves and hatch in July. Larvae immediately begin to feed on the corn plant. If eggs hatch before tassels emerge, the tiny larvae move directly into the developing tassels and feed on pollen. Feeding damage to the tassel is seldom of consequence because corn plants produce a great excess of pollen.

After tassel emergence deprives the young larvae of protection, they move into the silks of emerging ear tips. When $^{1}/_{2}$ to $^{3}/_{4}$ inch long, many of the larvae enter the ear tips or bore directly through the husks and feed on the developing kernels.

There is one generation each year. The species overwinters as pre-pupae (full-grown larvae ready to pupate) in the soil. Pupation occurs in June, and moths begin emerging in early July and lay eggs shortly thereafter.

Eggs are deposited in clusters of five to 200 on the top surfaces of upper leaves. Seen through a magnifying glass, individual eggs are round but somewhat compressed from top to bottom, with several angular ridges running down the sides. When first laid, they are white with a thin red ring around the top. The eggs become pink or pale blue, then gradually darken to blue-black or dark purple as larvae develop within. They hatch 5 to 7 days after they are laid.

Damage

Economic damage from western bean cutworm is restricted to the northwest corner of the Texas Panhandle. The primary damage is caused by the worms entering ears and feeding on kernels. The resulting mass of chewed material and worm feces (frass) is very messy. The damaged area is often invaded by molds or fungi that cause ear rot.

Western bean cutworm may enter a corn ear through the open tip or by chewing through the husk into the side of the ear. If a cutworm enters an ear that is quite small, it may chew partly into the cob and cause the ear to be deformed and stunted. Later entry causes less serious damage; the larva eats kernels and no-longer-needed corn silk. However, Western bean cutworm larvae are not cannibalistic, so several of them may be present in the same ear and cause a tremendous amount of damage. Two or more larvae per ear can reduce yields by 30 to 40 percent. An infestation may lower the quality of ensilage.

As corn ears begin to mature in late summer, larvae complete feeding, migrate down the stalk, and burrow into the soil. Each larva forms a concentration of saliva and soil particles around itself, leaving only a small exit zone from which the moth will emerge the next summer. Throughout the winter this hard cell protects the larva from predators, drought, mechanical damage, and temperature changes.

Scouting

Field scouting for western bean cutworm is most efficient when correlated with corn maturation. Inspections should begin just before the corn tassels and should concentrate especially on later-planted fields or the least mature plants within a field. Less mature plants seem to be more attractive to the moths for egg laying. Check 25 plants in each of several locations in a field. Current guidelines say to apply pesticide when either egg masses or small larvae are found on 8 percent or more of the corn plants when 90 to 95 percent of the tassels have emerged. These are guidelines; much more work needs to be done to refine this threshold.

Control

Economic infestations seem to be limited to corn grown in sandy soils. Early-planted corn tends to escape much of the damage.

Since current Bt corn technology does little more than suppress western bean cutworm, insecticides are the primary means of managing economic infestations. To be effective, insecticides must be applied during a critical few days when most of the larvae are on exposed parts of the plants and before kernel feeding begins. These dates must be determined on a field-by-field basis. The best results have been obtained by spraying when corn is 95 percent tasseled. Before that time, some larvae may not have hatched, while others are already within the first flag feeding on the tassel but doing no real damage. After 95 percent of the tassels have emerged, silks are also beginning to show, and more larvae will be moving to ear tips where they will soon be safe from insecticides.

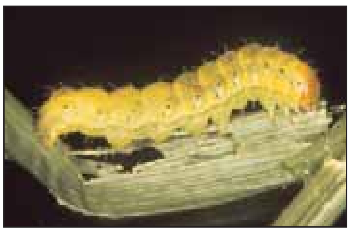
For aerial applications, use 3 gallons of finished spray product per acre to provide the adequate plant coverage necessary for control of this pest.

Corn Earworm (Cotton Bollworm)

Helicoverpa zea

Corn earworm larva.

Corn earworm adult.



Corn earworm larva.

Corn earworm egg.

Biology

The corn earworm is also the pest known as the cotton bollworm, and it is part of the sorghum headworm complex. There are several generations per year. Earlier generations (depending on the region of the state) develop on other crop and noncrop hosts, lay eggs on corn around the time of silking, and then move to cotton or late-planted corn in subsequent generations. While bollworms can be quite serious in cotton, they are not much of a worry in field corn except for their role in increasing the level of mycotoxins in grain. However, the corn earworm is a major pest of sweet corn because it is the typical "worm in the ear" that can be undesirable in the marketplace. It also can do economic damage in seed corn fields.

The corn earworm has many alternate hosts on which populations can build before corn begins to silk. Females prefer green silk as an egg-laying site, and the single, white to yellowish eggs can be seen on silk with just a bit of training. Eggs hatch in about 3 days and the larvae begin to feed on silks. As they age and grow larger they retreat into the shuck to feed and develop. There are five larval growth stages, and mature larvae are about $1\frac{1}{2}$ inches long. The corn earworm larva is cannibalistic, and while there may be more than one small larva in an ear tip to begin with, there is usually only one per ear by the time the larvae mature. Pupation takes place in the soil.

Larvae have many microspines on the back and sides of the body; these are not found on other common corn pests. Larvae have tan heads and alternating dark and light stripes running lengthwise down their bodies. They have many tubercles (dark spots) with long spines. Other pest species have stripes as well, but they do not have the abundance of microspines and tubercles, and a 10X hand lens will help you make an identification. There is no typical larval color; they may be light green, dark green to grey green, or pink.

Adults have buff-colored wings and rather stout bodies. The wingspan is approximately $1\frac{1}{2}$ inches. They are good fliers, can easily move from field to field, and often arrive in large numbers on storm fronts.

Damage

Corn earworm larvae can damage whorl stage corn, but this is of little importance. Larvae clip silks, consume kernels, and leave large amounts of frass (excrement). Silk clipping can result in poor pollination. Most of the damage occurs at the tip of the ear, where an earworm will damage 12 to 15 full-sized kernels. Feeding lower in the ear is usually from other pests such as the fall armyworm or western bean cutworm, but late-season (dent stage) corn earworm infestations can move down the ear.

Corn earworm ear tip damage.

Scouting

Green corn silk is the corn earworm's preferred egg-laying site, so late-planted fields are at the highest risk because the population has likely increased by late season. Sweet corn and seed corn scouts should learn to recognize eggs on silks, but looking for them is time consuming. The idea is to detect a significant infestation before small larvae can reach the safety of the ear tip. Look for eggs, silk damage, and frass in silks. A good way to monitor corn earworm numbers in general is to operate a pheromone trap just outside the field. These traps are baited with lures that simulate females calling for mates, and they are very good at capturing males. Pheromone traps should be operated from emergence until plants are well beyond the brown silk stage. Look for increases in the number of moths captured, which indicate increased egg laying. An excellent reference is the "Northeast Sweet Corn Production and Integrated Pest Management Manual" published by the University of Connecticut.

Control

Corn earworm control, and by extension scouting for corn earworms, is not economically justified in field corn. However, insecticide applications are routinely made in sweet corn and are often made in seed corn fields.

It is commonly accepted that corn earworm damage can result in more infections of ear and kernel rots, thereby increasing the amount of mycotoxins in grain. However, relatively little is known about the relationship between corn earworm and mycotoxin levels at harvest. It is thought that the worst mycotoxin levels will occur when the corn has both large numbers of corn earworms (or other ear pests) and moderate to severe drought stress. Lower mycotoxin levels are expected when one of these factors, especially drought stress, is missing. These relationships are being investigated. If irrigation is available, apply enough water to minimize drought stress from tasseling through milk stage.

In the battle to control mycotoxin levels in field corn, it would seem that using insecticides is not a promising way to go. Corn earworm is very expensive to control because larvae in ears are protected from insecticide residues. Sweet corn growers apply insecticide every 2 to 7 days with the hope of leaving enough insecticide on the silks to kill small larvae as they begin to feed. However, this is not cost effective in field corn. Current recommendations are to harvest early, at higher moisture, when there is a concern about mycotoxins, and then immediately dry the grain to 15 percent moisture to stop the mycotoxin level from increasing. This will not lower the amount of mycotoxin in the grain, but it will keep it from increasing during storage.

Grasshoppers

Order Orthoptera, Family Acrididae

Unlike many pests that seem to appear quickly, grasshoppers build up slowly over the course of the season. The key to grasshopper management is to detect them early outside the field and control them before they enter the field in large numbers. Unfortunately, adult grasshoppers are difficult to control, so the most effective strategy is to treat nymphs.

Grasshoppers cause some damage every year, but they become very destructive during outbreaks. The main factor affecting grasshopper populations is weather. Outbreaks, or exceptionally large populations, are usually preceded by several years of hot, dry summers and warm autumns. Dry weather increases the survival of nymphs and adults. Warm autumns allow grasshoppers more time to feed and lay eggs.

Biology

Grasshoppers have a high reproductive capacity. The female lays an average of 200 eggs per season, and sometimes as many as 400 eggs. Grasshoppers deposit their eggs $^1/_2$ to 2 inches below the soil surface in pod-like structures. Each egg pod consists of 20 to 120 elongated eggs cemented together. The whole mass is somewhat egg-shaped. Egg pods are very resistant to moisture and cold and easily survive the winter if the soil is not disturbed.

Eggs are deposited in fallow fields, ditches, fencerows, shelter belts and other weedy areas, as well as in crop fields, hay fields and alfalfa. Eggs begin hatching in late April or early May. Hatching peaks about mid-June and usually ends by late June. If spring weather is cool and extremely dry, hatching may be delayed and continue into July.

Young grasshoppers are called nymphs, and they undergo simple metamorphosis. They look like adults, but are smaller and have wing pads instead of wings. Nymphs go through five or six developmental stages and become adults in 40 to 60 days, depending on weather and food supplies. The adults of grasshopper species that damage crops become numerous in mid-July and deposit eggs from late July through fall. Usually only one generation of grasshoppers is produced each year.

There are six grasshopper species that commonly damage Texas corn. They all look very much alike, and they all do similar types of damage. The six species are the

- differential grasshopper, *Melanoplus differentialis*,
- red-legged grasshopper, *Melanoplus femurrubrum*,
- migratory grasshopper, *Melanoplus sanguinipes*,
- two-striped grasshopper, *Melanoplus bivitattus*,
- Packard grasshopper, *Melanoplus packardii,* and
- lubber grasshopper, *Brachystola magna*.

These are well described in Texas Cooperative Extension publication E-209, "Grasshoppers and Their Control."

Damage

Grasshoppers have chewing mouthparts. Their damage appears as large pieces of tissue removed from leaves. Feeding usually begins on the outside edges of leaves. Heavy infestations can remove all leaf tissue except for the midribs.

Scouting

Start watching for grasshoppers early in the season and begin control measures while grasshoppers are still nymphs and still within the hatching sites (roadsides, fencerows, etc.). Treating grasshoppers early means 1) having to treat fewer acres and use less insecticide, 2) killing grasshoppers before they cause extensive crop damage, and 3) killing grasshoppers before they can fly, migrate and lay eggs. Also, smaller grasshoppers are more susceptible to insecticides than larger ones.

You can estimate the size of a grasshopper infestation by surveying for nymphs or adults with the "square-foot method." Count the number of grasshoppers that hop or move within a square-foot area. Then take 15 to 20 paces and sample another square-foot area. Make 18 samples in all. Then add the numbers from each sample and divide the total by two to obtain the number of grasshoppers per square yard. The economic threshold for grasshoppers in corn is ten or more nymphs per square yard in crop margins.

Control

One way to control grasshopper populations is to eliminate sites where they might deposit eggs. Grasshoppers prefer undisturbed areas for egg laying, so tilling cropland in mid- to late summer discourages females. Tilling may reduce soil moisture and contribute to erosion, but those disadvantages must be weighed against potential grasshopper damage to the next crop.

In Conservation Reserve Program (CRP) acreage, tillage is not an option. However, plant tissue can be shredded to reduce the grasshopper food supply. Any implement pulled across CRP fields will crush many insects, but the cost of fuel might outweigh the benefits.

Controlling summer weeds in fallow fields has two benefits:

1) If grasshopper eggs are already in the field, there will be nothing for nymphs to feed on when eggs hatch.
2) Fields will not be attractive to egg-laying adults because there is nothing on which to feed.

Also eliminate tall grass and weeds from around any plants you wish to protect. This makes the area less attractive to grasshoppers and makes it easier for birds to prey on grasshoppers.

Grasshoppers have many natural enemies that help control their populations. A fungus, *Entomophthora grylli*, often kills many grasshoppers when the weather is warm and humid. Infected grasshoppers strike a characteristic pose at the top of a plant or other object. The grasshopper grasps the plant in a death embrace with the front and middle legs, while the hind legs are extended. It dies in this position. Fungal spores develop in and on the grasshopper's body, then become airborne and infect other grasshoppers.

Another natural enemy is a protozoan, *Nosema locustae.* Its spores have been incorporated with bran to make insecticide baits such as Semaspore®, Nolo Bait® or Grasshopper Attack®. These baits kill some nymphs but almost no adults, though infected adults lay fewer eggs. Baits act too slowly and kill too few grasshoppers to be useful for immediate control.

Other natural enemies include nematodes called hairworms and insects that feed on grasshoppers, such as the larvae of blister beetles, bee flies, robber flies, ground beetles, flesh flies and tangle-veined flies. Birds (quail, turkey, larks, etc.) and mammals also eat grasshoppers, but have little effect on large populations.

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