E-1300

Corn Insects
of North Dakota
Affecting the Crop after Emergence

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Cutworms

Several cutworm species affect regional crops (Figure 1). Three important cutworms, the dingy cutworm, *Feltia jaculifera*; the army cutworm, *Euxoa auxiliaries*; and the pale western cutworm, *Agrotis orthogonia*, overwinter as partially grown larvae. They are the first cutworm species to cause problems during crop emergence from late April to late May.

Female moths of the dingy cutworm are known to lay eggs on sunflower heads from mid-July through September. Crops following sunflowers in rotation are at greatest risk of injury from this species. Army cutworm moths migrate to the Plains from the Rocky Mountains in late summer and fall to lay eggs in soft soil of freshly cultivated weedy fields or newly seeded winter wheat. Army and pale western cutworms have been observed feeding as early as late April and as late as the end of May in southwestern North Dakota counties. Pale western cutworms prefer loose, sandy or dusty soil and are found most easily in the driest parts of the field, such as hilltops. In corn, the cutworms may cut off small seedlings at or below ground (Figure 2). As corn plants get larger, larvae can tunnel into the plant, feed on the growing point and kill the plant.

Other cutworms, such as the red-backed, *Euxoa ochregaster*, and the dark-sided, *Euxoa messoria*, overwinter as eggs that

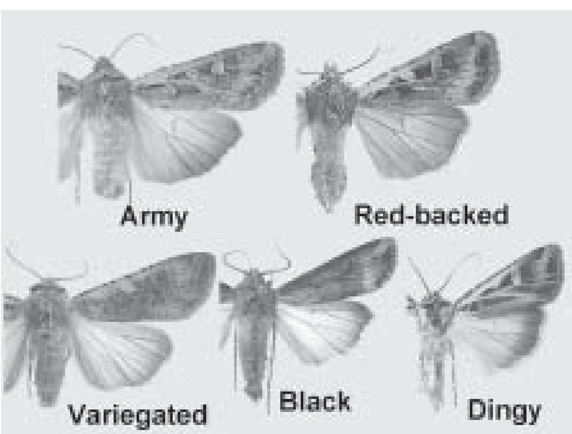

Figure 1. Wing markings of the common cutworm moths affecting corn production in North Dakota.

Figure 2. Cutworm larva feeding on corn seedling.

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hatch in mid to late May. Eggs are laid in the fall and survive in weedy, wet and reduced-tillage areas. Feeding injury from these cutworms normally occurs in late May to early June. The black cutworm, *Agrotis ipsilon*, and the variegated cutworm, *Peridroma saucia*, migrate into the region as adults and occasionally cause problems in row crops.

Some criteria that can help predict cutworm problems are: 1) field history of cutworm damage; 2) surface crop residue from reduced or minimum tillage; 3) bottom land or low spots in the field; 4) fair to poor drainage; and 5) proximity to shelterbelts or field margins with grassy ground cover. Because the important cutworms lay eggs during late summer in North Dakota, soil moisture at that time is important for their winter survival. Growers should be cautious when planting corn following pasture, alfalfa or clover. Cutworm survival may be greater in these types of locations.

Economic Thresholds

Begin scouting for cutworms when corn is emerged to a stand and continue until mid-June. Treat when 3 percent to 6 percent of the plants are cut and small (less than 3/4-inch-long) larvae are present. Use the lower percentage figure for lower plant populations (14,000 to 15,000/acre) and the greater figure with increasing plant populations (greater than 20,000/acre).

Scouting for Cutworms: Look for cutworm injury first on the corn leaves. This feeding injury helps identify potential problems. If you find leaf feeding, mark 100 plants in a row with stakes or flags so you can monitor these locations for plant cutting later. Do this in several places in the field if necessary. Return to these areas regularly to assess the infestation's progress. Scout fields until plants have five fully-developed leaves. Once plants reach this size, cutting the plant becomes very difficult for cutworms.

Cutworms are found in the soil during the daytime at the bases of plants, beneath soil clods or deep within soil cracks. If you see freshly cut plants, search near the base of these plants. Finding cutworms allows proper identification and age determination of the population based on larval sizes.

Postemergence Application: To control cutworms successfully after the crop has germinated, fields must be observed closely for developing infestations. In addition, to obtain acceptable control, make a bait or spray application while cutworms are small and immediately after you find an economic infestation. Crusting or a dry soil surface can reduce control potential of some insecticides and can be addressed through rotary hoeing immediately before or after the application. Pyrethroid insecticides have performed better without incorporation in most field studies. The effectiveness of current *Bt* corn hybrids against many of the cutworms is unknown.

True Armyworm, *Pseudaletia unipuncta*

The adult armyworm is a light brownish gray moth or "miller" (Figure 3) with a conspicuous white spot about the size of a pinhead on each front wing. When expanded, the wingspan is about 1½ inches. Armyworm larvae (Figure 4) are pale green in the early growth stage and dark green in later stages. Fully grown larvae are smooth, have longitudinal stripes and are almost hairless. They grow to a length of 1½ to 2 inches.

The true armyworm does not survive North Dakota winters. Armyworm infestations are due to moth migrations from the South during early June and July. Large infestations in Southern states occasionally produce significant moth flights that are blown northward. Outbreaks of armyworm larvae occur if weather, egg laying conditions and food supply are favorable when

Figure 3. True armyworm moth.

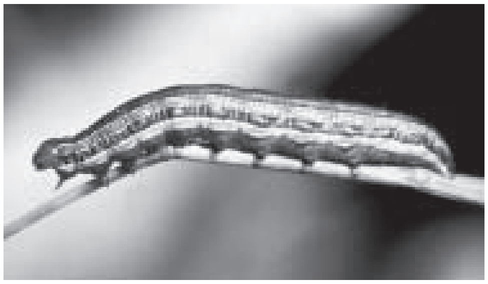

Figure 4. Armyworm larva.

moths arrive. However, parasitic insects that attack armyworms often increase rapidly and help prevent or minimize the extent of outbreaks.

Moths lay eggs at night in folded leaves or under leaf sheaths of small-grain plants and other grasses. They prefer to lay eggs in moist, shady areas of lodged, hail- or wind-damaged grains or grasses. Armyworm eggs look like small white beads arranged in masses or rows resembling miniature pearls. Larvae hatch from eggs in eight to 10 days. Feeding is complete in three to four weeks. If all the food is consumed at a site, larvae often move in hordes or "armies," eating and destroying vegetation as they move.

When feeding is complete, larvae move under litter and soil clods or burrow 2 to 3 inches into the soil, where they make small earthen cells and pupate. About two weeks later, moths emerge from pupal cases, mate and lay eggs for the next generation. Only one generation normally occurs in North Dakota.

Habits and Damage

The armyworm primarily is a pest of grasses, small-grain crops and corn in North Dakota. Feeding and movement occur at night or on cloudy days. Armyworms hide during the daytime under vegetation, loose soil or in soil cracks. Caterpillars consume more and more vegetation as they grow. Since they feed at night and hide during the daytime, armyworms often cause considerable damage before being discovered. Indications of armyworm feeding include leaf damage, worm frass (droppings) around the base of plants and severed leaf material that has fallen to the ground.

Economic Thresholds

Detecting and controlling armyworms while they are small and before they do extensive damage is extremely important. Do initial field scouting for armyworms in field margins, low areas with weedy growth and areas where plants have lodged.

In corn, treat when 25 percent to 30 percent of the plants have two or more worms or 75 percent of the plants have one worm. For migrating armyworms, treat a couple of swaths ahead of the infestation in the direction of movement to form a barrier strip.

Also, consider treatment if most armyworms are ¾ to 1¼ inches long and are damaging plants, and larvae are not exhibiting signs of parasitization (white eggs behind the head or small brown cocoons attached to the body). If armyworms are more than 1½ inches long, control likely will not provide economic return.

Common Stalk Borer, *Papaipema nebris*

This insect overwinters as an egg laid in grassy or weedy noncrop areas adjacent to fields. The caterpillar reaches 1¾ inches long, is purple to black colored with longitudinal white stripes that are interrupted by a conspicuous purplish band that rings the body in the region of the true legs.

Habits and Damage

Stalk borer larvae damage corn from mid-June to mid-July. Larger larvae migrate from smaller-stemmed grasses to larger-stemmed corn plants to finish feeding. Stalk borers tunnel into stalks or feed in the whorl. Feeding may kill center leaves of older plants, a symptom known as dead heart. Plants infested after the eight-leaf stage often tolerate the feeding with little to no visible injury. Plants along field margins typically suffer the highest levels of infestation, and damage usually is limited to the outer three to six rows of a field. No-till or minimum-tillage fields, particularly those with grassy weed escapes, may have damage more widely distributed over the field when planted to corn the next year. If persistent problems occur, rotation to a nonhost crop such as soybean aids in stalk borer management.

Use a degree-day (DD) model to predict the movement of stalk borer larvae from grassy weeds to corn. The model uses a base temperature of 41 F. When 1,300 to 1,400 DD have been accumulated from March 1, scout field margins for the presence of stalk borers.

Economic Thresholds

Insecticide treatment to the outer few rows usually is sufficient for managing stalk borers. Infestations of 15 percent to 50 percent may warrant treatment. Decisions are determined based on the percent of plants infested and leaf stage of the corn. Combinations of leaf stage and percent infestation used as economic thresholds are: one-leaf – 15 percent; two-leaf – 25 percent; three-leaf – 23 percent; four-leaf – 25 percent; five-leaf – 25 percent; and six-leaf – 50 percent.

Corn Leaf Aphid, *Rhopalosiphum maidis*

The corn leaf aphid (Figure 5) is the most common of at least four aphids that potentially can infest North Dakota corn. The aphid overwinters in Texas and winged migrants fly to the region each spring.

Populations include both winged and wingless females. They are a blue-green color with black legs, and have two tubelike projections at the rear of the body called cornicles. Females reproduce without mating and give birth to live nymphs. Numerous generations develop in a season. Colonies initially build up in the whorl, but move to other locations on the plant after tasseling. High numbers often occur on the tassels, and aphids also can be found on the silks and sheaths of developing ears.

Economic Thresholds

The corn leaf aphid is only an occasional pest of corn. Natural enemies, such as predators, parasites and fungal pathogens, often suppress populations. Insecticide applications for aphid management in corn rarely are justified. However, if large aphid populations develop on drought-stressed corn, treatment may be warranted. Use infestations of 50 to 400 aphids per plant on 50 percent of the plants as a treatment guideline.

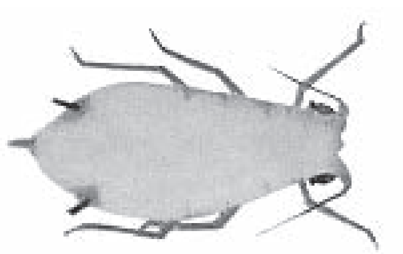

Figure 5. The corn leaf aphid is pale blue green with black legs and cornicles.

European Corn Borer, *Ostrinia nubilalis*

The European corn borer has been the region's No. 1 insect pest of corn. Managing corn borers in North Dakota is a challenge due to the lengthy interval of moths emerging from overwintering sites. In North Dakota, borers have the potential for one (univoltine) or two (bivoltine) generations during the season. The majority of recent corn borer problems in North Dakota have developed in mid to late July as a result of infestations by the later emerging and more numerous univoltine-type borer.

The bivoltine borer is present throughout the southeastern quarter of the state. Overwintered bivoltine corn borer larvae develop quicker in the spring, allowing them to pupate and emerge as moths earlier, usually in early June to early July (Figure 6). The univoltine type develops slower, resulting in later pupation and moth emergence in late June to late July. The univoltine borer is present throughout North Dakota. The result of this staggered emergence is a moth flight that could extend for a five- to six-week period in some areas. When these first-generation flights end, the true second-generation flight of bivoltine moths begins in August. Infestations can be observed in whorl-stage corn when the bivoltine members of the population are abundant in an area. Infestations develop in tasseling or older corn when univoltine members are most abundant.

The proportion of bi- and univoltine members within the corn borer population may shift from season to season. Multiple years with warm springs and late falls can result in a shift to more bivoltine-type borers. Cool

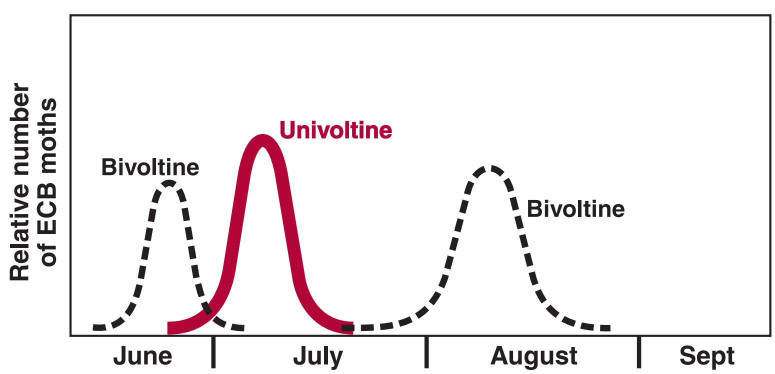

Figure 6. Approximate flight periods for moths of two-generation (bivoltine) and one-generation (univoltine) European corn borer populations in North Dakota.

springs followed by early fall seasons often shift the population to more univoltine-type borers. Because of this potential for shifting, field scouting during these first flight periods is critical to detect moth and larval activity, particularly in southeastern North Dakota, where bivoltine borers are more likely to be present.

Description

Adult moths are straw-colored with a 1-inch wingspan (Figure 7). Alternating light and darker wavy lines occur across the wings. Males are slightly smaller and darker. Egg masses are 1/8 to 3/16 inch long and contain an average of 20 to 30 eggs. Eggs usually are laid on the undersides of leaves near the midrib (Figure 9). Eggs within masses overlap like fish scales. As eggs develop, they change from white to a creamy color. Just prior to hatching, the black heads of developing larvae become visible through the shell; this stage is referred to as the black-head stage (Figure 10). Newly hatched larvae are 1/16 inch long, translucent white and have dark brown heads (Figure 11). Fully grown larvae of the European corn borer are up to 1 inch long and vary in color from gray to creamy white (Figure 8). Their body is covered with numerous dark spots and the head is black.

Life Cycle

European corn borers pass the winter as fully grown larvae in corn stalks, corn cobs, weed stems or other plant debris. Spring development resumes when temperatures exceed 50 F. The larvae pupate in June. Moths begin emerging in mid-June and continue well into July. Cool weather can delay the borers' development, whereas warm weather can accelerate development.

After emerging, moths spend the daylight hours in weeds and grasses bordering or within cornfields. Vegetation in these sites collects rain or dew droplets more effectively than the corn field. Moths use this water for drinking. Mating also occurs in these sites as females attract large numbers of males to where they are resting.

Eggs hatch in three to seven days, depending on temperatures. In vegetative-stage corn, hatched larvae move quickly into whorls and begin to feed. Larval feeding results in shot-holing of the leaves, which becomes more apparent as the leaves lengthen and emerge further from the whorl. Larvae feeding in tassel-stage or older corn can be found in leaf collars, tassels

Figure 7. European corn borer moth.

Figure 8. European corn borer larva.

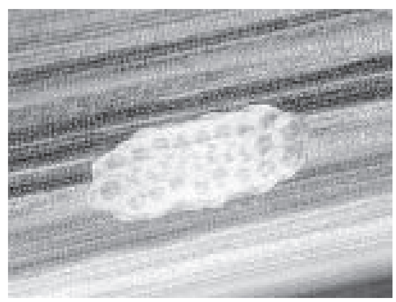

Figure 9. Newly laid eggs of the corn borer appear creamish white.

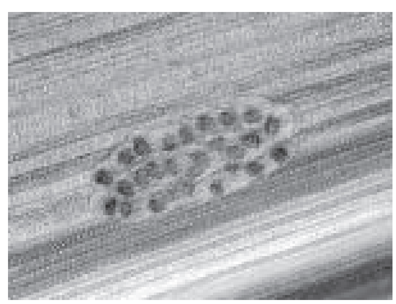

Figure 10. The black heads of developing larvae are visible just before hatching.

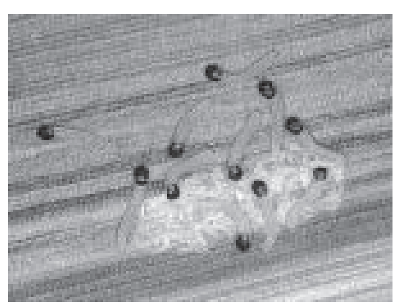

Figure 11. Newly hatched corn borer larvae.

and ear silks. Ten-day-old larvae reach a length about equal to the diameter of a dime and begin to tunnel into the midribs of leaves, followed by burrowing into the stalk, ear shanks and ears.

Damage

Yield losses due to European corn borer feeding damage to corn primarily are due to stalk tunneling that results in physiological stress. The later that larvae begin to tunnel in the development of the crop, the less direct impact on yield occurs, and risk of loss shifts to other potential problems. These additional risks occur when tunneling in stalks and ear shanks increases the risk of stalk breakage and dropped ears from persistent autumn winds, storms or dry conditions.

Management

Natural Control: Heavy rains that occur before borers are able to burrow into the plant may kill the insects by drowning them in whorls and leaf axils, or through physically removing them from the plant.

Cultural Control: European corn borers pass the winter as larvae in corn stalk residue. Harvesting corn for silage results in high corn borer mortality. Stalk shredding and deep plowing can reduce overwintering survival in individual fields, but seldom have significant impacts on populations on a regionwide basis because the highly mobile moths are capable of moving in from neighboring overwintering sites.

Field Scouting: The crop manager's challenge is to determine when egg densities and larval infestations can be tolerated and when control is needed. Corn should be monitored weekly for *at least* five weeks once plants have exceed an extended leaf height of 17 inches. Corn borer larvae are able to survive on the plant at this point. Inspect plants for the presence of egg masses, whorl feeding and live larvae. Observing moth activity around field margins or within a field may provide an alert to developing infestations.

Using Degree Days for Scheduling Scouting Activities: Degree-day models have been developed to predict the occurrence of bivoltine and univoltine flights of corn borer moths. The models predict occurrence of key biological events based on daily temperatures. As with other degree-day models, the models should help identify key times for field scouting. The bivoltine model predicts the appearance of first moths, peak flight and initial egg laying for both generations (Table 1). The univoltine model predicts the proportion of moths that have emerged (Table 2). Both models are based on accumulated degree days from April 1 when using a maximum-minimum, modified base 50 F, which is the same method used for monitoring corn growth with growing degree days.

The North Dakota Agricultural Weather Network (NDAWN) has a degree-day model to determine current degree-day accumulations for corn growth, which also can be used for monitoring corn borer emergence. NDAWN can be found at **http://ndawn.ndsu.nodak.edu/index.html** on the Internet.

Degree-day models also can provide information on the development of larval populations. Predictions of the

Table 1. Degree-day model (modified base 50 F) for predicting moth emergence and egg laying of bivoltine European corn borers.

Development Stage	Accumulated Degree Days
First Generation	
First spring moth	374
Peak spring moths	631
First eggs	450
Second Generation	
First summer moths	1,400
First eggs	1,450

(Source: J. Wedberg and B. Bland. 2004. Univ. of Wisconsin. www.mnipm.umn.edu/bugweb/publications/ecbnetwork/information/mnwipheno.htm. 9/30/04)

Table 2. Degree-day model (modified base 50 F) for predicting moth emergence of univoltine European corn borers.

Proportion of Moths Emerged	Accumulated Degree Days
10%	911
25%	986
50%	1,078
75%	1,177
90%	1,274

population's proportion for a given larval instar are possible by using univoltine moth emergence predictions and knowledge of degree-day development requirements for each larval instar (Figure 12). Make field scouting and treatment decisions before significant numbers of tunneling third-instar larvae are present. Third-instar larvae should be present by about 1,300 degree days.

Corn borers can be controlled with insecticides if they are applied correctly and applications are timed appropriately. Many insecticide treatments for corn-borer control are applied too late, and the usual assumption is that the treatment was a failure. In any one corn field, usually there are no more than seven to 10 days during which borers still are feeding in the whorl, leaf axils or other exposed sites and can be contacted by an insecticide treatment. Once borers tunnel into the stalk, you're too late to achieve effective control with any insecticide.

Treatment Decisions: Control of European corn borers in North Dakota during most years will be necessary only for first brood borers of either bivoltine or univoltine types. Second brood populations, or the second generation for the bivoltine borer, usually have minimal impacts on yield. Field scouting for first-brood borers should begin in late June and continue through July.

Determine the need to treat by using a simple threshold method based on percent of infestation or by a more dynamic threshold method that takes into account treatment costs, individual field yields and current market conditions (Table 3).

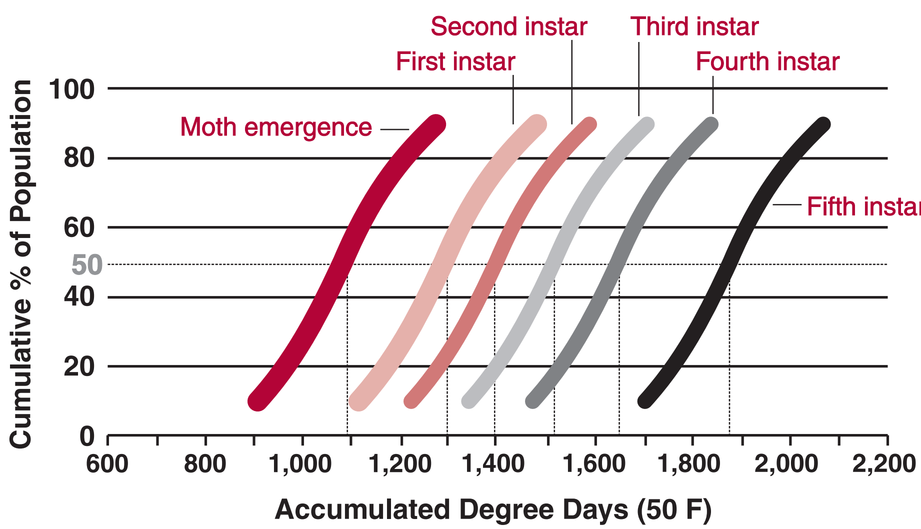

Figure 12. The expected occurrence of univoltine European corn borer life stages and the expected proportion of the population by degree-day accumulation. The degree-day accumulation for the 50 percent prediction time of a particular growth stage is indicated by the vertical dashed lines.

Table 3. Economic threshold (corn borers/plant) when factoring crop value and control costs.

Control Costs[2] ($/acre)	Value of Corn Crop[1] ($/acre)								
	200	250	300	350	400	450	500	550	600
6	0.75	0.60	0.50	0.43	0.38	0.34	0.30	0.27	0.25
7	0.88	0.70	0.58	0.50	0.44	0.39	0.35	0.32	0.29
8	1.00	0.80	0.67	0.57	0.50	0.45	0.40	0.37	0.34
9	1.12	0.90	0.75	0.64	0.56	0.50	0.45	0.41	0.38
10	1.25	1.00	0.83	0.71	0.63	0.56	0.50	0.46	0.42
11	1.38	1.10	0.92	0.79	0.69	0.61	0.55	0.50	0.46
12	1.50	1.20	1.00	0.86	0.75	0.67	0.60	0.55	0.50
13	1.63	1.30	1.08	0.93	0.81	0.72	0.65	0.59	0.54
14	1.75	1.40	1.17	1.00	0.88	0.78	0.70	0.64	0.59
15	1.88	1.50	1.25	1.07	0.94	0.84	0.75	0.68	0.63
16	2.00	1.60	1.33	1.14	1.00	0.89	0.80	0.73	0.68

[1] *Crop value = expected yield (bu/acre) X projected price ($/bu)*
[2] *Control costs = insecticide price ($/acre) + application costs ($/acre)*

Simple threshold:
In areas where bivoltine infestations in whorl-stage corn occur, consider treatment in field corn when 40 percent to 50 percent of the plants in dryland corn or 25 percent to 35 percent of the plants in irrigated corn have shot-holing damage in the whorls or egg masses on undersides of leaves, or live borers are visible in whorls. Be sure that live larvae still are visible in the whorls. If not, then very likely most borers have tunneled into the stalks, in which case an insecticide treatment will not be effective.

Dynamic Threshold:
Whorl-stage corn: Pull the whorls from 10 plants at five representative locations across the field. Select whorls at random, avoiding the purposeful selection of damaged plants. Unwrap the whorl leaves and record the number of live larvae found. Use the observations to determine percent of plants infested and the number of live larvae per infested plant. This method can work for both bivoltine and univoltine borers. Be aware that univoltine borers often infest corn in the tassel stage, causing some difficulties in checking for live borers on plants.

Tassel-stage or older corn: Examine the undersides of the middle seven leaves (three leaves above the ear, three leaves below and the ear leaf) on 20 plants from five representative locations in the field. Multiply the number of egg masses found by 1.1 (correction factor for eggs on other leaves). Complete the worksheet to determine the need for treatment.

Worksheet for whorl-stage corn — You fill in the blanks

1. ______	% of plants infested	x ______	avg no. borers/plant	= ______	borers per plant
2. ______	borers per plant	x ______	percent yield loss per borer*	= ______	percent yield loss
3. ______	percent yield loss	x ______	expected yield (bu/acre)	= ______	bushels per acre loss
4. ______	bushel loss per acre	x ______	price per bushel	= $______	loss per acre
5. ______	loss per acre	x ______	percent control**	= $______	preventable loss/acre
6. ______	preventable loss/acre	– ______	cost of control per acre	= $______	profit (loss)/acre

*5% for corn in the early whorl stage; 4% for late whorl; 6% for pretassel
**80% for granules; 75% for sprays.

Worksheet for tassel-stage or older corn — You fill in the blanks

1. ______	egg masses per plant*	x 4.5	borers per egg mass	= ______	borers per plant
2. ______	borers per plant	x ______	percent yield loss per borer**	= ______	percent yield loss
3. ______	percent yield loss	x ______	expected yield (bu. per acre)	= ______	bushels per acre loss
4. ______	bushel loss per acre	x ______	price per bushel	= $______	loss per acre
5. ______	loss per acre	x 80	percent control	= $______	preventable loss/acre
6. ______	preventable loss/acre	– ______	cost of control per acre	= $______	profit (loss) / acre

*Cumulative counts taken five to seven days later can be added here
**Use 0.04 for pollen-shedding corn, 0.03 if kernels are initiated

Genetically Modified Corn: Traits for European Corn Borer Management

A number of proprietary technology traits are available in corn that you should consider when selecting a hybrid. Many corn hybrids are available with single or multiple technology traits. One of the more widely used traits is the *Bt* trait for controlling corn borer and other caterpillar pests. These genetically engineered (transgenic) *Bt* corn hybrids contain genes that allow the plant to express an insect-specific toxin that renders the plant resistant to corn borer feeding. The gene for producing the toxin has been adapted from *Bacillus thuringiensis*, a naturally occurring soil bacterium. Several different events, or successful gene insertions, have been incorporated into the corn plant and developed and commercialized for use in corn borer management.

Bt Traits Available for Protection from European Corn Borer Include:

Herculex I® - This trait (Cry1F toxin) provides resistance to European corn borer, fall armyworm, black cutworm and western bean cutworm, and moderate resistance to corn earworm. The event is known as TC 1507. This transgenic trait is linked with glufosinate (LibertyLink®) herbicide tolerance.

YieldGard® Corn Borer - This trait (Cry1Ab toxin) provides resistance to European corn borer, southern cornstalk borer, southwestern corn borer and fall armyworm, and moderate resistance to corn earworm and common stalk borer. The YieldGard® trade name is used to identify *Bt* hybrids of two separate events, *Bt*11 and MON810.

YieldGard® Rootworm - Hybids with this transgenic trait (Cry 3Bb) have resistance to corn rootworm larvae, but not corn borer or other caterpillar pests.

YieldGard Plus® - These hybrids contain ECB - and rootworm - resistant traits (Mon 810 + Mon 863).

The National Corn Growers Association maintains a current listing of traits and their export status, titled **Know Before You Grow℠**, on the Internet at www.ncga.com/index.shtml

More information is available through the publication NCR-602, “Bt Corn and European Corn Borer — Long-Term Success Through Resistance Management.” This Web-based publication includes information on how *Bt* corn was created, details on how it works, safety, effects on beneficial organisms, economic benefits, strategies for minimizing resistance development and a glossary of terms to help understand the subject. NCR- 602 is available on the Internet at: www.extension.umn.edu/distribution/cropsystems/DC7055.html.

IRM: Insect-resistance Management

The Environmental Protection Agency mandates the insect-resistance management (IRM) plan, which is designed to preserve the usefulness of *Bt* technology, as a condition for granting the registrations that allow seed companies to market *Bt* corn. Each *Bt* corn grower has the responsibility to comply with the resistance-management guidelines when they sign the mandatory seed company/grower IRM stewardship agreement as they purchase *Bt* corn seed. Failure to comply can result in growers losing the privilege to use the technology, seed companies being restricted on their ability to sell the technology and the potential risk of losing future EPA registration of the technology.

The IRM plan requires that corn producers growing *Bt* corn establish a minimum of a 20 percent refuge of non-*Bt* corn on their farm. Non-*Bt* corn refuges must be planted within, adjacent to or near each *Bt* cornfield. Refuge (non-*Bt* corn) must be planted within one-half mile of the *Bt* corn and should be within one-quarter mile if the farm was located in an area where treatment of the refuge likely will occur.

The purpose of the non-*Bt* corn refuge is to produce a sufficiently large number of *Bt*-susceptible moths to mate with any potential survivors or potentially *Bt*-resistant individuals in the *Bt* cornfield. Without a nearby source of susceptible corn borers, resistant survivors likely will mate with each other, thus increasing the genetic trait for resistance in the population and producing a strain of corn borers that may survive on *Bt* corn hybrids.

Bt and non-*Bt* corn seed should not be mixed in the seed hopper. If you use a split planter arrangement to establish the refuge corn, refuge areas should be at least six rows wide to minimize the risk of resistance development due to larvae moving from plant to plant. Refuge corn cannot be treated with *Bt*-based insecticides. Refuges can be treated with other insecticides if corn borer populations within them exceed treatment thresholds. Spraying the refuge with a highly effective insecticide would threaten the purpose of the refuge planting.

Corn Rootworm

The western corn rootworm *(Diabrotica virgifera virgifera)* is regarded as the primary rootworm species of significance in North Dakota. Corn rootworm infestations have occurred in southeastern North Dakota since the early 1970s, although infestation levels fluctuate from year to year. The northern corn rootworm (*Diabrotica barberi*) and southern corn rootworm (*Diabrotica undecimpunctata howardi*) also occur, but generally at lower numbers.

Western corn rootworm beetles are about 1/4 inch in length, yellow-brown in color, with three longitudinal black stripes on the folded wing covers with yellow stripes in between them (Figure 13). Northern corn rootworm beetles are slightly smaller at 1/5 inch in length and are lime green to yellowish green in color, without stripes. Newly emerged adults are paler in color than older adults.

Corn rootworms overwinter in the egg stage. Eggs hatch in June during a period of several weeks. After egg hatch, the small, cream-colored, brown-headed rootworm larvae move to nearby corn roots and begin feeding on root hairs and small roots, progressing to tunneling and pruning of larger roots. Most rootworm larvae have matured and quit feeding by early July. They then construct a small pupal cell. Transformation from pupa to adult requires five to 10 days, depending on soil temperatures. Adult corn rootworm beetles usually begin emerging from the soil in early to mid-July. By the end of July, most larvae have changed into adult beetles. Following emergence, they feed, mate and lay eggs in corn fields. Females may lay 300 to 400 eggs in the upper 2 to 8 inches of soil, preferring moist areas with organic matter content above 1.5 percent. Beetles often use soil cracks at the base of corn plants as egg-laying sites. These eggs are the source of larvae that will attack the following year's corn crop.

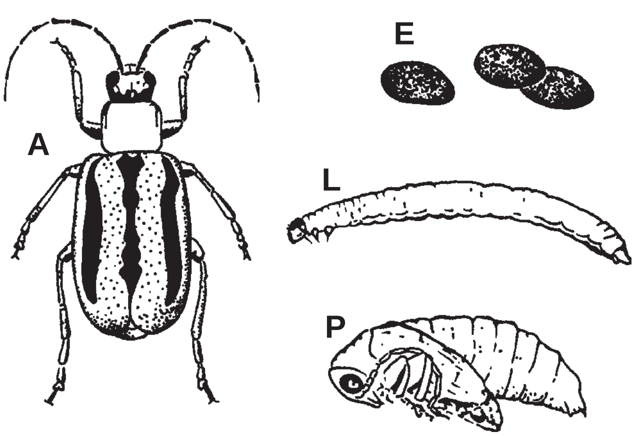

Figure 13. Western corn rootworm adult (A), eggs (E), larva (L) and pupa (P).

Feeding Damage – Adults

Rootworm beetles feed on the leaves, silks and pollen of corn. They also feed on pollen from other crops and weeds when corn becomes less palatable. Western corn rootworm beetles frequently feed on the more tender leaves of corn, especially if they emerge prior to silk and pollen production. Leaf feeding results in the green, upper surfaces of leaves being eaten off or skeletonized.

Occasionally, corn rootworm beetles congregate and feed on silks during early pollen shed. If peak emergence occurs at this time, the beetles can cause a sufficient amount of silk feeding to interfere with pollination. If silks are chewed back to tips of ears (less than ½ inch of silks protruding) during the first week of pollen shed, little pollination or grain set occurs. An average of five to seven rootworm beetles per silk mass can cause pollination problems. Silk removal after pollen shed does not reduce yield.

Management of Adult Rootworms

Control of adult rootworm beetles is justified if 20 percent to 25 percent of silks have been chewed back to a length of less than ½ inch protruding during the first week of pollen shed. Aerial application of insecticides can reduce beetle populations sufficiently to allow silk growth and pollination. Efforts to control silk feeding beetles after silks turn brown are not warranted.

Research is inconclusive as to whether controlling rootworm beetles before egg laying reduces larval population the following season. Therefore, adult control to prevent egg laying is not recommended.

Grasshoppers

The pest species of grasshoppers overwinter as eggs within pods that are laid in the soil, often near the bases of weeds or other plants. These elongate-shaped pods can contain from 20 to 120 eggs each. In the northern Plains, grasshopper egg hatch normally begins in late April to early May. Peak hatch occurs about mid-June. By August, most nymphs have matured to the adult stage. Grasshoppers feed during the day and rest during the afternoon and night on vegetation. Large infestations typically occur in areas of low rainfall and during drought years. Several years of hot, dry summers and warm autumns usually precede outbreaks. Cool and wet weather, especially during egg hatch and the early nymph stages, result in increased disease incidence and delayed grasshopper development, which can reduce the overall population.

Grasshoppers can be pests of many crops, mostly by feeding on leaves. Several species of grasshoppers can be found in crops, but only a few actually have pest potential. Populations can vary greatly from year to year. Damaging populations often develop in uncultivated areas, such as pasture and range, and move into cultivated fields.

Cultural Management

Early seeding: Allows for early establishment and vigorous plant growth.

Crop rotation: Avoid planting in areas of high-egg density. Fields with late-maturing crops or green plant cover attract adults, which then lay eggs.

Tillage: Fallow will act as a trap crop to attract females for egg laying. Spring tillage of these sites can reduce successful emergence of nymphs.

Treatment Thresholds

Grasshopper hatch often is concentrated in field margins. These areas should be monitored closely in the spring and early summer. Insecticide treatments directed at economic populations of young grasshoppers in hatching sites often can be made at lower rates and frequently require a smaller area to be treated than the entire production field. Later-maturing crops are attractive to adult grasshoppers in late summer and fall. In these situations, egg laying and subsequent hatch the next spring may be distributed throughout the field, necessitating management of grasshoppers in the entire field. Grasshopper populations that reach a threatening or greater rating are at risk of significant feeding damage and potential yield loss (Table 4).

Table 4. Grasshopper Infestation Ratings.

	Nymphs per square yard		Adults per square yard	
Rating	Margin	Field	Margin	Field
Light	25-35	15-23	10-20	3-7
Threatening	50-75	30-45	21-40	8-14
Severe	100-150	60-90	41-80	15-28
Very Severe	200+	120	80+	28+

Insecticides Approved for Use in Corn

For a listing of registered insecticides for use in corn, refer to NDSU Extension Service publication E-1143, the "North Dakota Field Crop Insect Management Guide." It is available through your local county Extension office or the NDSU Agricultural Communication office. The most recent issue also can be found on the Internet at www.ext.nodak.edu/extpubs/plantsci/pests/e1143w1.htm.

For more information on this and other topics, see: www.ag.ndsu.edu

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