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Managing Insect Pests

Kevin Steffey
Department of Crop Sciences
ksteffey@illinois.edu

Mike Gray
Department of Crop Sciences
megray@illinois.edu

Technically, an insect pest of crops is any species that feeds on crops and thus competes with producers for crop yield or quality. However, the mere presence of a crop-feeding insect is not enough to establish a species as a pest that requires expenditures for its management. The status of any given pest (major or minor) depends largely on how often and in what numbers it occurs, as well as the economics of managing the pest. Factors that contribute to choices about insect management include the market value of the crop, the cost of controlling the pest relative to its potential for causing crop loss, the susceptibility of the crop to the pest, and the environment, all of which are variable. Consequently, effectively managing insect pests of field crops requires considerable knowledge about the pests and the factors that affect their populations.

Tables 13.1 through 13.4 (which are described and appear later in the chapter) are abridged lists of insect pests of alfalfa, corn, soybean, and wheat in Illinois, species that represent a broad range of pest types, from key pests to those that infrequently cause economic losses. Not all species that occur in these crops are listed; rather, we included those that are encountered with relative frequency, at least in some regions of the state, or that represent unique threats. For example, blister beetles present in alfalfa hay may be toxic to livestock, particularly horses. We also included pests that transmit disease pathogens—aphids transmit viruses that cause diseases in wheat, bean leaf beetles transmit the virus that causes bean pod mottle in soybean, corn flea beetles transmit the bacterium that causes Stewart's bacterial wilt and leaf blight of corn, and wheat curl mites transmit the virus that causes wheat streak mosaic. For a more complete list of insect pests of field crops in Illinois, consult the tables in Chapter 2 in *Illinois Pesticide Applicator Training Manual 39-2: Field Crops* (2004, University of Illinois).

Note: Use of the term insects *in this chapter also includes insect relatives, such as mites.*

Although more than 100 species of insects can cause injury to alfalfa, corn, soybean, and wheat in Illinois, usually only a few species are capable of causing significant economic losses in crop yield or quality. These few species are often referred to as "key pests" because most producers develop their insect management strategies with these pests as a focus. Some key pests threaten crops annually, whereas others pose serious threats only when environmental conditions favor their survival and development.

Following are the key insect pests of the primary Illinois field crops:

- Alfalfa—alfalfa weevil, potato leafhopper
- Corn—corn rootworms, corn borers (European and southwestern), cutworms (primarily black cutworm), ear-attacking caterpillars, subterranean insects
- Soybean—bean leaf beetle, Japanese beetle, soybean aphid, twospotted spider mite
- Wheat—aphids, armyworm, Hessian fly

The species chosen for this list could be debated, but our rationale was to include insects characterized by one or more of four criteria: They occur relatively frequently at levels that threaten crop yields or quality; they can cause significant crop losses under certain circumstances (drought conditions, for example); they are the source of regular expenditures for control tactics; and they cannot be controlled after crop injury has been detected.

This chapter provides information about developing insect management strategies for alfalfa, corn, soybean, and wheat in Illinois, with focus on key pests, although we also provide observations about others. However, we do not include detailed lists of insect-resistant cultivars, insecticides, or other management tactics. Such details, which change fairly often, can be found at the University of Illinois Integrated Pest Management (IPM) website, www.ipm.illinois.edu. This site also will direct you to *the Bulletin* (www.ipm.illinois.edu/bulletin), a newsletter published weekly throughout the growing season to provide updates on current and pending situations regarding insects, weeds, and plant diseases as well as crop conditions. Current recommendations for management of specific insect pests and the issues associated with insect management tactics are addressed frequently in *the Bulletin*. More information about specific insects and scouting guidelines can be found in the *Field Crop Scouting Manual* and the accompanying CD (2004, University of Illinois).

Developing Insect Management Strategies

Broadly speaking, there are two strategies for managing insects that attack alfalfa, corn, soybean, and wheat in Illinois—preventive and curative (also referred to as therapeutic and remedial in other publications). There are benefits and limitations to both strategies, but both have merit under appropriate circumstances. The choice of strategies requires knowing the biology and ecology of the target pests, as well as a thorough understanding of the potential for any given pest to cause economic losses. The frequency of occurrence of a pest, the type of injury it causes, and the expectations for success of selected management tactics also dictate whether preventive or curative strategies are most suitable.

Preventive and curative strategies and their associated tactics should be integrated into a comprehensive approach of managing insect pests with environmentally and economically sound practices, which is one working definition of IPM. Integrating strategies and tactics safeguards against ecological disruptions, such as pest resistance or destruction of natural enemies, that often develop as a consequence of widespread reliance on a single tactic.

Preventive strategies are used primarily for insects that cannot be controlled easily or effectively after crop injury is discovered. Preventive strategies may incorporate cultural control tactics (farming practices such as crop rotation, tillage, and weed control), planting insect-resistant crops, and applying insecticides. *Curative strategies* usually focus on timely field scouting during the crop-growing season, followed by the use of insecticides if the density of an insect pest has reached or exceeded the economic threshold, a guiding principle of insect pest management programs.

Economic thresholds for insects usually are defined as the numbers of insects or the amount of crop injury that warrants a control tactic to prevent increasing numbers of insects from reaching economic-injury levels (**Figure 13.1**). An economic-injury level is the number of insects or the level of injury at which the cost of control equals the value of crop loss, and economic crop loss occurs when the value of crop loss exceeds the cost of control. Economic thresholds can be employed in conjunction with preventive strategies (for example, numbers of western corn rootworms in corn or soybean fields during the preceding year), but they are most commonly associated with the use of insecticides to control most insects that infest alfalfa, corn, soybean, or wheat during the growing season. Economic thresholds and guidelines for their use have been determined for many, although not all, insect pests that attack field crops in Illinois. Static thresholds are provided as rules of thumb in this chapter. However, it is important to note that economic thresholds should be dynamic because they are influenced by fluctuating variables such as crop value, costs of control, and crop susceptibility, the last of which can be affected by crop stress and a crop's relative tolerance of or resistance to insect attack. In general, economic thresholds decrease as crop value increases, increase as cost of control increases, and decrease as crop susceptibility increases. When dynamic economic thresholds are available for a given insect pest, we provide the necessary reference(s) to access them.

It is also important to recognize that making decisions about insect pest management should be placed in context with other factors. Natural enemies of pests (predators, parasitoids, and pathogens) and weather that is unfavorable for survival and development of pests may suppress their populations. Sharp declines in densities of some insect pests (often referred to as "population crashes") have been associated with epizootics of disease pathogens (**Figure 13.2**), large populations of predators, and inclement weather conditions. Consequently, estimates of densities of insect pests and/or the amount of crop injury should be accompanied by assessments of the potential impact of natural enemies and impending weather conditions.

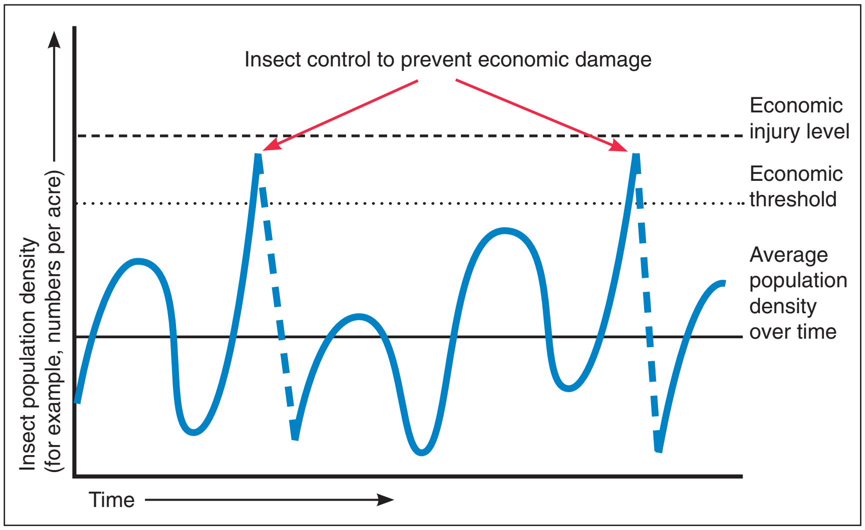

Figure 13.1. The relationship of average insect population density over time, economic threshold, and economic injury level, with insect control decisions indicated.

Figure 13.2. Armyworm larvae infected with virus.

In summary, developing a sound insect management program for insects that may threaten production of field crops in Illinois requires knowledge about these factors:

- the biology, ecology, relative frequency, and crop loss potential for the key pests of the crop
- the basic principles (scouting tactics, economic thresholds) associated with key pests and occasional pests
- the impact of natural enemies and weather on populations of insect pests
- the practicality and consistency of effectiveness of different insect management tactics for key pests and occasional pests
- the economic, ecological, and environmental consequences of insect management activities

The following sections include basic plans for developing insect management strategies for alfalfa, corn, soybean, and wheat in Illinois. The plans incorporate relevant information associated with the key pests of each crop as well as expectations for their management. Some details about the pests (such as descriptions and scouting procedures) are not included because such information is widely available in print and on the Internet. Insect control tactics, including the use of transgenic crops and insecticides, are discussed in general terms, excluding references to specific products. Consult references with current insect management information for recommendations about specific insect control products.

Alfalfa

Because of its perennial and lush growth, alfalfa is an excellent habitat for many insects, including species destructive to alfalfa and other crops, species that inhabit the alfalfa but have little or no effect on the crop, pollinating insects, incidental visitors, and predators and parasitoids of other insects. Because of the presence of so many beneficial insects in alfalfa, it is very important that chemical insecticides be used judiciously and only when necessary to avert significant economic losses.

Many species of insects can reduce alfalfa yield, impair forage quality, or reduce the vitality and longevity of the crop (see **Table 13.1** for an incomplete list of pests of alfalfa found in Illinois). However, only the alfalfa weevil and potato leafhopper are considered key pests. These two insects threaten the alfalfa crop at distinctly different times—alfalfa weevils threaten the first cutting, potato leafhoppers threaten the second and third cuttings—so insect management strategies for alfalfa should span its growing season. Failure to manage economically threatening numbers of either pest on any given cutting can affect the yield of subsequent cuttings and reduce the long-term productivity of the stand.

Developing insect management strategies for alfalfa begins with the purchase of seed—different varieties of alfalfa have different levels of tolerance or resistance to alfalfa weevils and/or potato leafhoppers. Currently there are no alfalfa varieties truly resistant to alfalfa weevils, although some varieties tolerate light to moderate feeding by the larvae. For potato leafhoppers, however, there are

Table 13.1. Insect and mite pests of alfalfa in Illinois.

Chew on leaves (defoliators) and/or stems	Suck plant fluids	Feed on below-ground plant parts
alfalfa blotch leafminer[a] alfalfa caterpillar alfalfa weevil blister beetles[b] clover leaf weevil cutworms[b] fall armyworm[c] grasshoppers[b] serpentine leafminers[b] webworms[b,c]	cowpea aphid pea aphid plant bugs[b] potato leafhopper spittlebugs[b]	clover root curculio cutworms[b,c]

Insects chosen for inclusion are encountered with relative frequency, at least in some regions of the state, or represent unique threats.
[a]Larvae (maggots) mine between leaf surfaces, rather than chew on leaves.
[b]More than one species.
[c]Primarily a pest of small alfalfa plants in new seedings.

many glandular-haired alfalfa varieties that are resistant to this very important pest. After the variety of alfalfa has been selected and seeded, insect management plans can be developed separately for the two key pests.

Alfalfa weevil. Newly hatched alfalfa weevil larvae feed in the growing tips of alfalfa plants in the spring, relatively early in southern counties and later in northern counties. An early sign of injury is pinholes in newly opened leaves. As larvae grow larger, they shred and skeletonize the leaves (**Figure 13.3**). Heavily infested fields appear frosted because of the loss of green leaf tissue. Anything that slows spring alfalfa growth increases the impact of weevil injury. Adults may also cause some injury a little later in the spring (leaves appear feathered, stems may be scarred), but the injury usually is not economic. However, both surviving larvae and newly emerged adults may affect regrowth after the first cutting in some years. They remove early shoot growth, depleting food reserves in the roots and reducing the stand.

Figure 13.3. Alfalfa weevil larva (inset) and injury to leaves. (Larger photo courtesy Matt Montgomery.)

The key to effective management of alfalfa weevils is timely monitoring. To determine when to begin scouting, development of alfalfa weevil larvae can be estimated with degree days accumulated after January 1 (www.isws.illinois.edu/warm/pestdata). However, in general, growers should inspect their fields from the time alfalfa begins to grow until first harvest and should examine the stubble after the first cutting of alfalfa has been removed. A rule of thumb for control of alfalfa weevils on the first crop of alfalfa is that treatment may be warranted when there are 3 or more larvae per stem and 25% to 50% of the tips have been skeletonized, depending on the height of the crop and the vigor of growth. Tall, rapidly growing alfalfa can tolerate considerable defoliation without a subsequent loss in yield.

Tables that incorporate the value of alfalfa hay and the cost of control may be consulted to determine if numbers of alfalfa weevils have exceeded economic levels. A primary source for this information is *Pest Management of Alfalfa Insects in the Upper Midwest*, published by Iowa State University in 1999. The decision-making table is excerpted, cited, and explained in early-season issues of *the Bulletin* (www.ipm.illinois.edu/bulletin) nearly every year.

After harvest of alfalfa, control may be warranted when larvae and adults are feeding on more than 50% of the crowns and regrowth is prevented for 3 to 5 days. This amount of injury usually requires 4 to 8 larvae per square foot.

Parasitic wasps and a fungal disease may regulate alfalfa weevil populations in the spring. When scouting, look for signs of parasitism and for diseased weevils (discolored, moving slowly, or not moving at all). When natural enemies and pathogens suppress weevil numbers, insecticide treatments may not be necessary.

Grazing and early cutting at first harvest are also effective tactics for managing alfalfa weevils in some areas, assuming that yield and quality are not compromised.

Potato leafhopper. Because potato leafhoppers do not overwinter in Illinois, they usually do not appear in alfalfa fields in Illinois until prevailing winds transport them from farther south in late April or early May. Nymphs develop from the eggs deposited by the immigrant females, and both nymphs and adults suck fluids from alfalfa plants (**Figure 13.4**). Several generations occur throughout the summer before cold temperatures kill the leafhoppers in the fall.

Nymphs cause more injury than adults. Initial injury is characterized by a V-shaped yellow area at the tips of the leaflets, often called “hopperburn” or “tipburn.” As the injury progresses, the leaves become completely yellow and

Figure 13.4. Potato leafhopper nymph (left) and adult. (Photo courtesy Marlin E. Rice.)

may turn purple or brown and die. Severely injured plants are stunted and bushy. Leafhopper injury also causes plants to produce more sugars and less protein and vitamin A, resulting in lower-quality alfalfa. If leafhoppers deplete root reserves of the late-season growth of alfalfa, the plants will be less hardy and may not survive the winter.

Sampling with a 15-inch-diameter sweep net before injury appears is the best method for monitoring populations of potato leafhoppers in alfalfa. By the time symptoms of injury appear, considerable yield and nutritional quality may have been lost. Economic thresholds are based on the number of leafhoppers per sweep of the sweep net. Tender, regrowing alfalfa is particularly susceptible to potato leafhopper injury, so scouting after a cutting is critical. Taller, more mature alfalfa can tolerate more leafhopper injury, and economic thresholds vary accordingly. As a rule of thumb, an insecticide may be warranted for alfalfa up to 3 inches tall when there is an average of 0.2 leafhopper per sweep. The treatment thresholds for 3- to 6-inch alfalfa, 6- to 12-inch alfalfa, and alfalfa taller than 12 inches are 0.5, 1, and 2 leafhoppers per sweep, respectively.

Tables that incorporate the value of alfalfa hay and the cost of control may be consulted to determine if numbers of potato leafhoppers have exceeded economic levels. A primary source for this information is *Pest Management of Alfalfa Insects in the Upper Midwest* (Iowa State University, 1999). Numerous decision-making tables have been published and are accessible from IPM websites in many states (e.g., Pennsylvania State University, paipm.cas.psu.edu/fldcrop/table18.htm).

As indicated earlier, glandular-haired alfalfa is resistant to moderate densities of leafhoppers. However, these varieties will not prevent leafhopper infestations during the first year of seeding, during seedling regrowth immediately after cutting, or during years when leafhopper infestations are severe. It is also important to note, however, that the economic thresholds developed for potato leafhoppers in alfalfa are higher in glandular-haired alfalfa, which can tolerate higher densities of this pest.

Corn

Corn has relatively more significant and frequently occurring insect pests than all other field crops grown in Illinois. Consequently, knowledge about the potential threats posed by several different insect species in different areas of the state is essential for developing sensible and effective insect management strategies for corn.

Collectively, corn rootworms, corn borers, cutworms, ear-attacking insects, and subterranean insects meet all of our criteria for key pests, including regular expenditures for their control with transgenic Bt corn hybrids and/or seed- or soil-applied insecticides. (See **Table 13.2** for an incomplete list of pests of corn found in Illinois.) Because these insect control products are used by corn growers to prevent yield losses caused by multiple pests and are the foundation of most insect management strategies for corn, they will be discussed in more detail. However, it is important to note that the use of these products is not warranted in all fields all of the time. The use of insect control products should be integrated with other tactics, including such preventive measures as crop rotation and weed control. In addition, insect management strategies for corn should include timely field scouting and knowing how and when to make insect-control decisions. A basic scouting plan for corn in Illinois should include looking for particular pests at particular times:

- early-season insects, such as cutworms, white grubs, and wireworms, shortly after crop emergence
- first-generation corn borers in early to mid-June (European corn borers statewide, southwestern corn borers in southern Illinois)
- corn rootworm adults and western bean cutworm eggs and larvae (primarily in northern counties) in July
- second-generation corn borers in late July and early August (European corn borers statewide, southwestern corn borers in southern Illinois)

Dedication to this basic scouting plan will enable corn growers to note the presence or absence of insect pests at critical times throughout a growing season and to assess the frequency of occurrence of insect pests in their fields over time.

Table 13.2. Insect and mite pests of corn in Illinois.

Feed on below-ground plant parts	Feed at, just above, or just below the soil surface	Chew on leaves (defoliators) and/or stems	Tunnel inside plants	Feed on silks, ears	Suck plant fluids
corn rootworm larvae[a] grape colaspis larvae seedcorn beetles[a] seedcorn maggot slugs[a,c] white grubs[a] wireworms[a]	billbug adults[a] cutworms[a] stink bugs[a] webworms[a]	armyworm cereal leaf beetle corn blotch leafminer[b] corn earworm corn flea beetle corn rootworm adults[a] cutworms[a] fall armyworm grasshoppers[a] slugs[a,c] southern corn leaf beetle webworms[a] yellowstriped armyworm	billbug larvae[a] European corn borer southwestern corn borer stalk borer	corn earworm corn rootworm adults[a] fall armyworm grape colaspis adults grasshoppers[a] Japanese beetle sap beetles[a] western bean cutworm woollybear caterpillars[a]	chinch bug bird cherry-oat aphid corn leaf aphid English grain aphid stink bugs[a] twospotted spider mite thrips[a]

Insects chosen for inclusion are encountered with relative frequency, at least in some regions of the state, or represent unique threats.
[a]More than one species.
[b]Larvae (maggots) mine between leaf surfaces, rather than chew on leaves.
[c]A mollusk, not an insect or mite.

Preventive Insect Control Products for Corn

Bt corn. Bt corn is a type of corn that has been genetically altered through biotechnology by inserting genes from the soil bacterium *Bacillus thuringiensis* (usually abbreviated as Bt) into the corn genome. Bt genes trigger production of toxic proteins that kill certain insects when the insects feed on the growing corn plants. Bt corn hybrids first became available commercially in the mid-1990s, primarily for management of European and southwestern corn borers. In 2003, the first Bt corn hybrids that express a protein to kill corn rootworm larvae were registered for commercial use.

Transgenic traits for insect control have been "stacked" in elite corn hybrids with traits for herbicide tolerance, resulting in double-, triple-, and quad-stacked hybrids. Bt corn hybrids available from most seed companies now offer protection against some or all (depending on the hybrid) of the following insect pests of corn in Illinois—black cutworm, corn earworm, corn rootworms (northern and western), European corn borer, fall armyworm, southwestern corn borer, stalk borer, and western bean cutworm.

To preserve the durability and effectiveness of Bt corn, the United States Environmental Protection Agency (EPA) mandates insect resistance management (IRM) strategies for Bt corn. The key IRM strategy for Bt corn is planting refuges of corn that does not include the Bt trait for the target insect(s). In general, a refuge ensures survival of target insects that are not exposed to Bt toxins, enabling these Bt-susceptible insects to mate with the rare individuals that possess a gene that imparts resistance to Bt.

As Bt corn products and programs change, IRM guidelines and requirements will change, too. However, as of 2009, corn producers who plant Bt corn are required to plant at least 20% of their acres to non-Bt corn. We recommend that refuge acres be planted within or adjacent to the field of Bt corn to ensure the best mixing of susceptible and potentially resistant insects. Some options for the arrangement of refuge acres with Bt corn are presented in **Figure 13.5**. For a thorough explanation about the importance of managing Bt corn technology and specifics about planting refuges, visit the National Corn Growers Association "Insect Resistance Management" website (ncga.eweb3.socket.net/node/168).

Bt corn hybrids are convenient and effective insect management tools, and corn growers have enthusiastically adopted their use to control or suppress the most important and sometimes difficult-to-control insect pests of corn in North America. However, the benefits of Bt corn will continue to be realized only if it is grown responsibly and is integrated with other insect management tactics.

Seed-applied insecticides. In the late 1990s, chloronicotinyl insecticides were introduced as seed treatments that would protect corn against attack by several insects. The convenience and promised efficacy of these products generated so much demand that their use has become widespread. Most corn seeds now are treated with either a low or high rate of a chloronicotinyl insecticide.

Chloronicotinyl insecticides, also known as nicotinoids or neonicotinoids, are systemic, meaning they are absorbed by treated plants and translocated to other plant tissues. Insects are killed either by contact with the chemical in the soil or by feeding on plant parts into which the chemical has been translocated.

All rootworm Bt corn seed is treated with a low rate of a chloronicotinyl insecticide because the Bt toxin for

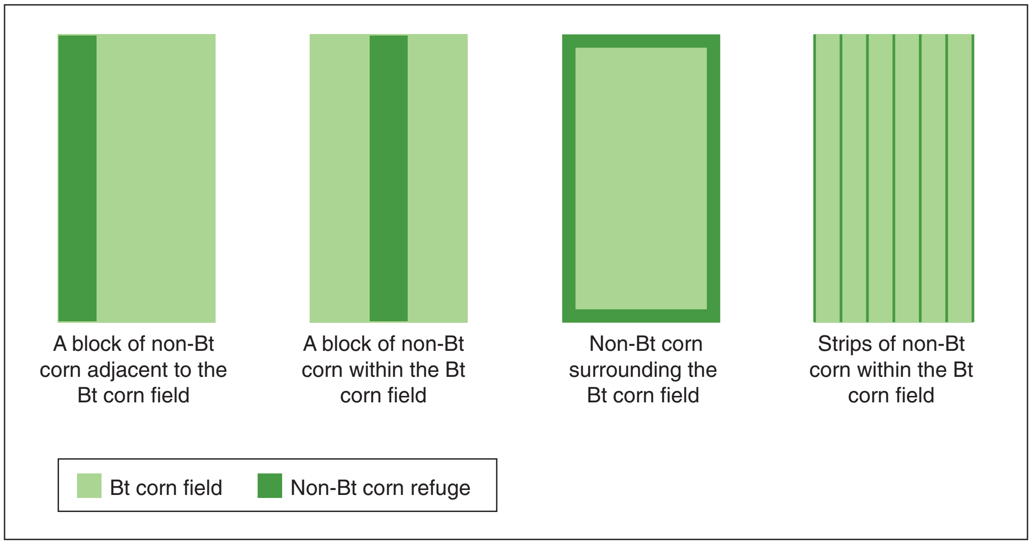

Figure 13.5. Types of arrangements of non-Bt corn refuge acres with Bt corn.

rootworms does not control other soil-inhabiting insects, such as white grubs and wireworms. The low rate of seed-applied insecticides also is labeled for control of a few aboveground pests such as corn flea beetle and southern corn leaf beetle. Seed of many non-Bt corn hybrids is treated with either a low or high rate of a chloronicotinyl insecticide, with the higher rate directed toward control of corn rootworm larvae.

Research has not demonstrated that the widespread use of chloronicotinyl insecticides in corn seed treatments is warranted. There are limited data regarding the efficacy of these products against several of the target species. However, research conducted over several years has shown that seed-applied chloronicotinyl insecticides are not very effective for control of corn rootworm larvae when rootworm infestations are heavy.

Soil-applied insecticides. From the 1950s until the introduction of chloronicotinyl seed treatments and rootworm Bt corn, soil-applied insecticides were the primary preventive tactic for control of insects that feed on belowground parts of corn plants. For 40 years, millions of corn acres in Illinois were treated annually with soil insecticides, although their use in many fields was not always warranted. The widespread use of rootworm Bt corn hybrids and chloronicotinyl seed treatments has reduced the number of corn acres treated with soil insecticides. However, soil insecticides remain a viable alternative for control of rootworms and can be applied to the corn refuges associated with rootworm Bt corn. In addition, soil insecticides protect against other soil-inhabiting insects, such as white grubs and wireworms, insects that cannot be controlled effectively after the injury they cause has been discovered.

Most soil insecticides are applied during planting, either directly into the seed furrow or as a 6- to 8-inch band over the planted row. The placement and rate of application of a soil insecticide depend on both the product and the target insect(s). Both granular and liquid formulations of soil insecticides are available. In general, soil insecticides are effective for controlling rootworms and other soil-inhabiting insect pests, but their efficacy can be compromised by unfavorable environmental conditions, such as too much or too little soil moisture.

Key Insect Pests of Corn

Corn rootworms. Northern and western corn rootworms are the most important insect pests of corn in North America. Although northern corn rootworms are capable of causing significant injury to corn in Illinois, the western corn rootworm is the predominant and most injurious rootworm species in the state. Most of the information here applies primarily to western corn rootworms, although the management tactics discussed are relevant for both species unless indicated otherwise.

Corn rootworm larvae hatch from overwintered eggs in May and June. If corn has been planted in the field, larvae begin feeding on roots. Rootworm larvae survive on the roots of corn and more than a dozen species of grass, such as foxtail species. They cannot survive on the roots of soybean and other broadleaf species.

Newly hatched corn rootworm larvae tunnel into root tissue; older larvae feed on the outside of the roots (**Figure 13.6**). As the larvae grow and continue to feed, they often prune roots back to the stalk (**Figure 13.7**). Large densities of corn rootworm larvae may cause extensive damage to the root system, reducing the efficient uptake of water and nutrients. Severe root pruning may cause plants to lodge (**Figure 13.8**). Yield losses are most acute when both root pruning and lodging occur. After larvae complete feeding, they pupate within small earthen cells, where they transform to adults.

Western corn rootworm adults (**Figure 13.9**) begin to emerge in late June and early July. Although they will feed on corn leaves and weed blossoms, they prefer corn silks

Figure 13.6. Corn rootworm larvae feeding at the base of a corn plant.

Figure 13.7. Severe pruning injury caused by corn rootworm larvae.

Figure 13.8. Corn lodged as a result of severe rootworm larval injury.

and pollen. Typically, the adults chew on fresh, green silks at the ear tip, injury that may interfere with pollination. Rootworm adults mate, and the females lay eggs in the soil from late July to early September. The eggs of western corn rootworms remain in the soil until the following spring, when the larvae hatch. There is only one generation of western corn rootworms each year.

For many years after their first appearance in Illinois in 1964, western corn rootworms could be managed effectively by annually rotating corn and soybean in the same field. The females laid eggs only in corn fields, and larvae could not survive on soybean roots. However, by the mid-1990s, a variant western corn rootworm had become established in several counties in east-central Illinois and northwestern Indiana. Research has determined that variant western corn rootworm females lay eggs in soybean fields, although they also will lay eggs in corn fields and fields planted with other crops such as alfalfa. Consequently, crop rotation no longer is reliable for managing western corn rootworms in areas where the variant has become established. The range of the variant western corn rootworm has expanded to include most of the northern two-thirds of Illinois as well as regions of other states—the northern two-thirds of Indiana, southeastern Iowa, southern Michigan, western Ohio, and southern Wisconsin.

Most corn growers prevent injury caused by corn rootworm larvae by planting a rootworm Bt corn hybrid, applying a soil insecticide, or planting corn after soybean, which is still an effective tactic in southern Illinois, where the variant western corn rootworm is not established. Rootworm Bt corn hybrids and soil insecticides usually provide effective control of corn rootworm larvae, although incidents of inadequate root protection by all rootworm control products have been noted.

Scouting for western corn rootworm adults in the summer is recommended for determining whether a preventive tactic is needed the following year. The recommended scouting procedures and thresholds for western corn rootworm adults are different for corn planted after corn and corn planted after soybean. If a producer intends to plant corn after corn, counting western corn rootworm adults on corn plants every week from mid-July through August is recommended. As a rule of thumb, an average of 0.75 western corn rootworm adults per plant suggests that a rootworm control product is warranted when corn is planted the next year. If a producer intends to plant corn after soybean in an area where the variant western corn rootworm is established, placement of yellow sticky traps in soybean fields from late July through August is recommended. As a rule of thumb, an average of 5 to 10 western corn rootworm adults per trap per day suggests that a rootworm control product is warranted when corn is planted the next year.

More detailed information about these scouting procedures and interpretation of results is accessible at the University of Illinois IPM website (www.ipm.illinois.edu/fieldcrops/insects/western_corn_rootworm/index.html).

Management of corn rootworm adults is necessary only if their feeding on corn silks interferes with pollination. Application of a chemical insecticide to prevent silk-clipping damage is warranted if there is an average of 5 or more adults per plant, the beetles are clipping silks to within half an inch of the ear tip, and pollination is not complete.

Corn borers (European and southwestern). European and southwestern corn borers are among the most important insect pests of corn in North America; both are capable of causing significant yield losses. European corn borers are present throughout the state of Illinois, whereas southwestern corn borers usually are not found very far north of Illinois Route 50.

Both species of corn borer usually complete two generations per year in Illinois. The injury caused by the first generation of both species is similar—feeding on leaves in corn whorls in June, followed by tunneling of larger larvae in the stalks (June–July). Newly hatched larvae of the second generation of European corn borers feed initially on leaf-collar tissue and pollen that accumulates in the leaf-collar areas, after which more mature larvae tunnel into the stalks (**Figure 13.10**), ear shanks, and ears. Second-generation southwestern corn borer larvae also tunnel into corn stalks (**Figure 13.11**), eventually tunneling to the base of the plant, where they girdle the stalk internally while excavating an overwintering cell.

Tunneling by corn borer larvae causes yield loss due to interference with the transport of nutrients and water in the stalk and leaves. In addition, tunneling weakens cornstalks and predisposes them to stalk rot organisms, often causing stalks to lodge or break. Feeding in the ear shank may result in ear drop. The second generation of both species causes more economic damage than the first generation.

Before Bt corn hybrids were available for corn borer control, management of both European and southwestern corn borers required timely scouting for first-generation larvae and their injury and for second-generation egg masses, followed by well-timed insecticide applications before the larvae tunneled into corn stalks. Management worksheets were developed to aid in making decisions about control of first- and second-generation European corn borers with insecticides. These worksheets are accessible as "calculators" at the University of Illinois IPM website (www.ipm.illinois.edu/fieldcrops/insects/european_corn_borer/index.html) and are still useful for managing European corn borers in non-Bt corn, including the refuges associated with Bt corn.

Figure 13.9. Western corn rootworm adult.

Figure 13.10. European corn borer larva.

Figure 13.11. Southwestern corn borer larvae, pupae, and stalk tunneling. (Photo courtesy Ron Hines.)

Bt corn hybrids that express proteins that are toxic to corn borers are extremely effective for controlling both species, with expectations of at least 99% control. We speculate that the widespread planting of Bt corn hybrids for corn borer control has reduced densities of European corn borers dramatically since the mid-1990s, with historic lows being recorded in 2007 and 2008. In light of the very low numbers of European corn borers in many areas, some corn growers have questioned the continued need for Bt corn hybrids for corn borer control. However, many elite Bt corn hybrids express proteins for control of both corn rootworms and corn borers, and most corn growers wish to continue planting "stacked" hybrids because of their effectiveness, convenience, and yield benefits. So compliance with IRM strategies, including planting refuges with corn that does not express the Bt protein for corn borer control (see **Figure 13.5**), is essential for the long-term viability of the technology.

Cutworms (primarily black cutworm). Although several species of cutworms feed on young corn plants, the most economically threatening species in Illinois is the black cutworm. Other cutworm species, such as the claybacked cutworm and sandhill cutworm, may cause significant stand loss, but their distributions are limited, so their overall impact is relatively minor.

Black cutworms do not overwinter in Illinois. Prevailing winds during March through May assist black cutworm adults migrating northward from southern states. When they arrive in Illinois, female black cutworms typically seek small winter annual weeds on which to lay eggs. After hatching, the small larvae feed on the weeds until herbicides kill the weeds, after which larger larvae begin feeding on corn seedlings.

Small black cutworm larvae feed on the leaves of seedling corn plants. Such leaf feeding does not result in economic damage, but the injury is an early warning that larger larvae will cut off seedlings just above, at, or below the soil surface or will chew into the base of the plant (**Figure 13.12**). Plants cut off below the growing point do not survive, and a significant reduction in plant population may result in significant yield loss. Although plants cut off above the growing point usually survive, there is evidence that such injury may contribute to yield losses.

As the larvae grow in size, they consume larger numbers of corn seedlings. A single cutworm will cut three or four seedlings if the plants are in the two-leaf stage or smaller. After corn plants reach the four-leaf stage, a single cutworm will cut only one or two plants during the remainder of its larval stage. Development through six or seven instars (stages of larval development) requires approximately a month, after which the larvae pupate and then transform into adults. Adults of the second and later generations typically do not lay their eggs in corn fields, so only the first generation of black cutworms threatens corn production in Illinois.

Pheromone traps can be used to monitor for black cutworm moths flying into Illinois in the spring. Although the numbers of moths captured in these traps do not necessarily correlate with larval injury in given fields, spring moth captures provide an early warning of the pest's appearance. Degree days accumulated from the date of an intense capture of moths (nine or more captured in one to two nights) can be used to estimate black cutworm larval development (www.isws.illinois.edu/warm/pestdata).

Figure 13.12. Black cutworm larva and injury to small corn plant. (Photo courtesy Robert Bellm.)

Control of winter annual weeds in the fall reduces the potential that black cutworm females will lay eggs in the field when they arrive in Illinois the following spring. Seed-applied chloronicotinyl insecticides, some soil insecticides, and some Bt corn hybrids provide protection against black cutworms. However, these products may not provide adequate control of large infestations of large black cutworm larvae, so early-season scouting for the larvae and signs of their injury to corn seedlings is strongly encouraged. As a rule of thumb, a "rescue" insecticide application may be warranted if 2% to 5% of corn seedlings are cut below ground or 6% to 8% are fed on or cut above ground and black cutworm larvae are still feeding.

Ear-attacking caterpillars. In the past, caterpillars that fed on the ears of field corn were largely ignored, primarily because they were difficult to control and yield losses attributed to their injury were poorly understood. However, Bt corn hybrids that express proteins that are toxic to corn borers also control or suppress corn earworms and fall armyworms, both of which feed in corn ears. In addition, the western bean cutworm has become fairly well established in northern Illinois, and this species is also capable of causing significant injury to corn ears. Collectively, ear-attacking caterpillars can be considered key pests of corn.

Fall armyworms do not overwinter in Illinois, and corn earworms likely survive the winter only in southern Illinois. Consequently, infestations of both insects originate primarily from immigration of moths from farther south. The adults of both species lay eggs in corn fields, often

Figure 13.13. Fall armyworm larva (inset) and injury to corn leaves.

Figure 13.14. Corn earworm larva and injury to corn ear. (Photo courtesy Mitch Wirth.)

preferring later planted fields, and larvae that hatch from the eggs feed on leaves (**Figure 13.13**). Injury to leaves appears ragged and often messy—considerable frass, or caterpillar excrement, is produced from the caterpillars' feeding. Although this injury typically does not cause economic losses, it indicates the presence of the caterpillars and the potential for injury to corn ears. Adult female corn earworms also lay eggs on corn silks, and newly hatched larvae usually enter the ears at the tips (**Figure 13.14**).

The western bean cutworm has spread rapidly eastward from the Great Plains since 2000, being found for the first time in Illinois in 2004. Western bean cutworms overwinter as prepupae in Illinois, but adults do not emerge until late June or July. Females lay eggs on the upper leaves of corn, and young larvae eventually move downward on the plant to feed on silks and ears, entering the ears through the tips or the sides, often chewing directly through the husks (**Figure 13.15**). Multiple larvae can infest one ear, causing significant injury to developing kernels.

Figure 13.15. Western bean cutworm larva (inset) and injury to corn ear. (Larva photo courtesy Jim Donnelly.)

Although there are scouting procedures for all three species, all of these ear-attacking caterpillars are difficult to control with chemical insecticides, especially after the larvae enter the corn ears. Economic thresholds for corn earworms and fall armyworms are often based on the percentage of plants with whorl injury, and they are unreliable relative to yield loss caused by damage to the ears. An insecticide application may be warranted for control of western bean cutworms if 8% of the plants have egg masses and/or small larvae. In most instances, however, insecticides applied after ear-attacking caterpillars have entered the ears are not effective.

The current primary tactic for managing ear-attacking caterpillars in field corn is planting corn hybrids that express Bt proteins that are toxic to one or more of these pests. Please note that not all Bt corn hybrids are effective for controlling all ear-attacking caterpillars.

Figure 13.16. Wireworm larvae.

Figure 13.17. White grub larva (inset) and injury to corn seedling. (Photo courtesy Kevin Nelson.)

Figure 13.18. Grape colaspis larva (inset) and injury to corn seedlings. (Larva photo courtesy Benjamin Kaeb.)

Subterranean insects. This category includes all insects that feed on corn plants below ground except corn rootworm larvae and black cutworms, with primary emphasis on grape colaspis larvae, white grubs, and wireworms. Although these pests often are referred to as "secondary," we include them as key pests because corn growers regularly spend money to control them with seed- or soil-applied insecticides, and the pests cannot be controlled effectively after injury has been detected.

Several species of wireworms (**Figure 13.16**) attack the seed or drill into the base of the stem below ground, damaging or killing the growing point. Aboveground symptoms are wilted, dead, or weakened plants and spotty stands. Grape colaspis larvae and a few species of white grubs (primarily *Phyllophaga* species) (**Figure 13.17**) feed primarily on corn roots early in the season, usually stripping off the fine roots. Injury symptoms above ground include spotty stands, stunting, wilting, and purpling of the leaves and stems, the purpling a result of the plants' inability to take up phosphorous. Injury caused by grape colaspis larvae also results in browning of the tips and edges of corn leaves on small plants (**Figure 13.18**).

It is doubtful that any of these insects occur at economic levels in more than a relatively small percentage of fields every year; however, anticipating their occurrence is difficult. In addition, insecticides are not effective against these pests after the injury has been detected, and the only solution may be replanting (an expensive response) if stand reduction is significant. Consequently, most corn growers rely on experience and past history with these pests to develop management strategies, or they simply rely on seed- or soil-applied insecticides as a form of insurance. Bt corn hybrids do not control grape colaspis larvae, white grubs, or wireworms, although the chloronicotinyl insecticide on the seed should provide some protection. However, control by seed-applied insecticides may not be satisfactory when infestations are heavy.

Soybean

Although significant transformations in insect management have occurred with transgenic Bt corn, soybean insect management in the Midwest still mainly involves regular field scouting to determine whether a chemical insecticide is warranted to prevent yield loss—a curative approach. One preventive tactic is planting seed treated with a chloronicotinyl insecticide, usually in combination with a fungicide, with expectations for early-season protection against insects such as bean leaf beetle, seedcorn maggot, and soybean aphid. The benefits derived from the chloronicotinyls in these seed treatments are still uncertain. More promising is the eventual availability of soybean varieties with resistance to soybean aphids, which will provide soybean growers with a preventive tactic that can be integrated easily into insect management strategies for soybean.

Currently, insect management strategies for soybean should focus primarily on timely field scouting and knowing how and when to make insect-control decisions; see **Table 13.3** for an incomplete list of pests of soybean found in Illinois. A basic scouting plan for soybean in Illinois should include looking for particular insects at particular times:

- early-season insects, such as bean leaf beetle, shortly after crop emergence
- defoliators (insects that chew holes in leaves, such as bean leaf beetle, green cloverworm, and Japanese beetle) and insects or mites that suck plant fluids in June and July, such as soybean aphid and twospotted spider mite
- soybean aphids in late July and August
- late-season defoliators and pod feeders, such as bean leaf beetle and grasshoppers, in late July and August

Dedication to this basic scouting plan will enable soybean growers to note the presence or absence of insect pests at critical times throughout a growing season and to assess the frequency of occurrence of insect pests in their fields over time.

One other recommended skill for making insect control decisions in soybean is the ability to accurately assess the percentage defoliation caused by defoliators. Examples of different levels of soybean defoliation are shown in **Figure 13.19**. Although economic thresholds based on percentage defoliation of soybean have been called into question because of their "age" (they were developed in the 1970s and 1980s), they currently are the most widely published and consistently used thresholds for soybean defoliators. General percentage defoliation levels necessary for treatment with an insecticide range from 40% to 50% during vegetative stages (to about stage V7); 15% to 20% during flowering, pod development, and pod fill; and more than 25% from pod fill to harvest. These thresholds can be used to assess the need for an insecticide application for control of any soybean defoliator, and they will not be repeated in discussions of the key pests that follow.

Bean leaf beetle. Bean leaf beetles overwinter as adults and become active very early in the spring, flying first to alfalfa and clover fields to feed. As soon as soybean plants begin to emerge, the beetles abandon alfalfa and clover fields to colonize soybean fields, where they feed on cotyledons, leaves, and stems (**Figure 13.20**). After they finish feeding, they lay eggs in the soil to begin the first generation.

Adults of the first generation usually emerge in July. The beetles feed on soybean foliage, leaving small holes in the leaves. If the infestation is severe, soybean plants may be completely riddled with holes. The beetles again lay eggs in soybean fields, and a second generation occurs. Adults of the second generation usually emerge in August. They remain in soybean fields as long as there are tender plant parts to chew on. They may chew on pods after the leaves deteriorate, and their feeding creates scars that provide an avenue of infection by certain plant pathogens (**Figure 13.21**). Mild infection results in seed staining; severe infection results in seed decay.

Table 13.3. Insect and mite pests of soybean in Illinois.

Feed on belowground plant parts	Chew on leaves (defoliators) and/or stems	Suck plant fluids	Tunnel inside plants	Feed on pods
bean leaf beetle larvae grape colaspis larvae seedcorn maggot slugs[a,b] white grubs[a] wireworms[a]	bean leaf beetle blister beetles[a] corn earworm cutworms[a] fall armyworm grape colaspis adults grasshoppers[a] green cloverworm Japanese beetle slugs[a,b] thistle caterpillar (adult known as painted lady butterfly) webworms[a] western corn rootworm adults woollybear caterpillars[a] yellowstriped armyworm	plant bugs[a] potato leafhopper soybean aphid soybean thrips stink bugs[a] twospotted spider mite whiteflies[a]	European corn borer soybean stem borer (also known as Dectes stem borer) stalk borer	bean leaf beetle corn earworm grasshoppers[a] stink bugs[a]

Insects chosen for inclusion are encountered with relative frequency, at least in some regions of the state, or represent unique threats.
[a]More than one species.
[b]A mollusk, not an insect or mite.

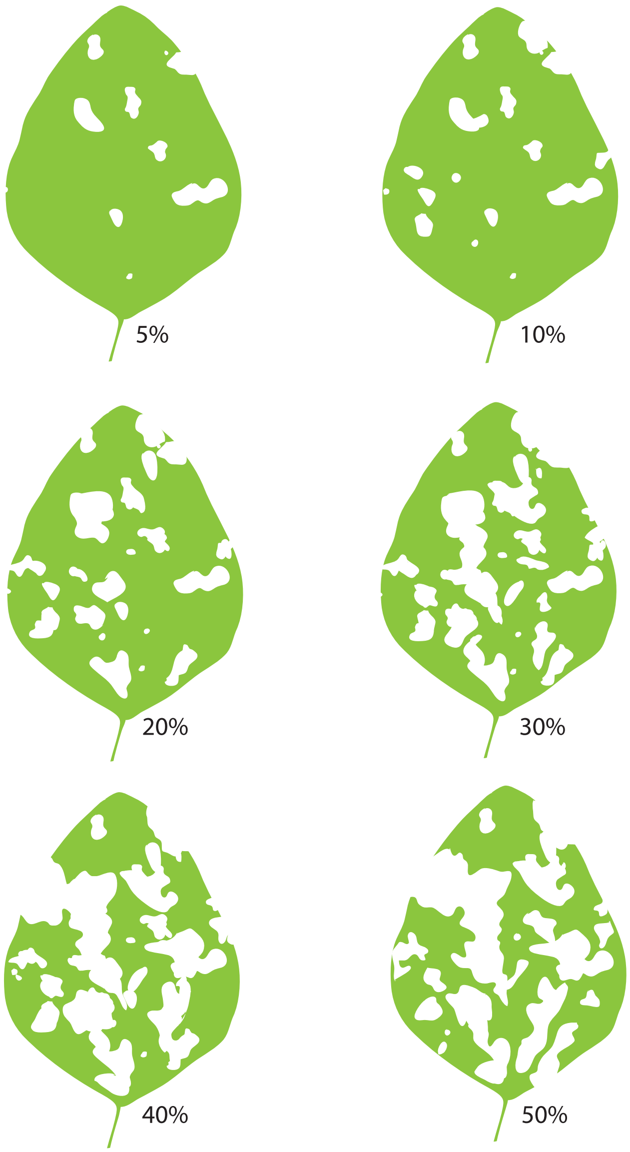

Figure 13.19. Different levels of defoliation of soybean leaves. (Illustration originally published in *Soybean Insects: Identification and Management in Illinois*, 1982, University of Illinois.)

Research has shown that seed treatments with chloronicotinyl insecticides effectively control bean leaf beetles that feed on seedling soybeans. Because of the large densities of beetles required to cause economic injury to seedling soybean (16 per foot of row in the early seedling stage or 39 per foot of row at stage V2), foliar-applied insecticides to control bean leaf beetles in seedling soybeans are infrequently justified.

Bean leaf beetles also may transmit the bean pod mottle virus. The virus may overwinter in the adults, so the insect may infect soybeans relatively early in the year. However, the actual timing of transmission is still unknown. There-

Figure 13.20. Bean leaf beetle (inset) and injury to seedling soybeans. (Beetle photo courtesy Marlin E. Rice.)

Figure 13.21. Bean leaf beetle injury to soybean pods.

fore, management guidelines to prevent bean leaf beetles from transmitting the virus have not been established.

An insecticide may be economically justified during the pod-filling stage if percentage defoliation and numbers of beetles per foot of row exceed established economic thresholds. An insecticide for control of adults feeding on pods may be warranted when 5% to 10% of the pods are injured and the leaves are still green.

Japanese beetle. Numbers of Japanese beetles have been very large in some areas of Illinois over the past few years, and defoliation in soybean fields has been conspicuous. Because defoliation of soybeans by Japanese beetles occurs almost exclusively in the upper canopy, the effect on yield is poorly understood. However, their large numbers and very visible activity (they move around a lot, especially on hot days) elicit responses that often result in insecticide applications.

Japanese beetles overwinter as grubs in the soil throughout Illinois. As temperatures warm up in the spring, the grubs begin feeding on the roots of grasses, including corn. Shortly thereafter, Japanese beetles pupate and transform into adults, which begin emerging in June. Japanese beetle adults feed on more than 300 species of plants, including soybean, corn, and many fruits and ornamental plants. By mid- to late July, the very active adults begin feeding on the leaves in flowering soybean fields (**Figure 13.22**). When they finish feeding for the summer, the females lay eggs in the soil, and the grubs develop to the third (and final) instar to overwinter. There is only one generation per year.

Standardized percentage defoliation thresholds can be used for making decisions about controlling Japanese beetles. However, for reasons indicated previously, the correlation between defoliation by Japanese beetles and soybean yield is not clear. Furthermore, defoliation often is not evident throughout an entire field because the beetles occur in clumps, often confined to field edges or other small areas. Consequently, soybean producers are strongly encouraged to assess the situation throughout a field to determine whether "spot treatment" with an insecticide will address the problem.

Soybean aphid. Soybean aphids were discovered for the first time in North America late in 2000, spreading throughout the Midwest very rapidly thereafter. This species quickly became established as the most important insect pest of soybean throughout the Midwest. Before 2008, widespread outbreaks of soybean aphids occurred primarily during odd-numbered years, with the most economically damaging outbreak occurring in many states in 2003. However, a widespread, economically damaging outbreak occurred in 2008, breaking the every-other-year cycle for this pest. Localized outbreaks of soybean aphids have occurred every year since their discovery.

The soybean aphid has a complex life cycle, with as many as 18 generations annually. Two different host plants are required by the aphid. The aphids spend the winter as eggs on their primary host, buckthorn (*Rhamnus* species), a woody perennial. Nymphs (immature aphids) hatch in the spring, develop through four instars, and become adults that begin giving birth to living young for the next generation. After two to three generations on buckthorn, winged females fly away in search of their secondary host, soybean. Soybean aphids colonize soybean fields and can increase their numbers rapidly—doubling in 3 to 4 days, depending on temperature. On actively growing soybean plants, colonies are found on leaves near the tops of the plants (**Figure 13.23**). On reproductive soybean plants, aphids are found on the undersides of leaves and on stems and pods. When an infestation in a given field becomes very large, winged aphids fly away to seek other soybean fields. Soybean aphids can be found in soybean fields from about mid-June to mid-September in Illinois. Winged aphids begin to fly back to buckthorn in September to complete the annual cycle.

Figure 13.22. Japanese beetles feeding on soybean leaves. (Photo courtesy Ron Hines.)

Soybean aphids suck fluids from soybean leaves and stems, causing injured leaves to crinkle or cup. The consequences of their feeding injury include early defoliation, shortened stems, stunting, reduced numbers of pods and seeds, and reduced seed weight. Sooty mold also develops on the honeydew that aphids excrete, causing heavily infested plants to appear dirty. Heavy infestations of soybean aphids can cause significant reductions in yield.

A foliar-applied insecticide may be warranted when densities of soybean aphids reach or exceed 250 aphids per plant, a widely acknowledged economic threshold. However, economic yield loss usually does not occur until densities of aphids reach or exceed 675 aphids per plant (the economic injury level). The economic threshold is conservative to allow for the time necessary to schedule an insecticide application. It is also important to note the presence and activity of predators of soybean aphids, especially the multicolored Asian lady beetle. Large numbers of predators and other natural enemies (parasitoids, pathogens) may prevent soybean populations from reaching the economic injury level.

Twospotted spider mite. We include twospotted spider mite as a key pest of soybean because of its capacity to cause devastating yield losses during widespread, prolonged drought conditions. However, localized outbreaks of twospotted spider mites often occur during years when

Figure 13.23. Soybean aphids on a soybean leaflet. (Photo courtesy Jim Morrison.)

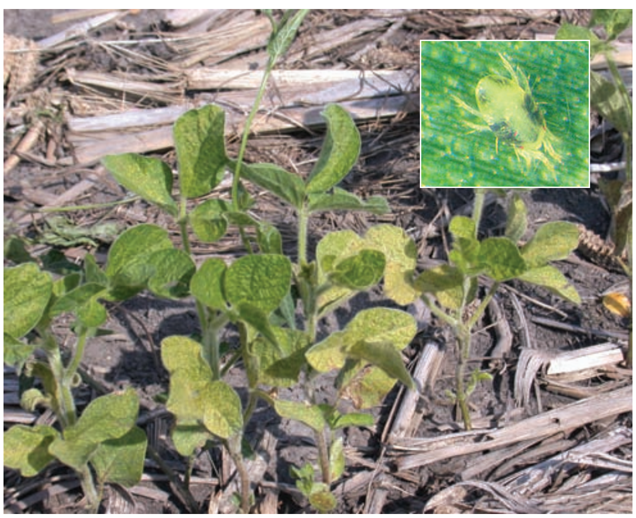

Figure 13.24. Twospotted spider mite (inset) and injury to soybeans. (Mite photo courtesy Marlin E. Rice.)

hot, dry conditions also are localized, so scouting for signs of their presence is recommended every year. If soybeans have an adequate supply of moisture, the mites usually do not cause much, if any economic damage.

Twospotted spider mites usually overwinter as females in areas covered with vegetation or plant debris, often along field edges. They also may overwinter on winter annual weeds within cultivated fields. In the spring, females begin laying eggs on plant leaves. Larvae with six legs emerge from the eggs and progress through two nymphal stages, each with eight legs. After the last nymphal molt, the eight-legged adults emerge. Spider mites complete a generation in 1 to 3 weeks, depending on environmental conditions (primarily temperature), and there are multiple generations within a growing season.

Spider mites crawl from weed hosts to soybean plants, so infestations usually appear first along field edges or in spots within a field. Mites can also move throughout fields by "ballooning"—spinning webs and moving to a position on a leaf from which they can be blown aloft. They can also move from row to row by bridging (moving across leaves in contact) when the canopy is nearly closed.

Spider mites puncture plant cells and suck plant fluids. Damaged plant cells do not recover. Initial injury results in a yellow speckling of the leaves (**Figure 13.24**). Heavy infestations cause leaves to wilt and die, and yield losses can be substantial. Another sign of the presence of spider mites is the webbing they produce on the undersides of the leaves.

Because numbers of twospotted spider mites can increase rapidly during hot, dry weather and because infestations can spread relatively quickly within a field, spider mites must be discovered and treated early to prevent significant yield losses. Reliable economic thresholds have not been developed, so insecticide applications are warranted primarily if prolonged hot, dry weather is expected after symptoms of mite injury begin to appear. Spot treatments along field edges may prevent further movement of spider mites into the field, although scouting throughout the field is strongly encouraged.

Wheat

Few insects cause recurring economic damage to wheat in this state. However, because most wheat is grown in southern counties, where temperatures frequently are suitable for insect survival and development, there is always potential for insect pest problems. Wheat grown in northern Illinois is threatened infrequently by insect problems.

Insect management strategies for wheat in Illinois include components of host plant resistance, cultural control, and the use of insecticides, and they begin with the purchase of wheat seed. (See **Table 13.4** for an incomplete list of pests of wheat found in Illinois.) Varieties resistant to Hessian flies are available, although Hessian flies can develop biotypes that can overcome the genes for their resistance. Wheat growers also can purchase wheat seed treated with a chloronicotinyl insecticide, which will protect wheat seedlings from aphids and reduce the risk of their transmitting the barley yellow dwarf (BYD) virus. Foliar-applied insecticides in the fall are warranted primarily if colonies of aphids begin to increase, although insects that devour seedlings (fall armyworm, for example) should also be monitored.

Insect management for wheat continues with the date of seeding. For decades, "fly-free" dates (dates by which Hessian fly adults have died) have been published, and we still encourage wheat growers to plant after the fly-free dates in their regions. As the term implies, wheat planted after fly-free dates is not exposed to egg-laying female Hessian flies. Wheat planted after the fly-free date also is less susceptible to the BYD and wheat streak mosaic viruses, transmitted by aphids and mites, respectively. Estimates of fly-free dates for wheat in Illinois are provided in Chapter 5.

After wheat begins growing in the spring, regular monitoring for insects is recommended. Numbers of aphids can increase in the spring when environmental conditions are favorable, although yield losses associated with their feeding injury in the spring are not common. Defoliators, such as armyworms and cereal leaf beetles, are the most common insect pests of wheat in the spring, and excessive defoliation may result in significant yield losses. Foliar-applied insecticides are warranted when numbers and injury caused by these pests exceed economic thresholds.

Aphids. Four different species of aphids occur in wheat fields in Illinois—bird cherry-oat aphid, corn leaf aphid (**Figure 13.25**), English grain aphid, and greenbug. All aphids can increase their numbers very quickly. However, there has been very little research to indicate that economic yield losses result from aphid feeding (sucking plant fluids) in Illinois wheat.

Of greater concern with aphids in wheat is their ability to transmit viruses that cause BYD disease. The potential for transmission of the viruses by aphids that colonize wheat in the fall has elicited the use of preventive tactics, such as chloronicotinyl insecticide seed treatments and foliar-applied insecticides in the fall. However, the guidelines for controlling aphids in wheat in the fall are not very well

Figure 13.25. Corn leaf aphids.

developed in Illinois, so foliar-applied insecticides often are applied as insurance treatments. We are not convinced that their widespread use is warranted annually.

When numbers of aphids begin to increase in the spring, there is potential that yield loss might occur from their feeding injury. As a rule of thumb, insecticide may be warranted when numbers reach or exceed 25 to 50 aphids per stem (depending on species: 25 greenbugs, 30 corn leaf or bird cherry-oat aphids, 50 English grain aphids), up to the boot stage. Insecticides are not recommended for aphid control from the dough stage to maturity.

Armyworm. Few armyworms overwinter in Illinois, but some partly grown larvae probably survive the winter under debris in southern counties. Moths that migrate from southern states into Illinois add to the resident population, and large numbers may trigger an outbreak, depending on environmental condition. So the key to effective management of armyworms in wheat is regular field scouting in the spring.

Armyworm moths may lay numerous eggs in wheat fields, especially in areas with thick stands. Young larvae scrape the leaf tissues; older larvae feed from the edges of the leaves (**Figure 13.26**) and consume all of the tissue, working their way up from the bottom of the plants. Injury to the lower leaves causes no economic loss, but injury to the upper leaves, especially the flag leaf, can result in yield reduction. After armyworms devour the flag leaves, they often chew into the tender stem just below the head, causing the head to fall off. After the grain matures or is harvested, the larvae will migrate into adjacent corn fields. Although there are two or three generations each year in Illinois, only the first generation threatens wheat production.

Early detection of an armyworm infestation is essential for effective management. Examine dense stands of wheat for larvae first. Because armyworm larvae feed at night or on overcast days, they usually are found on the ground under plant debris. If the number of armyworms exceeds 6 non-

Table 13.4. Insect and mite pests of wheat in Illinois.

Chew on leaves (defoliators) and/or stems	Suck plant fluids	Tunnel inside plants
armyworm cutworms[a] cereal leaf beetle grasshoppers[a] wheat head armyworm[b]	bird cherry-oat aphid chinch bug corn leaf aphid English grain aphid greenbug Hessian fly wheat curl mite	stalk borer

Insects chosen for inclusion are encountered with relative frequency, at least in some regions of the state, or represent unique threats.
[a]More than one species.
[b]Also feeds on developing grain.

Figure 13.26. Armyworm larva in wheat.

parasitized larvae (at least 3/4 to 1-1/4 in. long) per foot of row, an insecticide may be warranted.

Weather and natural enemies are the major causes of reductions in armyworm numbers. Hot, dry weather promotes the development of parasitoids and diseases, reducing populations of armyworms. Cool, wet weather is most favorable for an outbreak.

Hessian fly. Although Hessian flies have not caused economic damage to wheat in Illinois for many years, their continuing presence and development of new biotypes pose a constant threat to wheat growers. Consequently, planting wheat after fly-free dates and destroying volunteer wheat are widely recommended throughout the United States.

The Hessian fly overwinters as a full-grown maggot inside a puparium. In the spring, maggots change into pupae inside the puparia and emerge as adults. After females have mated, they lay eggs in the grooves on the upper sides of wheat leaves. After hatching from eggs, the maggots move behind the leaf sheaths and begin feeding on the stem. The maggots feed for about 2 weeks and then form a puparium in which they pupate, usually well before harvest time. The small brown puparium, commonly called a "flaxseed," can be found behind leaves next to the stem (**Figure 13.27**). Hessian flies remain in this stage in the stubble throughout the summer. Flies emerge again in late summer and seek egg-laying sites on volunteer wheat plants or on fall-seeded wheat. After hatch, the fall generation of maggots begins feeding on seedling plants.

Figure 13.27. Hessian fly puparium, or "flaxseed" (left), and larva. (Photo courtesy Kevin Black, Growmark.)

Wheat infested in the fall usually is stunted, and the leaves are dark blue-green, thickened, and more erect than healthy leaves. Severely damaged plants may die during the winter. In the spring, injured plants appear much like they do in the fall. In addition, infested plants often break over when the heads begin to fill.

Because foliar-applied insecticides are neither practical nor reliable for control of Hessian flies, the best preventive tactics are destruction of wheat stubble and volunteer wheat and planting resistant or moderately resistant wheat varieties after the fly-free dates. Where wheat is seeded on or after the fly-free date for a specific location, Hessian fly adults usually emerge and die before the crop is out of the ground. Seed-applied chloronicotinyl insecticides provide some protection against Hessian flies and are recommended, particularly if wheat must be planted before the fly-free dates.