Ecology and management of European corn borer in Iowa field corn

ECONOMIC IMPORTANCE

This publication discusses the European corn borer life cycle, injury to corn, and management options with a focus on Iowa field corn production. European corn borer, *Ostrinia nubilalis* (Figs. 1–2), is a moth in the family Crambidae (formerly Pyralidae). European corn borers in the Midwest affect corn production (i.e., field corn, popcorn, seed corn, and sweet corn), as well as sorghum, wheat, and many vegetables. Caterpillars can feed on almost any part of the corn plant, except roots, and cause severe economic injury (Fig. 3).

Figure 1. European corn borer caterpillar. [1]

Prior to the widespread planting of Bt corn, this insect was estimated to cost growers in the United States one billion dollars annually in yield losses plus control costs. With the advent of transgenic Bt corn hybrids in 1996, European corn borer populations significantly declined throughout the Midwest during the following decade. Even those farmers not using Bt corn benefitted from the dramatically lower population of European corn borers in the landscape. In recent years, Iowa farmers have gradually begun to plant more acres to hybrids without the Bt corn borer control technology, and populations of the insect have resurged in some areas.

Figure 2. European corn borer adult. [2]

DISTRIBUTION IN NORTH AMERICA

European corn borer is native to western Asia and Europe. It was unintentionally brought to the United States in the early 1900s, probably in broom corn, which was used to make hand brooms. The insect was discovered in Massachusetts and it quickly spread westward. European corn borers reached Iowa in 1942 and has been a consistent economic pest. This pest now occurs in nearly all corn-growing regions east of the Rocky Mountains.

Figure 3. Second generation European corn borers can tunnel into corn stalks and ear shanks. [3]

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LIFE CYCLE

European corn borer goes through complete metamorphosis and has four distinct life stages: egg, larva (borer or caterpillar), pupa, and adult (moth). The development through these four life stages comprise one generation. The larvae go through five molts, or instars. With each molt, the larvae shed their skin and get larger.

There are two generations of European corn borer per year in Iowa, but there may be a partial third generation in longer, warmer summers (Fig. 4). The insect survives the winter in Iowa by diapausing as a mature larva in cornstalks, corn cobs, corn residue, or weed stems. Diapause is a resting metabolic state that ends in April or May, and resume development when ambient temperatures exceed 50°F.

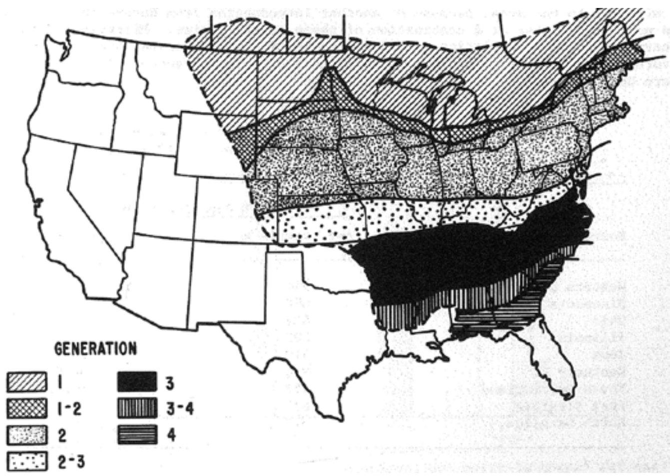

Figure 4. Approximate distribution of European corn borer generation zones in the United States. [4]

DESCRIPTION

Eggs. Female European corn borers lay eggs in small masses. The eggs overlap like fish scales, are somewhat flattened, and are approximately one-fourth inch in diameter (Fig. 5). An egg mass may contain up to 60 eggs, but the average number is 15 eggs in the first generation and 30 eggs in the second generation. First-generation females produce fewer eggs because they use energy reserves as larvae during the winter diapause. A mated female can lay an average of two egg masses per night for 10 nights, but most eggs are laid during the first six nights after mating. A second-generation female will lay about 400 eggs during her life.

Figure 5. Newly-deposited European corn borer eggs overlap in the mass. [3]

Egg masses are normally deposited on the underside of corn leaves, often near the midrib and on the basal two-thirds of the leaf blade. Newly deposited eggs are creamy white. For eggs that are about to hatch, the black heads of the larvae are visible through the translucent egg shells (Fig. 6). Egg hatch occurs 3–7 days after deposition, depending on the temperature.

Larvae. First instars, also called neonates, emerge from the egg (Fig. 6). The heads are distinctly black in young larvae and typically dark brown in full-grown larvae. The body color is dirty white in young larvae. In older larvae, the body may be a pinkish gray or pale brown with a dark gray stripe running the length of the body down the back and four small circular spots on the top of each body segment (Figs. 1, 10). Mature larvae are about one inch in length.

Figure 6. Neonate European corn borers. [3]

Pupae. The pupae are dark reddish brown with slightly rounded heads and pointed "tails" (Fig. 7). Live pupae will typically wiggle when disturbed. Second-generation pupae are found in cornstalks, corn cobs, corn residue, or weed stems.

Figure 7. European corn borer pupae are brown with tapered abdomens. [3]

Adults. European corn borer adults are about 1/2–5/8 inches long and nearly triangular in shape when at rest. The wings of females are a light buff color while males are a darker brown (Figs. 2, 14). Both sexes have irregular, wavy lines extending laterally across the front wings. Adults are smaller than other common pest moths (e.g., black cutworm, armyworm, western bean cutworm, and corn earworm).

Figure 8. Grassy areas next to cornfields are common aggregation sites for European corn borer moths. [6]

MATING AND EGG LAYING

In the spring, European corn borer moths emerge from crop residue and fly to areas of dense vegetation. These areas, called aggregation sites, are where adults find moisture, places to rest, and mates. Preferred aggregation areas include grasses, including bromegrass and giant foxtail in fencerows, roadside ditches, and conservation lanes (Fig. 8). In mid-summer, dense soybean stands also may serve as aggregation sites. Dew accumulates and is retained in grassy areas more effectively than in cornfields. Adults do not feed but must drink water. Unmated females must drink water before they begin emitting a sex attractant (pheromone), which occurs at night. Most adults leave aggregation sites at dusk; however, they return to aggregation sites, but not necessarily the same ones, before dawn.

Females normally begin mating the second night after emergence from the pupal case. Another three days are needed for the eggs to mature before they can be laid. Once ready to lay eggs, females leave the aggregation sites and enter cornfields. Egg deposition begins shortly after sundown and continues to midnight. After several nights of laying eggs, older females may return to aggregation sites to mate again. Adults tend to remain in grass during the day.

European corn borer dynamics are closely related to corn growth and development. Corn contains a natural European corn borer feeding deterrent called DIMBOA (2-4 dihydroxy-7-methoxy-1, 4-benzoxazin-3-one). The concentration of DIMBOA is highest in very young corn plants, and larvae feeding on V4–V8 stage plants have a poor chance of survival. As the plant reaches V9 and later, larvae have a higher probability of survival. Usually corn between stages V6–V10 is when most of the first-generation eggs are laid in Iowa (Fig. 9). Even if corn is at the optimal stage for laying eggs, dry winds, high temperature, heavy rainfall, and natural enemies may kill 70 percent, or more, of newly-hatched larvae.

First-generation females are attracted to the tallest corn plants for egg laying. In whorl-stage corn, most eggs are laid on the underside of fully-emerged leaves. Mated females prefer recently-tasseled corn plants (VT–R1) on which to lay second-generation eggs (Fig. 9). Ninety percent of the eggs are laid on the basal two-thirds of the underside of the three leaves above or below the ear, on the ear husk, and on the underside of the ear leaf.

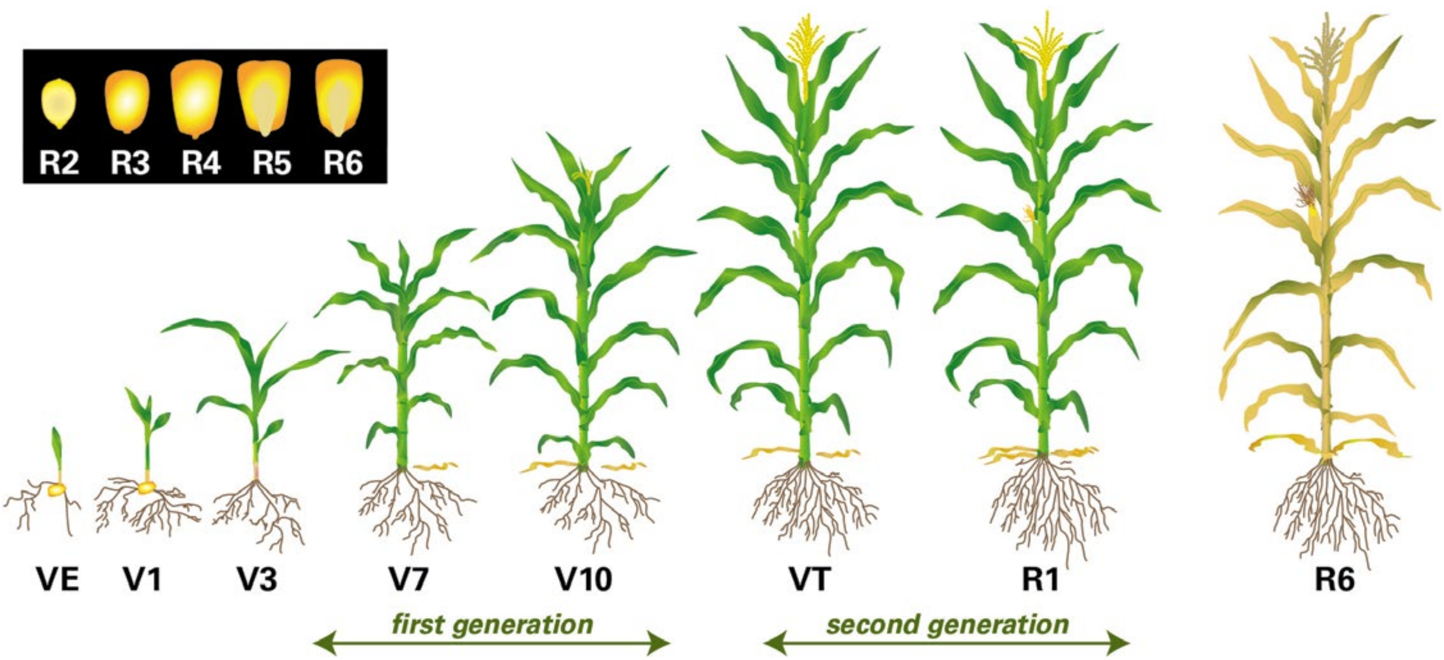

Figure 9. Corn growth and development in relation to the European corn borer life cycle. [5]

PLANT DAMAGE AND YIELD LOSS

European corn borers will feed on and injure almost any part of the corn plant except the roots. Feeding by first and second instars creates a windowpane effect on the leaves, because only one layer of transparent epidermis remains after consumption of the mesophyll (Fig. 10). Young larvae also chew holes through the unfurled leaves, creating a series of repeating-pattern holes, often called shotholes (Fig. 11a). Larval feeding can be seen by looking down into the whorl for injury to the young leaves (Fig. 11b). Larvae will tunnel into the leaf midrib, causing the leaf to break over. Older larvae crawl to and tunnel into the stalk (Figs. 3, 11c).

Figure 10. Young European corn borers can scrape the mesophyll off of corn leaves. [3]

European corn borer injury results in poor ear development, broken stalks, and dropped ears. The majority of yield loss is the result of reduced grain production due to the effects of larval feeding. The combination of persistent autumn winds, dry weather, and larval tunneling can increase stalk and shank breakage, resulting in substantial loss of ears before harvest (Figs. 3, 11c). Hybrids with stiffer stalks and larger shanks reduce ear loss. Full-season non-Bt hybrids tend to be more susceptible to second-generation larvae, but often compensate with greater yield potential than shorter-season hybrids.

Figure 12. Gibberella ear rot. [6]

Larvae that initiate feeding during a plant's mid-vegetative development (V6–16) or early reproductive stages (VT–R3) have a greater potential to reduce yield than those feeding in the later reproductive stages (R4–R5). During growth stages V6–V10, there is approximately 5–6 percent loss in grain yield for each larva per plant. During ear development (R2–R4), the loss per larva per plant is about 2–3 percent. However, if corn plants experience prolonged drought stress after significant European corn borer tunneling, the loss per larva per plant can be as high as 12 percent. In cases of severe infestation, ears can break off the plant.

Grain loss from direct feeding on the mature kernels is generally insignificant in field corn. However, feeding on the ear tip and kernels by larvae can allow the entry of ear molds and other kernel contamination, such as *Aspergillus*, *Fusarium*, *Diplodia,* or *Gibberella* (Fig. 12). Some fungi produce mycotoxins, which pose serious health issues, including liver and esophageal cancer in humans, decreased reproduction and quality in poultry, and feed refusal, vomiting, nausea, immunosuppression, and loss of productivity in livestock.

Figure 11. Feeding injury caused by European corn borers, including a) shothole injury from young caterpillars [6], b) first-generation injury to the whorl [3], and c) second-generation injury to corn stalks [3].

DEGREE-DAY DEVELOPMENT

Insects are cold-blooded animals, and development from egg to adult is based on ambient temperature or heat units. The accumulation of heat units, commonly known as degree days, results in predictable maturation to adult. Degree days are the average number of degrees above the developmental threshold temperature occurring each 24-hour period. For European corn borer, degree days can be calculated using a lower developmental threshold of 50°F and the upper developmental threshold of 86°F. European corn borer life stages and general behavior can be predicted based on degree-days accumulated from initial capture of adults in the spring (Table 1). The initial moth capture is called a biofix.

Predictions of development will be most accurate when degree-day accumulations start with the capture of the first spring adults (biofix) in pheromone or light traps placed near cornfields in mid May. This will improve a prediction for when eggs will be laid and later larval development through a generation.

Step 1. (Minimum temperature + maximum temperature) divided by 2 = mean daily temperature. The minimum is the lowest, and the maximum the highest, temperature recorded during a 24-hour day. If the minimum temperature is below the lower developmental threshold (50°F), replace the minimum temperature in the calculation with 50°F. If the maximum temperature is below the lower developmental threshold, a negative number is calculated in this step. It is too cold for insect development; thus degree days are recorded as "0." If the maximum temperature is above the upper developmental threshold (86°F), replace the maximum temperature in the calculation with 86°F.

Step 2. Mean daily temperature minus the lower developmental threshold = degree-days generated for that day.

Step 3. Sum of daily degree-days to estimate accumulated degree-days.

Table 1. European corn borer accumulated degree-days (base 50°F), life stage first occurrence, and general activity from initial spring capture of adults

Accumulated degree days	First occurrence of life stage or event	Days to first occurrence[a]	Mean daily temperature	General activity
0	first spring adult (biofix)			mating and egg laying
First generation				
212	1st instar (egg hatch)	16.3	63	pin-hole leaf feeding
318	2nd instar	6.6	66	shot-hole leaf feeding
435	3rd instar	6.5	68	mid-rib and stalk boring[b]
567	4th instar	6.6	70	stalk boring
792	5th instar	10.2	72	stalk boring
1,002	pupa	8.8	74	development to adult
1,192	adult	7.6	75	mating and egg laying
Second generation				
1,404	1st instar (egg hatch)	8.2	76	pollen and leaf-axil feeding
1,510	2nd instar	4.1	76	leaf-axil feeding
1,627	3rd instar	4.3	77	sheath, collar, and mid-rib boring
1,759	4th instar	5.1	76	stalk boring
1,984	5th instar	9.0	75	stalk boring

[a]Average number of days of development (in most two-generation regions) to reach the first occurrence of a life stage since initiation of the previous stage. This time frame is based on the mean daily temperature for the time of year when that particular life stage normally occurs.

[b]First generation larvae bore into stalks earlier than second generation because younger stalks are more tender than mature plants.

Figure 13. Heliothis trap with female European corn borer pheromone. [2]

PHEROMONE TRAPPING

Pheromone traps can be used to establish the date of first adult appearance (biofix). This date, combined with degree day calculations, can predict when eggs will be laid or when larvae can be found, and therefore guide management decisions. One advantage of the pheromone traps is that catches usually consist solely of European corn borer males (Fig. 14), making them easier to count than light trap captures, which contain a mixture of other insects. The most offective pheromone trap is called a Hartstack trap (also called a Heliothis trap; Fig. 13). Pheromone traps are most effective when the base is placed at least 6 inches below the top of the vegetation in potential aggregation sites areas adjacent to cornfields. Pheromone lures should be changed every two weeks and never discarded in the field. Wing traps also use a pheromone, but is not recommended because they capture fewer moths.

Figure 14. Female (left) and male (right) European corn borer adults. [3]

MANAGEMENT WITH BT CORN

With the introduction of transgenic corn hybrids in the mid-1990s, losses due to European corn borer have been virtually eliminated in fields containing Bt traits. Transgenic corn, or genetically-engineered corn, offers a broad range of desirable characteristics, such as additional protection from insect injury, resistance to diseases, herbicide tolerance, increased yield potential, ability to tolerate environmental extremes, and other factors that provide more value for the grower.

Genetic traits that control insects and which are expressed within the plant are referred to as plant-incorporated protectants (PiPs). One widely used PiP in corn is a crystalline (Cry) protein derived from the soil bacterium *Bacillus thuringiensis*, and corn with one or more types of Cry proteins is commonly known as Bt corn (Fig. 15). One group of Bt corn hybrids offers protection against caterpillar pests such as European corn borer, southwestern corn borer, and other select pests in the insect order Lepidoptera. Another group of Bt corn hybrids offers protection against western and northern corn rootworm larvae.

Figure 15. European corn borers killed by Bt proteins. [7]

Many of the seed products available offer protection for both of the insect groups combined. Farmers often prefer Bt corn hybrids for their convenience and benefits that simplify pest management and reduce the risk of crop loss due to insect injury. Bt corn has been highly effective in preventing European corn borer yield loss compared to corn lacking Bt protection. Stalk tunneling by corn borers is eliminated in Bt corn compared to non-Bt corn. Bt corn hybrids for control of European corn borer also eliminate the need for insecticide sprays, saving control costs and reducing impact on the environment, as well as providing improved grain quality. Most of the Bt corn hybrids on the market have proven to be very effective in controlling European corn borers, but a substantial technology fee is associated with the seed.

RESISTANCE MANAGEMENT

A significant concern of entomologists and the seed industry is the development of resistance to the Bt toxins in corn. This is especially true with the high adoption rate of Bt corn in the Midwest. To help delay resistance, farmers are required to plant a refuge of non-Bt corn where insects are not exposed to the toxin. Refuge corn produces susceptible moths that can potentially mate with any resistant insects that survive in the Bt corn. This mating of Bt susceptible and Bt resistant insects can slow down the evolution of resistance development.

Bt requirements. At the time of Bt corn seed purchase, Iowa farmers sign a stewardship agreement that they will plant a refuge of non-Bt corn. The complexity of using products that possess multiple Bt components can be challenging for the practitioner when trying to configure a field plan. An easy refuge calculator to assist farmers in determining refuge acreage requirements is available on page 12 of this publication.

Refuge types. There are three different types of refuge configurations: seed blends, row-strips, and blocks. Seed blend refuges, sometimes called "refuge in the bag," are a mixture of Bt and non-Bt seed, usually 95 percent Bt and 5 percent non-Bt. A mixed seed blend does not require any extra compliance on the part of the farmer. Row-strips of non-Bt corn must be at least four contiguous rows wide. Block refuges are solid plantings of non-Bt, ranging from 5-20%, that achieve at least the minimum number of acres required to meet the stewardship guidelines (Fig. 16).

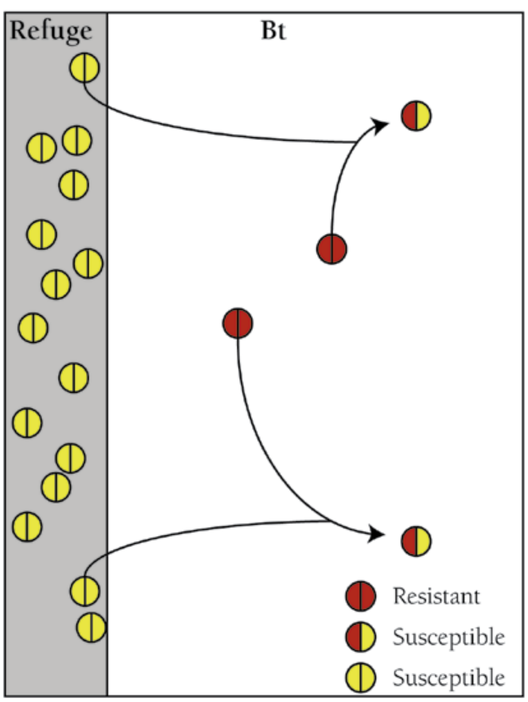

Figure 16. Example of a block refuge strategy. [6]

MANAGEMENT IN NON-BT CORN

Successfully managing European corn borers in traditional, non-Bt corn hybrids depends on several biological and economic factors. Simple management calculations are presented with appropriate examples and forms for reaching a management decision. Successful control usually can be achieved by integrating management components for a particular location, cropping system, and production practice. Under certain conditions, Bt corn may be planted only for corn rootworm control and not European corn borers. In situations of this nature, the management options presented in the next section will apply.

CULTURAL CONTROL

Planting time. Extremely early planting (or earlier than neighboring fields) of non-Bt hybrids may result in heavier-than-average infestation of first-generation larvae. Late planting can be attractive to egg-laying females during the second generation. Basically, non-Bt corn should not be some of the first or last fields to be planted in an area unless the fields are properly scouted with the intent of using insecticides to control an infestation.

Early harvest. Second-generation larvae feed primarily in the lower portion of the plant which can cause stalk lodging and dropped ears. Early harvesting effectively reduces yield losses from broken and lodged plants and dropped ears.

Tillage practices. The highest survivorship of overwintering larvae occurs when corn stalks are disked. The lowest survivorship of overwintering larvae is when stalks are left above ground during the winter followed by disking in the spring before larvae pupate. Disking seems to provide some degree of protection to the larvae presumably because they are in stalks partially or fully buried in soil and escape exposure to extreme temperatures. However, because European corn borer adults disperse widely after emergence, reduction of overwintering populations in one field will not provide a direct benefit to that same field. Also, no-till fields should not expect to have more European corn borers the following year because moths disperse to aggregation sites outside cornfields for moisture and mating. Destruction of overwintering larvae would have to occur on an area-wide basis to significantly reduce the overall European corn borer population.

SCOUTING TECHNIQUES

Scouting is necessary to assess field populations and to determine whether the potential for economic loss exists. Attempting to manage European corn borer without scouting is often economically ineffective and may result in wasted application costs. Use Tables 1-6 to guide initiation of scouting and to determine if insecticidal control is required to protect yield.

First generation. Larvae occur after susceptible corn plants reach V6 (28 inches extended leaf height). Infestations are indicated by feeding injury in the whorl and on the youngest leaves. Begin scouting 170 degree days after detecting the first spring adult or starting at V6 to determine the number of live larvae per 100 plants (Table 1, Fig. 17). When counting larvae, look for leaf feeding (windowpane effect or shotholes) in the whorl. Pull and unwrap leaves only from injured whorls; plants without visible injury are unlikely to contain larvae. Samples should be taken from five representative sets of 20 consecutive plants for every 40 to 50 acres. The chances of making a wrong decision increase greatly if fewer samples are taken. If more than one hybrid is planted in the same field, consider each hybrid as a separate field for scouting purposes. Use the cost-benefit analysis in Tables 2–3 to determine if insecticidal control measures are economically justified.

Second generation. Scouting for second-generation activity is completely different from first-generation scouting because the focus is on finding egg masses instead of larvae. Egg laying usually occurs over a 20-day period beginning at VT–R1 (pollen shedding). Determine when egg laying began, based on degree days or moth captures. Once the date of first egg laying has been determined, scouting should be done 8 to 10 days after this date to determine the density of the egg population. Sampling 8 to 10 days into the egg laying cycle reduces sampling errors caused by scouting for low egg mass densities earlier in the cycle yet still allows time to initiate chemical control if needed.

Determine the number of egg masses per plant. Mark off 20 plants in a row. Repeat this procedure at four more representative field locations. This will give a total of 100 plants that have been scouted for egg masses. Count only egg masses on the ear and middle seven leaves (ear leaf and three leaves above and three leaves below). Eggs will primarily be on the underside of the leaves. Calculate the expected number of larvae per corn plant, use the cost-benefit analysis forms in Tables 4–5, and determine if control measures are economically justified.

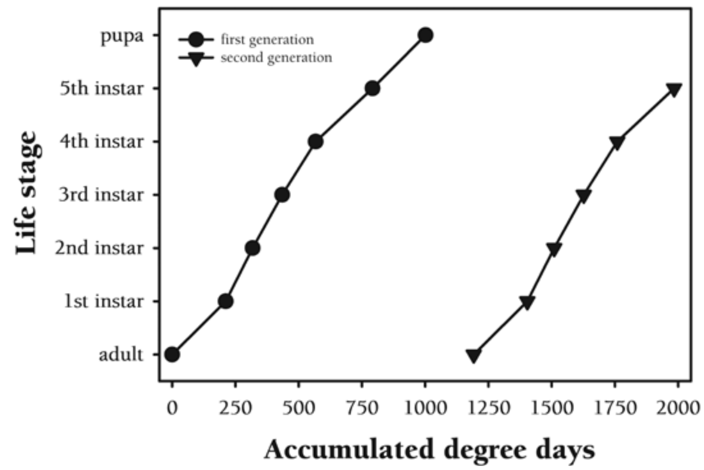

Figure 17. First occurrence of European corn borer life stages by accumulated degree days. [6]

Timing of insecticidal control for second generation is critical. Applications must be made soon after egg hatch and before the larvae enter deep into the leaf axils, sheath, collar, or ear tip, and before they bore into the stalk or ear shank. A second application may be needed in 7 to 10 days depending on the duration of the egg-laying period.

Late-planted corn typically has the largest populations of second-generation borers because egg laying is largely influenced by crop growth stage. Fields that are VT–R1 and have green silks are more attractive to female moths than fields with browning silks (R2). After the brown silk (R3) stage, there is no need to scout for new egg masses if the economic threshold has not been reached.

INSECTICIDAL CONTROL

Insecticides kill larvae over a relatively short period of time; therefore, they must be applied before all the eggs are deposited. If the treatment is delayed, larvae from eggs deposited early in the egg-laying period will enter the plant and will not be controlled. Application timing is one of the most critical aspects of corn borer control with insecticides. Treatment of V6–V16 corn depends on the severity of the infestation and the degree of control desired.

Effective control can be accomplished as long as the majority of larvae are in the whorl. However, once the larvae migrate out of the whorl and enter the stalk, control is unachievable. Likewise, second-generation larvae must be sprayed before they enter the stalk or ear. For a single application, an insecticide should be applied from 10 to 14 days after initiation of egg laying. One application is usually sufficient on whorl-stage field corn

Table 2. Example form of first generation cost-benefit analysis of European corn borer management in V6–V16 (whorl) stage non-Bt corn

1. 250 larvae found	x 0.4 expected percent survivorship[a,b]	= 100 surviving larvae
2. 100 surviving larvae	÷ 100 plants examined	= 1.0 larvae per plant
3. 1.0 larvae per plant	x 0.06 percent yield loss per larva[a,c]	= 0.06 percent yield loss
4. 0.06 percent yield loss	x 200 expected yield (bushels per acre)	= 12.00 bushels lost per acre
5. 12.00 bushels loss per acre	x $4.00 price per bushel	= $48.00 lost per acre
6. $48.00 loss per acre	x 0.8 percent control[a]	= $38.40 preventable loss per acre
7. $38.40 preventable loss per acre	- $20.00 cost of control per acre	= $18.40 profit (loss) per acre

[a]*All percents must be written using decimals (i.e., 50% = 0.5).*

[b]*Expected survivorship usually is 0.2 to 0.5 (20 to 50%) depending on the life stages and degree of environmental stress on the larvae before they bore into the plant.*

[c]*Use 0.06 for V10 stage corn, or 0.05 for V16 stage corn.*

Table 3. Blank form for first generation cost-benefit analysis of European corn borer management in V6–V16 (whorl) stage non-Bt corn

1. ______ larvae found	x ______ expected percent survivorship[a,b]	= ______ surviving larvae
2. ______ surviving larvae	÷ ______ plants examined	= ______ larvae per plant
3. ______ larvae per plant	x ______ percent yield loss per larva[a,c]	= ______ percent yield loss
4. ______ percent yield loss	x ______ expected yield (bushels per acre)	= ______ bushels lost per acre
5. ______ bushels loss per acre	x ______ price per bushel	= ______ lost per acre
6. ______ loss per acre	x ______ percent control[a]	= ______ preventable loss per acre
7. ______ preventable loss per acre	- ______ cost of control per acre	= ______ profit (loss) per acre

[a]*All percents must be written using decimals (i.e., 50% = 0.5).*

[b]*Expected survivorship usually is 0.2 to 0.5 (20 to 50%) depending on the life stages and degree of environmental stress on the larvae before they bore into the plant.*

[c]*Use 0.06 for V10 stage corn, or 0.05 for V16 stage corn.*

Table 4. Example form of a cost-benefit analysis of European corn borer management in R1 stage or later in non-Bt corn

1. 14 July (date of scouting)	– 6 July (date eggs first laid)	= 8 days after first eggs laid
2. 13 egg masses found	÷ 0.91 (for middle 7-leaf samples)	= 14 adjusted egg masses
3. 14 adjusted egg masses	÷ 100 plants examined	= 0.14 egg masses per plant
4. 8 days after first eggs laid	@ 0.14 egg masses per plant	= 2.00 larvae predicted per plant[a]
5. 2.00 larvae per plant	x 0.04 percent yield loss per larva[b,c]	= 0.08 percent yield loss
6. 0.08 percent yield loss	x 200 expected yield (bushels per acre)	= 16 bushels lost per acre
7. 16 bushels lost per acre	x $4.00 price per bushel	= $64.00 lost per acre
8. $64.00 lost per acre	x 0.67 percent control[b]	= $42.88 preventable loss per acre
9. $42.88 preventable loss per acre	– $20.00 cost of control per acre	= $22.88 profit (loss) per acre

[a]*Requires **Table 6**; go to the column below day after first eggs laid and cross reference it with the row corresponding with the number of egg masses per plant that was determined above.*

[b]*All percents must be written using decimals (i.e., 5.0% = 0.05).*

[c]*Use 0.04 for R1 stage corn, 0.031 for R2 or R3 stage corn, or 0.024 for R4 stage corn (see Table 3).*

Table 5. Blank form of a cost-benefit analysis of European corn borer management in R1 stage or later in non-Bt corn

1. ______ (date of scouting)	– ______ (date eggs first laid)	= ______ days after first eggs laid
2. ______ masses found	÷ 0.91 (for middle 7-leaf samples)	= ______ adjusted egg masses
3. ______ adjusted egg masses	÷ ______ plants examined	= ______ egg masses per plant
4. ______ days after first eggs laid	@ ______ egg masses per plant	= ______ larvae predicted per plant[a]
5. ______ larvae per plant	x ______ percent yield loss per larva[b,c]	= ______ percent yield loss
6. ______ percent yield loss	x ______ expected yield (bushels per acre)	= ______ bushels lost per acre
7. ______ bushels lost per acre	x ______ price per bushel	= ______ lost per acre
8. ______ lost per acre	x ______ percent control[b]	= ______ preventable loss per acre
9. ______ preventable loss per acre	– ______ cost of control per acre	= ______ profit (loss) per acre

[a]*Requires **Table 6**; go to the column below day after first eggs laid and cross reference it with the row corresponding with the number of egg masses per plant that was determined above.*

[b]*All percents must be written using decimals (i.e., 5.0% = 0.05).*

[c]*Use 0.04 for R1 stage corn, 0.031 for R2 or R3 stage corn, or 0.024 for R4 stage corn.*

Table 6. Number of European corn borer larvae predicted per plant in non-Bt corn based on egg masses recorded 5–20 days after initiation of egg laying

	Number of days after initiation of egg laying (top row) and proportion of egg laying completed (in parenthesis) up through the respective day[a]															
Number of egg masses per plant	**5** (0.12)	**6** (0.18)	**7** (0.245)	**8** (0.32)	**9** (0.405)	**10** (0.50)	**11** (0.595)	**12** (0.68)	**13** (0.755)	**14** (0.82)	**15** (0.875)	**16** (0.92)	**17** (0.955)	**18** (0.98)	**19** (0.995)	**20** (1.00)
0.02	0.72	0.50	0.37	0.28	0.22	0.18	0.15	0.13	0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.09
0.04	1.44	1.00	0.74	0.56	1.44	0.36	0.30	0.26	0.24	0.22	0.21	0.20	0.19	0.18	0.18	0.18
0.06	2.24	1.56	1.14	0.88	0.69	0.56	0.47	0.41	0.37	0.34	0.32	0.30	0.29	0.29	0.28	0.28
0.08	2.96	2.06	1.51	1.16	0.91	0.74	0.62	0.54	0.49	0.45	0.42	1.40	0.39	0.38	0.37	0.37
0.10	3.68	2.56	1.88	1.44	1.14	0.92	0.77	0.68	0.61	0.56	0.53	0.50	0.48	0.47	0.46	0.46
0.12	4.40	3.06	2.24	1.72	1.36	1.10	0.92	0.81	0.73	0.67	0.63	0.60	0.58	0.56	0.55	0.55
0.14	5.12	3.56	2.61	2.00	1.58	1.28	1.08	0.94	0.85	0.78	0.73	0.70	0.67	0.55	0.64	0.64
0.16	5.92	4.11	3.02	2.31	1.83	1.48	1.24	1.09	0.98	0.90	0.85	0.80	0.77	0.76	0.74	0.74
0.18	6.64	4.61	3.39	2.59	2.05	1.66	1.40	1.22	1.10	1.01	0.95	0.90	0.87	0.85	0.83	0.83
0.20	7.36	5.11	3.76	2.88	2.27	1.84	1.55	1.35	1.22	1.12	1.05	1.00	0.96	0.94	0.92	0.92
0.22	8.08	5.61	4.12	3.16	2.49	2.02	1.70	1.49	1.34	1.22	1.10	1.10	1.06	1.03	1.02	1.01
0.24	8.80	6.11	4.49	3.44	2.72	2.20	1.85	1.62	1.46	1.34	1.26	1.20	1.15	1.12	1.11	1.10
0.26	9.60	6.67	490	3.75	2.96	2.40	2.02	1.76	1.59	1.46	1.37	1.30	1.26	0.22	1.21	1.20
0.28	10.32	7.12	5.27	4.03	3.19	2.58	2.17	1.90	1.71	1.57	1.47	1.40	1.35	01.32	1.39	1.29
0.30	11.04	7.67	5.63	4.31	3.41	2.76	2.32	2.03	1.83	4.68	1.58	1.50	1.45	1.41	1.39	1.38
0.50	18.40	12.78	9.39	7.19	5.68	4.60	3.87	3.38	3.05	2.80	2.63	2.50	2.41	2.35	2.31	2.30
0.75	27.60	19.17	14.08	10.78	8.52	6.90	5.80	5.07	4.57	4.21	3.94	3.75	3.61	3.52	3.47	3.45
1.00	36.80	25.56	18.78	14.38	11.36	9.20	7.73	6.76	6.09	5.61	5.23	5.00	4.82	4.69	4.62	4.60
1.25	46.00	31.94	23.47	17.97	14.20	11.50	9.66	8.46	7.62	7.01	6.57	6.25	6.02	5.87	5.78	5.75
1.50	55.20	38.33	28.16	21.56	17.04	13.80	11.60	10.15	9.14	8.41	7.89	7.50	7.46	7.23	6.93	6.90

[a]*Conversion to whole plant count = 7-leaf count x 100; see page 8 for explanation.*

BIOLOGICAL CONTROL

European corn borer eggs and larvae are attacked by predators, parasitoids and pathogens. Predators include lady beetles, lacewings, insidious flower bugs, spiders, and predaceous mites that feed on the eggs and young larvae (Figs. 18–19). Larvae also are parasitized by several species of wasps and flies. When combined, predators and parasites kill an average of about 7.5 percent of European corn borer larvae in the Midwest. The reduction of foliar insecticides can promote biological control of European corn borer. The fungus, *Beauvaria bassiana,* can kill overwintering larvae under conducive conditions (e.g., rainfall and temperatures in the mid-80s).

Figure 18. Lady beetle adults and larvae are common generalist predators in cornfields. [2]

Figure 19. Lacewing larvae are common generalist predators in cornfields. [2]

USEFUL REFERENCES

Online resources

European corn borer, Iowa State University; http://www.ent.iastate.edu/pest/cornborer/ (Accessed February 14, 2017)

European corn borer, Purdue Extension; http://bit.ly/2rCXzcH (Accessed May 25, 2017)

National Corn Growers Association; http://refuge.irmcalculator.com/ (Accessed February 14, 2017)

Trapping and sampling supplies

BioQuip Products, Inc.; www.bioquip.com

Great Lakes IPM; www.greatlakesipm.com

Carolina Biological Supply Co.; www.carolina.com

Ward's Natural Science Establishment; http://wardsci.com/

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PHOTO CREDITS

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