Managing Insect Pests[1]

by Nick Seiter[2]

Introduction

Insects can reduce crop yield and quality, either by feeding directly on the marketable portion or by indirectly stressing or killing the plant. Many insects can be considered pests of alfalfa, corn, soybean, or wheat; however, only a relative few are frequently encountered at economically significant densities in Illinois. This chapter considers "key" pests, which should form the basis of insect management strategies for these crops, as well as some "occasional" pests that, while frequently encountered, rarely cause economic damage. (Note that the pests considered in this chapter are not comprehensive; for a more complete list of insect pests in these crops in Illinois, consult either Chapter 2 of the Illinois Pesticide Applicator Training Manual 39-2: Field Crops (2013, University of Illinois), or the Illinois Field Crop Scouting Manual (2021, University of Illinois).

Integrated pest management (IPM) refers to the harmonious use of multiple means to reduce the impacts of insect pests. Some foundations of this approach are to use pest monitoring to guide management decisions, to tolerate insect feeding that does not reach the level of economic damage, and to rely on multiple, complementary control tactics. The IPM approach requires information on insect biology, activity, and injury potential. Benefits of IPM include:

- limiting inputs to those that will provide a positive return on investment through preserved yield;
- avoiding unnecessary selection pressure (and delaying subsequent resistance development) from over-reliance on a single control tactic; and
- initiating tactics that complement, rather than interfere with, each other (e.g., using selective insecticides to preserve natural enemies).

1 Thanks to Dr. Erin Hodgson (Iowa State University) and Dr. Bruce Potter (University of Minnesota) for providing expert reviews of this material

2 Update to "Managing Insect Pests" by Kevin Steffey and Mike Gray, Ch. 13 2009 Illinois Agronomy Handbook, pp. 179-196.

Scouting and Economic Thresholds

An informed decision on insect management is not possible without some information on the size and timing of a pest infestation. The methods we use to scout for insects and monitor their populations vary depending on the crop, time of year, and target pest. Often, we can combine information gathered from monitoring with information on field history, weather conditions, and cultural practices to assess the risk of a pest infestation; for instance, black cutworm is more likely to be a significant pest when early-season weed control is poor.

Economic decision-making is used in conjunction with monitoring to determine whether or not a control action is needed. Three critical levels help to guide this decision. First, the "gain threshold," expresses control cost in terms of the commodity. (We often think of this as the "break-even point," or how many bushels a control needs to save to be worthwhile; if an insecticide costs $10 per acre to apply and corn is $4.00 a bushel, it needs to save 2.5 bushels per acre of yield to justify the cost – this is the gain threshold). The economic injury level expresses the gain threshold in terms of pest density; it is the level of pest infestation where those 2.5 bushels will be lost if no control is applied. (For example: research has determined that, at the $10 control cost and $4.00 corn prices mentioned earlier, 0.93 western bean cutworm larvae per corn ear will cause damage equal to the cost of control – the economic injury level [Paula-Moraes et al. 2013]). Finally, the economic threshold is the point where you should apply your control; it is *lower* than the economic injury level to provide time to apply a control before economic losses occur. This may be set as an arbitrary percentage of the economic injury level (i.e. 75%), or it may be based on the rate of insect development. Economic thresholds form the basis of practical recommendations for insect management, and appear in this chapter whenever they are available for a particular insect pest.

Insect Control Methods

"Control" means any method specifically used to reduce an insect population's ability to feed, reproduce, and damage a crop – usually (but not always) by killing them.

Effective pest management strategies rely on multiple control methods used in a complementary way. This can take many forms: choosing a more selective insecticide over one with a broader spectrum to conserve non-target species; optimizing fertility to allow vigorous plants to more effectively overcome insect feeding; using a resistant plant genetics to slow or prevent insect development, promoting improving control by natural enemies; or simply foregoing an unnecessary insecticide to prevent a secondary pest outbreak caused by the removal of natural enemies.

Chemical control is the use of an insecticide to kill, inhibit, or repel insects. Insecticides are often deployed in agronomic crops as a broadcast or banded spray, an in-furrow application at planting, or applied directly to the seed depending on the target pest and situation. Most insecticides used in agronomic crops target the insect nervous system, though some target other processes/systems such as insect molting or mitochondrial respiration. (A detailed description of the modes of action of different insecticide chemical classes is available at https://irac-online.org). Some insecticide classes often used in agronomic crops in Illinois include: carbamates (group 1A); organophosphates (group 1B); pyrethroids (group 3A); neonicotinoids (group 4A); insect growth regulators (groups 15, 18, and others); and diamides (group 28).

Host plant resistance involves the use of crop varieties with characteristics that make them less susceptible to insect injury. This can be accomplished by killing the insect or slowing its development ("antibiosis"), repelling the insect or inhibiting its ability to find the plant ("antixenosis" or non-preference), or maintaining yield and quality despite insect feeding that would harm a normal, susceptible plant ("tolerance"). Transgenic insect-resistant varieties are produced by inserting a gene from another species into the genome of the target plant; this trait is then "introgressed" into commercial varieties through plant breeding. This is the approach used to produce Bt corn hybrids resistant to European corn borer, corn rootworms, and other pests. Breeders incorporate other insect-resistant traits into crop varieties (such as those used to control Hessian fly in wheat, soybean aphid in soybean, or potato leafhopper in alfalfa) using traditional plant breeding methods.

Biological control is the use of natural enemies to limit insect population growth. These natural enemies may be predators, parasites/parasitoids, or pathogens. Conservation biological control means facilitating the activity of native natural enemies, either through the judicious and selective use of insecticides (i.e., only applying an insecticide when an economic threshold has been reached), environmental manipulations to provide food or habitat to natural enemies, or supplementing native natural enemies by inoculating fields.

Cultural control is the manipulation of cultural practices (such as planting date, tillage, irrigation, fertility, etc.) to reduce the impact of insects on a crop. An example would be the use of crop rotation to mitigate the risk of corn rootworm damage (in parts of Illinois where rotation resistance is not prevalent). Insect management is usually not the primary consideration when deciding on cultural practices such as tillage or planting date; however, understanding the role that cultural practices can play in favoring or deterring certain pests should be part of a successful insect management strategy. For example, fields that have livestock or green manure incorporated just prior to planting are at greater risk of seed corn maggot infestation; similarly, wheat fields planted before the fly-free date into a field surrounded by volunteer wheat are more likely to be attacked by Hessian fly.

Insect Resistance

Insect resistance to control measures occurs due to selection pressure placed on the insect population when a tactic is used. The typically rare individuals with genetic traits that allow them to overcome a control are more likely to survive and reproduce after the control is applied than the more common susceptible individuals. Over the course of generations, the frequency of these resistant traits increases in the population. Eventually, the frequency of these resistant traits becomes high enough that the control becomes less effective. While selection pressure is always the driver of resistance (not just in insects, but in weeds and pathogens as well), the specific mechanism that leads insects to overcome a control varies. Resistant insects may produce enzymes that more effectively break down an insecticide, or the binding site may change such that the material no longer has its toxic effect. Behavioral changes in the population may result in the avoidance of the material, or the cuticle of the resistant insect may be less permeable. While resistance is often associated with insecticides due to the high selection pressure they place on insect populations, resistance is possible to any control. For example, behavioral resistance to crop rotation in the western corn rootworm has dramatically altered management practices for this pest in Illinois over the last three decades.

Resistance management, or strategies to delay the onset of resistance, should focus on reducing the selection pressure that leads to the development of resistance within the insect population. The strategy used will vary depending on the biological characteristics of the pest and the nature of the control; for example, a resistance management strategy developed for European corn borer and Bt corn might not effectively delay pesticide resistance in spider mites. However, general principles of resistance management that apply to essentially all systems are to avoid controls that are not justified based on the likelihood of economic damage, and to avoid repeated use of a single control tactic.

Alfalfa

Alfalfa is an excellent habitat for many insects, including some pests, beneficial insects, and other species that have little or no effect on the crop. Insecticides should be used only when necessary based on economic thresholds; unnecessary applications reduce beneficial insect populations needlessly, and can result in ecological backlash (including secondary pest outbreaks and harm to pollinators).

Many species of insects can reduce alfalfa yield, impair forage quality, or reduce the vitality and longevity of the crop. However, only alfalfa weevil and potato leafhopper are considered key pests in Illinois that require frequent monitoring and management. Alfalfa weevils threaten the first alfalfa cutting, while potato leafhoppers threaten the second and third cuttings; therefore, insect management strategies for alfalfa are needed throughout the growing season. Regardless of which cutting is affected, failure to control either pest if one reaches economically damaging levels can 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 resistance to alfalfa weevils and/or potato leahoppers. Alfalfa varieties with resistance to alfalfa weevil tolerate light to moderate feeding by the larvae, but additional control is still necessary at high population densities. In contrast, glandular-haired alfalfa varieties with resistance to potato leafhopper provide control by repelling the insects and preventing nymphs from feeding effectively (note that these glandular hairs take some time to develop after a new stand of resistant alfalfa is planted; therefore, a new planting may not be immediately resistant to potato leafhopper). Resistant varieties should still be scouted for leafhoppers, but economic thresholds are much higher than in susceptible varieties.

Insect pests of alfalfa

Alfalfa weevil. Newly hatched alfalfa weevil (*Hypera postica*) larvae feed in the growing tips of alfalfa plants in the spring. Pinholes in newly opened leaves are an early sign of injury, which often show up initially on south-facing slopes. As larvae develop, they shred and skeletonize the leaves (Fig. 1). Damaged fields often appear “frosted” because of the loss of green leaf tissue. Environmental stress or other factors that slow plant growth in the spring will increase the impact of weevil injury. Adults may cause some injury later in the spring, but the initial injury by the larvae is the primary concern. However, both surviving larvae and newly emerged adults

Fig. 1. Alfalfa weevil larva (image: Clemson University, USDA Cooperative Extension Slide Series, Bugwood.org)

occasionally affect regrowth after the first cutting. In these situations, they remove early shoot growth, depleting food reserves in the roots and reducing the stand.

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 using degree days accumulated after January 1. (the Illinois Climate Network Pest Degree-Day Calculator can help to make this determination: https://go.illinois.edu/degreedays). In general, field inspections should be conducted from the time alfalfa begins to grow in the spring until first harvest, with a final inspection of the stubble shortly after the first cutting. As a rule of thumb, consider an insecticide application when larvae are present and 40% of the tips have been skeletonized. Tall, rapidly growing alfalfa can tolerate more defoliation without suffering yield reductions than shorter or slower-growing alfalfa. If you are within 7 days of harvest, a spray is likely not necessary; harvest is a good control option if growth is sufficient. After the first cutting, control may be warranted when larvae and adults are feeding on more than 50% of the crowns and regrowth is prevented for 3-5 days. This amount of injury usually does not occur unless there are 4-8 larvae per square foot. More detailed economic thresholds based on the number of larvae per 30 stems that incorporate the expected value of the hay, cost of control, and plant height are available from Penn State University Extension: https://extension.psu.edu/alfalfa-weevil

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 (which will be discolored and moving slowly, if at all). When natural enemies and pathogens suppress weevil population densities, an insecticide treatment may not be necessary.

In addition to chemical control, grazing and/or early cutting of the first harvest are effective cultural control tactics for alfalfa weevils.

Potato leafhopper. Potato leafhoppers (*Empoasca fabae*) do not overwinter in Illinois, and they usually do not appear until prevailing winds transport them from further south in late April or early May. Nymphs develop from eggs deposited by the immigrant females, and both nymphs and adults suck fluids from alfalfa plants (Fig. 2). Several generations occur throughout the summer before they migrate south or cold temperatures kill them off in the fall.

Fig. 2. Potato leafhopper nymph (image: Frank Peairs, Colorado State University, Bugwood.org)

Potato leafhopper nymphs cause more damage than the adults do. The initial injury is characterized by a V-shaped yellow area at the tips of the leaflets; this injury is often called “hopperburn” or “tipburn”. As the injury progresses, the leaves become completely yellow and 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 most effective method for monitoring potato leafhoppers in alfalfa. By the time symptoms of injury appear considerable yield and quality reductions may have already occurred. Because tender, re-growing plants are particularly susceptible to leafhopper injury, scouting immediately after a cutting is critical. Taller, more mature alfalfa can tolerate more leafhopper injury, and the economic thresholds vary accordingly. As a rule of thumb, an insecticide should be considered for alfalfa up to 3-inches tall when sweep nets yield an average of 0.2 leafhoppers per sweep (i.e., 5 leafhoppers in 25 sweeps). Action thresholds increase to 0.5 per sweep (12.5 per 25 sweeps) for 3-6-inch alfalfa, 1 per sweep (25 per 25 sweeps) in 6-12-inch alfalfa, and 2 leafhoppers per sweep (50 per 25 sweeps) if alfalfa is greater than 12 inches tall. More detailed economic thresholds that incorporate hay value, cost of control, and plant height are available from Penn State University Extension: https://extension.psu.edu/potato-leafhopper-on-alfalfa

While glandular-haired resistant varieties are effective for moderate densities of potato leafhopper, these varieties provide limited protection during the first year of seeding and during regrowth immediately after a cutting. In addition, excessively high population densities can “overwhelm” the varietal resistance.

Corn

Of the agronomic crops discussed in this chapter, corn is the most likely to suffer economic damage due to insect feeding in Illinois. Corn rootworms (including the western and northern corn rootworm species) are the most economically important pests of corn in Illinois. Additional pests, such as cutworms, corn borers, and ear-feeding caterpillars also cause economic injury each year in Illinois to a lesser extent. Bt corn hybrids have become the primary tool for controlling corn rootworms and corn borers in Illinois. These and other preventative tools are discussed in more detail below. Like “rescue” treatments, these preventative tools should be used in accordance with the actual risk of economic damage following an integrated pest management approach based on pest monitoring.

A basic scouting plan for corn in Illinois should include the following:

- Early season (emergence to around V5): stand reduction and pest activity due to cutworms, wireworms, armyworm, and other seedling pests
- Early-mid June (mid-late whorl): first-generation corn borers (European corn borer statewide, southwestern corn borer in southern Illinois)
- July-August (late whorl to early reproductive stages): corn rootworm adults and western bean cutworm egg masses and larvae
- Late July-early August (mid-reproductive stages): second generation corn borers, ear feeding caterpillars

Preventative insect control products for corn

Biotech traits for insect control. Close to 90% of the corn planted in Illinois includes Bt traits for control of at least one insect pest complex (https://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us/). The Bt proteins expressed in commercial hybrids are marketed as components of “above-ground” or “below-ground” trait packages based on the spectrum of insect pests they control: above-ground traits target several pests in the order Lepidoptera (caterpillars, the larvae of moths and butterflies), while below-ground traits target corn rootworms in the order Coleoptera (beetles). In both cases, the insect must feed on plant tissue expressing the Bt protein for it to be effective, further increasing the species-specificity of these pest control tools. In addition to Bt proteins, a biotech trait that relies on RNA-interference for control of corn rootworm has recently been approved for commercial use in the U.S., and additional traits using this technology are in development.

Many different combinations of insect control and herbicide tolerance traits are commercially available. Extension personnel at Michigan State and Texas A&M maintain a list of these trait packages called the “Handy Bt Trait Table for U.S. Corn Production,” which is updated annually and available for download at: https://www.texasinsects.org/bt-corn-trait-table.html.

Insect resistance to biotech traits is a constant threat, and the biggest obstacle to insect management using this approach; western and northern corn rootworm, western bean cutworm, corn earworm, fall armyworm, and European corn borer have all developed resistance to at least one Bt protein in parts of their range. In Illinois, western and northern corn rootworm, western bean cutworm, and corn earworm all have confirmed or suspected resistance to one or more of the traits that we use. The United States Environmental Protection Agency (EPA) mandates insect resistance management strategies for biotech corn as a condition of registration. As part of this strategy, a farmer planting corn that expresses a biotech insect-resistance trait must also plant a certain percentage of “refuge” corn that does not express the insect-resistance trait. Refuge requirements vary from one hybrid to another depending on the target insect and how many Bt proteins are expressed; "pyramided" hybrids, which express more than one protein for control of a particular pest, require a smaller refuge than single-trait hybrids. Refuge requirements have changed over time and will continue to do so, and you should consult your seed dealer when purchasing biotech seed to determine the requirements for a particular hybrid. As of 2021, most biotech hybrids sold within Illinois include a 5% refuge that is blended into the purchased seed and do not require a separate refuge to be planted.

Seed-applied insecticides. Almost all field corn seed planted in Illinois includes one or more seed-applied insecticides. The rates of these insecticides are measured by the amount of the active ingredient applied to each individual seed; for example, a "250" rate indicates that each seed is coated with 0.25 mg of the insecticide active ingredient. Most insecticide seed treatments planted in Illinois include an insecticide from the neonicotinoid class (including materials such as clothianidin and thiamethoxam). Seed treatments including a diamide insecticide (chlorantraniliprole) have also become available in recent years. At lower rates (250 or 500), these products target early-season stand-reducing pests such as wireworms, seedcorn maggot, cutworms, grape colaspis, and white grubs. Use of these materials should correspond to the actual risk of infestation by one or more of these pests, which is low in most Illinois fields. Risk factors for these pests may include green or livestock manure (seedcorn maggot), recent conversion of pasture or grassy vegetation/weeds (white grubs and wireworms), early pressure from winter annuals or other weeds (black cutworm), and field history (grape colaspis and wireworms). Higher (1250) rates are marketed for control of corn rootworm; these should be deployed, like other rootworm controls, based on expected levels of rootworm pressure.

Soil-applied insecticides. Insecticides can be applied at planting for control of corn rootworm and early-season stand reducing pests. These are typically applied either directly into the seed furrow, or as a 6- to 8-inch band over the planted row. While use of these materials has become less common since the introduction of Bt corn hybrids, they are still a viable method of control. Both granular and liquid formulations of soil insecticides are available. Several of the liquid materials are formulated to be compatible with liquid fertilizer applications at planting. Unfavorable environmental conditions (including too much or too little soil moisture) can compromise soil insecticide efficacy in some cases.

Insect pests of corn

Corn rootworms. Corn rootworms are the most important pests of corn in Illinois and throughout the North Central U.S. Western corn rootworm (*Diabrotica virgifera virgifera*) (Fig. 3) is the most impactful species in Illinois; northern corn rootworm (*Diabrotica barberi*) (Fig. 4) can be just as damaging, but is not nearly as widespread. In recent years, populations of both species have been lower than historical averages, though they remain a consistent threat.

Corn rootworm larvae (Fig. 5) hatch from overwintered eggs in May and June; the timing of egg hatch depends on annual temperature accumulation, and can be estimated using degree days. (A degree day calculator to estimate the timing of egg hatch in Illinois can be found at the following link: https://go.illinois.edu/degreedays). The larvae immediately begin feeding on corn roots if they hatch into a cornfield. While they are capable of surviving on several species of grasses, corn is the primary developmental host. Larvae (including larvae from rotation-resistant populations) are not capable of feeding or surviving on soybean or other broadleaf plants; therefore, any larvae that hatch into a soybean field will die unless they encounter volunteer corn or grass weeds.

Newly hatched corn rootworm larvae tunnel inside of root tissue; older larvae feed on the outside of the roots. This feeding often results in "pruning" of the roots back to the stalk. Pruning inhibits the ability of the corn plant to take up water and nutrients. In addition, pruning reduces the ability of the roots to support the plant, and can allow plants to lodge. This is often called "gooseneck" lodging based on the appearance of the corn stalk after the plant straightens itself back up. (Fig. 6) Both lodging and the reduced water and nutrient uptake due to pruning contribute to yield losses, which have been estimated at 15% of yield for every node that is pruned (Tinsley et al. 2013). After they complete their

Fig. 3. Western corn rootworm adult (image: Joseph Spencer, Illinois Natural History Survey)

Fig. 4. Northern corn rootworm adult (image: Joseph Spencer, Illinois Natural History Survey)

Fig. 5. Corn rootworm larva (image: Joseph Spencer, Illinois Natural History Survey)

Fig. 6. Lodging due to corn rootworm injury (inset) (images: Nick Seiter, University of Illinois)

Fig. 7. Adult rootworm feeding on corn foliage (image: Nick Seiter, University of Illinois)

development, larvae pupate in earthen cells below the soil surface and emerge as adults.

Corn rootworm adults typically begin to emerge in late June or early July. They feed readily on corn silks and pollen, as well as the pollen of pumpkins and squashes. Corn rootworm adults will also feed on pollen from weeds and other plants. In addition to pollen, or when pollen is not readily available (for example, if they emerge in a field that has not yet tasseled), corn rootworm adults will feed on corn foliage, leaving behind a “window pane” appearance (Fig. 7). This feeding does not affect yield. The adults will mate soon after emerging and lay eggs in the soil throughout the rest of the summer. Corn rootworms have one generation per year, with the eggs overwintering. Western corn rootworm eggs hatch the following spring after remaining dormant for one winter; northern corn rootworm eggs may hatch after remaining dormant for one, two, or more winters.

Rotation resistance. Western corn rootworm can circumvent crop rotation as a control tactic by laying eggs in soybean and other rotational crops in addition to corn. Eggs deposited in soybean usually hatch into corn the following season, allowing the insect to complete its development and cause damage to the corn crop. The northern corn rootworm is also capable of circumventing crop rotation through extended diapause, in which the eggs remain dormant in the soil for multiple seasons before hatching. As corn rootworm populations have declined in recent years, damage to rotated corn has become less common in much of Illinois; the risk of rootworm damage is much higher in continuous corn than in rotated corn. However, crop rotation should not be considered a reliable control tactic in much of the state, and should not be relied on independent of information on beetle abundance. Monitoring soybean fields for rootworm adults is critical to determining how much rootworm pressure to expect in rotated corn.

Control tactics. Currently, the mostly widely used and effective control tactic for corn rootworm is the use of a Bt corn hybrid with multiple toxins that target rootworm larvae. These are known as “pyramided” trait packages because they include multiple traits that attack the same insect. Consult the “Handy Bt Trait Table for U.S. Corn Production” (https://www.texasinsects.org/bt-corn-trait-table.html) to identify the traits and Bt proteins included in commercially available trait packages.

Resistance development to Bt traits is an ongoing concern for Illinois farmers. Resistance or reduced susceptibility has been confirmed in at least part of Illinois to all of the individual traits available for rootworm control. (Note: the “Handy Bt Trait Table for U.S. Corn Production” referenced above includes a list of insects that have been confirmed resistant to particular trait packages). Most Bt hybrids sold in Illinois now include a 5% non-Bt blended refuge, eliminating the requirement to plant a structured non-Bt refuge. However, consult your seed dealer on the refuge requirements associated with a particular trait package.

In addition to Bt traits, soil insecticides (primarily from the pyrethroid, organophosphate, and neonicotinoid chemical classes) are also available to control corn rootworm larvae. Insecticides can be applied at planting within or banded over the seed furrow, or can be applied directly to the seed at rates sufficient to control corn rootworm. Soil-applied insecticides may be formulated as a granular material or as a liquid to be diluted in water or liquid fertilizer.

Monitoring. Adult populations should be monitored from late July-early September to determine the likelihood of a damaging larval population the following year and the need for control at planting. Both soybean and corn can be monitored using yellow sticky card traps. Consider an economic threshold of 2 beetles per trap per day in corn following corn, or 1.5 beetles per

Fig. 8. Black cutworm larva and damage (image: Clemson University, USDA Cooperative Extension Slide Series, Bugwood.org)

trap per day in corn following soybean (Dunbar and Gassmann 2013).

Cutworms (primarily black cutworm). Several species of cutworms can damage seedling corn; the black cutworm (*Agrotis ipsilon*) is by far the most common of these in Illinois, as well as the most economically important. Black cutworm does not typically survive Illinois winters, but the moths migrate from southern states during the spring each year. The moths seek vegetation such as winter annual weeds (or, occasionally, cover crops) in which to lay their eggs. The larvae begin feeding on foliage after they hatch. Most of their feeding occurs at night; during the day, cutworm larvae tend to hide either within the plants (for example, in the whorl of a corn plant) or just underneath the soil surface or crop residue.

A clean, weed-free stand of corn is not usually an attractive egg-laying site for cutworm moths. However, the larvae are often forced to leave their initial host plants and move to corn following a herbicide application. Small larvae simply feed on the leaves, resulting in cosmetic damage with no impact on yield. Once cutworm larvae develop to the 4th instar (≥ ¾ inch in length) their feeding often cuts corn plants at or just below the soil surface (Fig. 8), resulting in stunting of the plant or stand loss.

Monitoring and Control. Effective control of winter annual weeds will reduce the attractiveness of cornfields to egg laying moths and reduce the risk of a cutworm infestation. Several above-ground Bt trait packages control cutworm larvae, while most provide only suppression. Insecticide seed treatments with a neonicotinoid active ingredient provide suppression, but not effective control, of cutworm larvae. Black cutworm moths can be monitored using pheromone traps. These traps determine the timing of moth flights in the spring, which can be used to predict the "cutting date" when larvae will be large enough to reduce corn stands through their cutting behavior. Because cutworm larvae are mostly nocturnal, it is usually easier to scout for their damage first. When damage (particularly cutting) is observed, scrape away the top layer of soil or residue in the area surrounding the cut plant to uncover the larvae. Cutworm larvae have a characteristic "sheen" that can help to distinguish them from other caterpillars. Consider a broadcast insecticide application when 2-5% of plants have been cut and cutworms are still present in the field.

Corn borers. Corn borers were among the most consistent and damaging pests of corn in Illinois for many years. Over the last several decades, populations of these insects have declined with the introduction of above-ground Bt traits for their control. These traits remain effective in Illinois, and corn borer infestations are currently rare in conventional corn production. The suppression of corn borers over a wide area has also benefited non-Bt production of field corn and specialty varieties (e.g., sweet corn, popcorn, etc.) (Hutchison et al. 2010). However, corn borers are still troublesome pests in certain areas, especially where there are localized pockets of continuous non-Bt corn production.

There are two primary species of corn borers in Illinois: the European corn borer (*Ostrinia nubilalis*) (Fig. 9) (present throughout the state) and the southwestern

Fig. 9. European corn borer larva (Joseph Spencer, Illinois Natural History Survey)

Fig. 10. Southwestern corn borer larva (Frank Peairs, Colorado State University, Bugwood.org)

corn borer (*Diatraea grandiosella*) (Fig. 10) (generally only an issue in the southern tip of Illinois). Both species usually complete two generations per year in Illinois. The first generation of each species causes similar damage: the larvae begin feeding on leaves in corn whorls during June, then the larger larvae tunnel into corn stalks in late June-early July. The second-generation European corn borer larvae initially feed on leaf collars and on the pollen that accumulates in the leaf collar area. As the larvae mature, they tunnel into the corn stalks, shanks, and ears. Second generation southwestern corn borer larvae also tunnel into corn stalks; they typically work their way to the base of the plant, where they girdle the stalk internally to create an overwintering cell.

Corn borer tunneling interferes with water and nutrient translocation in the plant, resulting in indirect yield loss. Tunneling also weakens stalks and facilitates infection by stalk rot pathogens, often leading to stalk lodging. Feeding in the ear shank can result in ear lodging. The second generation of both European corn borer and southwestern corn borer causes more economic damage than the first generation.

Bt corn hybrids are the primary corn borer control tactic used for conventional production in Illinois. Several above-ground trait packages result in greater than 99% control of larvae from both species. Current information on Bt trait packages available for control of these and other insect species can be found using the Handy Bt Trait Table for U.S. Corn Production: https://www.texasinsects.org/bt-corn-trait-table.html. Unlike corn rootworms, no resistance to Bt traits has been observed in either corn borer species in Illinois – a remarkable success considering the first Bt trait for corn borer control was introduced over 20 years ago. However, there have been instances of control failures due to resistance observed in other parts of North America. The first observed instance of field-evolved resistance to a Bt trait in European corn borer was observed in Nova Scotia, Canada in 2018 (Smith et al. 2019).

Insecticides can be used for control of corn borers in non-Bt corn. Economic threshold tables are available to guide the use of insecticides for either the first generation (based on live larvae scouted during whorl stages) or second generation (based on egg masses scouted during reproductive stages). (University of Minnesota Extension maintains a dynamic threshold calculator, which can be accessed here: https://extension.umn.edu/corn-pest-management/european-corn-borer-minnesota-field-corn#table-1.-dynamic-economic-threshold-for-ecb-in-whorl-stage-corn-%28example%29.-2221310). Insecticides targeting the second generation must contact the larva between the time it hatches and the time it enters the plant to be effective.

Ear-feeding caterpillars. Corn earworm (*Helicoverpa zea*), fall armyworm (*Spodoptera frugiperda*), and western bean cutworm (*Striacosta albicosta*) feed directly on corn ears, potentially resulting in losses of both yield and quality. This feeding can facilitate the development of ear rot pathogens, which further reduce quality. Some ear rots produce mycotoxins that are harmful to human and livestock consumers.

Fall armyworms do not overwinter in Illinois; corn earworms (Fig. 11) survive the winter only at relatively low levels in Illinois, and only in the southern portion of the state. Damaging infestations of these insects originate from moths that have immigrated into Illinois from the south, and infestations are more likely in later planted corn. The moths are capable of laying eggs in corn at any growth stage, but oviposition of corn earworms is typically greatest during silking. Feeding during the whorl stages by either species rarely causes economic losses in Illinois. Larvae that are present during the reproductive stages usually enter the ears at the tips. Both species can be cannibalistic (corn earworm is particularly aggressive) which often limits the number

Fig. 11. Corn earworm larva (Joseph Spencer, Illinois Natural History Survey)

of larvae per ear to one. Feeding by these two species is more damaging to grain quality than to yield in Illinois. Control of these species with an insecticide is generally not necessary or effective in field corn in Illinois.

Western bean cutworm (Fig. 12) is another species of caterpillar that feeds on corn ears. In Illinois, western bean cutworm is primarily an issue in the northeastern portion of the state in areas with lighter/sandier soils. Western bean cutworm overwinters in Illinois, and adults emerge in late June or early July. Females lay eggs on the upper leaves of corn. Upon hatching, the larvae move down the plant to feed on silks and ears. Unlike corn earworms that feed primarily at the ear tips, western bean cutworm larvae may enter at the tip or the side

Fig. 12. Western bean cutworm larva (Frank Peairs, Colorado State University, Bugwood.org)

of the ear, and often chew directly through the husks. In addition, the larvae are less aggressive to each other than corn earworm larvae, and multiple larvae often infest a single ear. Consider an insecticide for western bean cutworm in non-Bt field corn if 8% of plants scouted have egg masses and/or small larvae. (Note: currently the only Bt protein effective for control of this insect is Vip3A; hybrids that lack this protein, even if they have other above-ground traits, should be treated like non-Bt corn with respect to western bean cutworm). Like other ear-feeding caterpillars, insecticides will not provide effective control once the larvae have entered the ears.

The primary control method used for ear-feeding caterpillars in Illinois is the use of corn with an above-ground trait package targeting one or more species. Note that not all trait packages target these insects, and all three of the major ear-feeding species in Illinois have developed resistance to at least one of the Bt traits available (see Handy Bt Trait Table for U.S. Corn Production: https://www.texasinsects.org/bt-corn-trait-table.html).

Occasional pests

Wireworms. Wireworms are the larvae of click beetles (Family: Elateridae), and several species feed on germinating seeds and developing plants. The resulting damage includes loss of stand, stunting, and wilting of seedlings. Like many early season pests, wireworm injury is most severe when cool conditions early in the season slow crop growth and development. Warmer soil temperatures generally push wireworms deeper into the soil profile, where they are no longer a threat to corn. The multi-year life cycle of most wireworms (up to 4-7 years for some species) often results in problem fields that are damaged for several years in a row. Fields that were planted to sod, small grains, or left fallow or in a conservation planting are at increased risk of wireworm damage, as the adults often lay eggs near the roots of grasses in the spring. Several insecticides (applied at planting or as a seed treatment) are available for wireworm control.

Sampling for wireworms can be difficult, as they are unevenly distributed below the soil surface. The most reliable sampling methods rely on creating bait stations at several locations throughout the field (ideally, around 12 stations per 40 acres). These stations can be baited with dough balls or grains (e.g. wheat and corn); these materials release CO_2 as they decompose and/or germinate, which serves as an attractant to wireworms that seek out roots and decomposing plant material in the soil to feed on. A solar bait station can be constructed using the following procedure:

1. Dig a hole 3-4 inches deep and 9-10 inches wide at the soil surface.
2. Bury ½ cup of equal parts untreated wheat and corn seed at the bottom of the hole. (Note: another grain can be substituted, but a viable seed is preferable).
3. Fill the rest of the hole with loose soil, and create a mound to prevent standing water in the hole.
4. Cover the mound with an 18 × 18-inch (or larger) black plastic sheet; a heavy-duty black garbage bag cut into sections works well for this. The black plastic will warm the soil and speed germination of the seeds.
5. Shortly before planting, uncover the grain bait and count the wireworm larvae found within each station. If you find an average of one or more wireworm larvae per station, use a soil insecticide or seed treatment labeled for wireworm control.

Seedcorn maggot. Seedcorn maggot (*Delia platura*) larvae can destroy germinating seed, resulting in stand loss. They are most commonly a problem in fields with fresh organic matter, for example those that have recently been treated with manure or had green plant material incorporated into the soil. Cool temperatures that slow germination and emergence can increase the potential for seedcorn maggots to reduce stand.

Grape colaspis. Grape colaspis (*Colaspis brunnea*) is a small beetle that feeds on legumes (including alfalfa and soybean) and lays its eggs in the soil during early-mid summer. The larvae feed on roots until the fall, when they move deep into the soil profile to overwinter. The following spring, the larvae move up the soil profile and resume feeding. At this point, they can feed on the root hairs and roots of corn seedlings, resulting in stand reduction. Above-ground symptoms initially resemble a nutrient deficiency. Damaging infestations often occur on well-drained, lighter textured soils, and are often more severe on high points in the field.

Fig. 13. Evidence of stink bug feeding (Image: Nick Seiter, University of Illinois)

Stink bugs. In recent years, stink bugs (primarily the brown stink bug, *Euschistus servus*) have increasingly been observed as damaging pests of corn in the southern United States. While damaging infestations are rare in Illinois, high densities of stink bugs are capable of stunting or reducing plant stand if they are present during the seedling stages (prior to V6) and can deform ears if they feed just prior to ear formation (V14-VT). Research conducted by entomologists at NC State University indicates an insecticide should be applied if 1 or more stink bugs are observed per 10 plants prior to V6, if 1 or more stink bugs are observed per 8 plants from V14-VT, or if 1 or more stink bugs are observed per 4 plants from R1-R2. (https://corn.ces.ncsu.edu/stink-bug-management-in-corn/). When stink bugs feed in whorl stage (V7-V13) corn, they leave behind a repeating pattern of tattered holes in the leaves (Fig. 13). This damage, which has no impact on yield, is a common sight in Illinois; unusually high levels of this whorl damage are no reason for an insecticide application, but should cue sampling for stink bugs prior to tassel.

Soybean

While a wide variety of insect pests can be found in soybean, infestations that reach economically damaging levels are relatively uncommon in Illinois. Insect pest management in soybean follows a scout-and-treat

Fig. 14. Bean leaf beetle (Image: Nick Seiter, University of Illinois)

Fig. 15. Bean pod mottle virus symptoms on a soybean leaf (Image: Nathan Kleczewski, Growmark)

approach: perform regular field scouting to determine whether a pest exceeds its economic threshold, and apply a "rescue" application if and when it does. Insecticide seed treatments are available to control early-season pests. Consider these for fields that are at elevated risk for a stand-reducing pest due to cultural practices or field history (e.g., seedcorn maggot, wireworm, grape colaspis in continuous soybean, bean leaf beetle where there is a history of bean pod mottle virus). Note that prophylactic (or preventative or insurance) insecticide seed treatments usually do not preserve yield equivalent to their cost in Illinois, as economic damage due to insect pests early in the season is rare in the Midwest.

A basic scouting plan for soybean in Illinois should include the following:

- Seedling stages: slugs, bean leaf beetle, stand-reducing pests such as seedcorn maggot and grape colaspis
- Season-long: defoliating pest complex (economic threshold is 30% defoliation before bloom and 20% defoliation after bloom), spider mites (emphasize scouting when drought conditions occur)
- Late July-August: soybean aphid; pod feeders such as bean leaf beetle and stink bugs beginning around R5
- September-October (pre-harvest): stem girdling due to dectes stem borer (southern IL only)

Insect pests of soybean

Bean leaf beetle. Bean leaf beetles (*Cerotoma trifurcata*) (Fig. 14) are a common defoliating pest of soybean. They go through two generations per year; adults overwinter, and begin feeding on soybean seedlings (and other legume foliage) when they emerge in the spring. The adults lay eggs, and the larvae feed below ground on soybean nodules and roots; larval feeding does not impact yield or quality, and the larvae are not considered a pest. The first generation adults usually emerge in July and again feed on the foliage of soybean and other legumes. Second generation adults typically emerge in August, and this is the cohort that will overwinter.

Bean leaf beetles can damage soybean in several distinct ways. While feeding on soybean foliage is often conspicuous (especially when overwintered adults feed on the seedling stages), it is uncommon for this injury alone to lead to economic damage. The economic threshold for soybean defoliation prior to bloom is 30% of the canopy removed, while after bloom it is reduced to 20%. Bean leaf beetle is capable of transmitting bean pod mottle virus (Fig. 15), which can reduce yields especially when plants are infected early in their development. During the late pod-fill stages, bean leaf beetles sometimes feed on the pods themselves, resulting in scarring (Fig. 16). As the scarred pods mature, this can lead to the formation of cracks and a potential entry

Fig. 16. Pod scarring caused by bean leaf beetle feeding (Image: Nick Seiter, University of Illinois)

point for moisture and, ultimately, pathogenic fungi. The economic threshold for this kind of damage is 8-10% of pods scarred prior to a mature pod color being reached, with bean leaf beetle adults still present in the field; a decision table that includes pod injury, developmental stage, and bean leaf beetle numbers is available from Purdue University Extension: https://extension.entm.purdue.edu/fieldcropsipm/insects/bean-leaf-beetle.php

<ins>Other defoliators</ins>. Defoliating insects should be managed as a complex by: (1) scouting fields for the overall level of insect defoliation; (2) determining when that level of defoliation has reached an economic threshold (30% defoliation prior to bloom, 20% defoliation after bloom); and (3) identifying the pest(s) responsible, confirming they are still active in the field at relevant densities, and choosing an appropriate control method. Note that defoliation (Fig. 17) is often overestimated; insect defoliation rarely exceeds economic thresholds in Illinois.

Fig. 17. A soybean canopy that has reached 16% defoliation due to insect feeding (Image: Nick Seiter, University of Illinois)

Japanese beetle. Japanese beetles (*Popillia japonica*) (Fig. 18) are among the most recognizable insect defoliators in soybean in Illinois. Japanese beetles often congregate in large masses, resulting in conspicuous defoliation in the upper canopy. However, this defoliation is often concentrated on the edges of fields, and rarely meets economic thresholds.

Fig. 18. Japanese beetles and their feeding injury(Image: Nick Seiter, University of Illinois)

Green cloverworm. The green cloverworm (*Hypena scabra*) is present in virtually every soybean field in Illinois each year during mid-late summer. The light green larvae can be distinguished from other caterpillars found in soybean by their three pairs of abdominal prolegs (Fig. 19). While insecticides are highly effective against them, the need for such applications is rare. Green cloverworm larvae are susceptible to diseases and parasites which typically prevent them from reaching economic thresholds.

Fig. 19. Green cloverworm larva (Image: Adam Sisson, Iowa State University, Bugwood.org)

Thistle caterpillar. The larvae of the painted lady butterfly, thistle caterpillars (*Vanessa cardui*) feed on soybean foliage (Fig. 20). Thistle caterpillars use silk to fold soybean foliage into a protective “envelope” to protect them during feeding. Peak densities are usually observed in mid-late June, when soybeans are in the vegetative stages and highly tolerant to defoliation.

Fig. 20. Thistle caterpillar (Image: Nick Seiter, University of Illinois)

Fig. 21. Soybean aphids (Image: Chris DiFonzo, Michigan State University, Bugwood.org)

Soybean aphid. Soybean aphids (*Aphis glycines*) (Fig. 21) are an invasive species, and appeared in Illinois in 2000. Large, widespread outbreaks quickly made it the most economically important pest of soybean in the Midwest. In recent years, outbreaks have become relatively uncommon in Illinois, although occasional economically relevant infestations can occur especially in northern counties. Elsewhere in the Midwest (particularly in Minnesota, northern Iowa, and the Dakotas), soybean aphid remains a more frequent problem. Populations of soybean aphid with resistance to pyrethroid insecticides have been observed in recent years in these states, potentially increasing the cost of control (Koch et al. 2018). While this resistance has not been observed in Illinois at the time of this writing, pest managers should be vigilant and evaluate the level of control achieved if they use an insecticide.

The soybean aphid life cycle includes two hosts, soybean and the woody perennial buckthorn (*Rhamnus* spp.). Soybean aphids overwinter as eggs on buckthorn shrubs. These eggs hatch in the spring, and the aphids feed and develop on buckthorn before migrating to soybean, typically beginning in mid-June. On soybean, the aphids go through asexual reproduction, produce live young, and rapidly increase their population densities if conditions are favorable. Environmental factors including crowding and declining host quality lead to the development of winged aphids, which infest new fields. Winged aphids migrate back to buckthorn in the fall, where they undergo sexual reproduction and deposit the overwintering eggs.

Soybean aphids feed on plant fluid at the stems and leaves. The removal of plant fluid reduces yield indirectly by placing stress on the plant, and can reduce stem length, number of pods per plant, seeds per pod, and seed weight. In addition, the black sooty mold that grows in the honeydew (sugary excrement) produced by soybean aphids can prevent sunlight from reaching the plant foliage, further contributing to indirect reductions in yield. Severe reductions in yield are possible when soybean aphids reach high population densities.

A foliar insecticide should be applied for soybean aphid control if they exceed the economic threshold of 250 aphids per plant. (This target is to prevent them from reaching the economic injury level of 675 aphids per plant, where the cost of control is equal to the value of soybean yield protected by the application). A method for "speed scouting" of soybean aphid is available from Iowa State University Extension: https://www.ent.iastate.edu/soybeanresearch/files/page/files/2009_speed_scouting_blank_form.pdf

Spider mites. Twospotted spider mite (*Tetranychus urticae*) can be a serious pest of drought-stressed plants. Infestations can be widespread during growing seasons where drought conditions are extensive; more commonly, localized hot, dry conditions lead to small, sporadic mite outbreaks. If soybeans have adequate moisture, economic damage from this pest rarely occurs.

Twospotted spider mites are arachnids, and overwinter as females in areas with winter annuals, dormant vegetation, or plant debris – often on the edges of fields. Females lay eggs on the foliage of a wide variety of plant species beginning in the spring. The mites go through multiple generations per year, with each generation taking 1-3 weeks (depending primarily on temperature) and involving three immature stages. The mites are active throughout the growing season, and outbreaks can potentially occur whenever dry conditions persist. The first immature stage, which is quite small, has six legs, while the remaining immature stages and the adult have eight. Like all arachnids, mites lack wings; they often arrive in fields at the edges first (mowing grass along the edges of fields during hot, dry conditions sometimes induces this). Twospotted spider mites produce silk,

Fig. 22. Soybean foliage with spider mite damage; inset shows close-up of stipling (Images: Nick Seiter, University of Illinois)

and like some spiders can "balloon" further distances by releasing a strand of silk that is caught in the wind.

Spider mites feed on cellular fluid that they obtain by puncturing (and subsequently killing) plant cells. This injury appears as a yellow speckling or "stipling" of the leaves (Fig. 22). Heavy infestations can cause foliage to wilt and die, and can result in substantial yield losses. Spider mite infestations can develop rapidly, and reliable economic thresholds have not been developed. Note the weather outlook when making a control decision – consider a miticide application if areas with spider mite damage are confirmed within a field and continued hot, dry conditions are anticipated. Spot treatments may be effective if the initial infestation is limited to the edge of the field; if a spot treatment is considered, thoroughly scout to verify that the interior of the field has not been infested.

Stink bugs. Several species of stink bugs (Fig. 23) are capable of damaging soybean in Illinois. The most common species include the brown stink bug (*Euschistus servus*), the onespotted stink bug (*Euschistus variolarius*), and the green stink bug (*Chinavia hilaris*). The invasive brown marmorated stink bug (*Halyomorpha halys*) is also increasingly found in soybean in Illinois. All of these species have multiple host plants, which include a wide variety of crops and non-cultivated plants. Stink bugs feed preferentially on the seeds and reproductive structures of their hosts, and the mobile adult stages often move among host plant species to seek out these structures as they develop. Stink bugs typically move to soybean fields during the reproductive stages, particularly during pod fill (R5-R6). Most stink bugs go through one or two generations per year in Illinois. They overwinter as adults in leaf litter, behind tree bark and other shelters, and occasionally in homes and other structures.

Stink bugs damage soybean when they feed on the developing seeds with their piercing-sucking mouthparts. The stink bug injects digestive enzymes into the feeding site, which facilitates their ingestion of fluid material but also results in deformation and discoloration of the feeding site. This feeding can lead to both yield and quality losses; the impact on yield is greatest when the feeding occurs earlier in seed development. Quality losses can lead to a discounted price at the elevator if sufficient discolored or deformed soybeans are present. Wet conditions and pathogens can lead to damage that is similar in appearance even without stink bug feeding, and quality discounts are not always due to stink bugs. However, stink bug damage is often exacerbated when conditions are wet during pod maturity, and stink bug feeding sites can serve as entry points for pathogens.

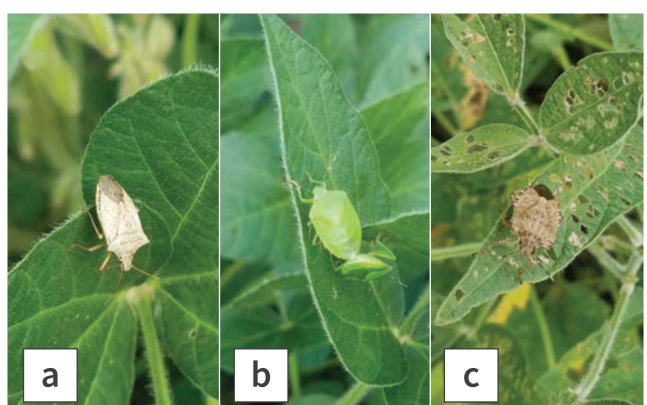

Fig. 23. (a) Brown, (b) green, and (c) brown marmorated stink bug (Images: Nick Seiter, University of Illinois)

Fig. 24. Dectes stem borer in an overwintering cell at the base of a soybean plant (Image: Talon Becker, University of Illinois Extension)

Stink bugs can occur throughout the reproductive stages, but in Illinois the most important scouting window is during the R5-R6 growth stages. Stink bugs can be controlled with a broadcast insecticide applied at an economic threshold of 9 stink bugs per 25 sweeps (if sampled using a sweep-net) or 1 stink bug per row-ft (if sampled using a drop cloth or visual examination of the canopy).

Dectes stem borer. This insect is a longhorned beetle whose larvae tunnel into the pith of soybean stems. Dectes stem borer (*Dectes texanus*) goes through one generation per year, and the adults are active from late June until August. The females lay eggs in soybean petioles, and the larvae tunnel through the petiole and into the main stem as they mature. While the appearance of this damage is often startling, the stem tunneling itself does cause substantial reductions in yield. As plants senesce, the larvae move to the base of the stem where they create an overwintering cavity (Fig. 24). In doing so, they often girdle the base of the plant, which can result in lodging. When it occurs, this lodging can reduce yields and harvest efficiency.

Because dectes stem borer larvae are protected within the plants, control with insecticides has typically been ineffective and is not recommended. Management should focus on identifying infested fields and managing those fields to prevent lodging. The first sign of an infestation is typically dying petioles caused by the tunneling larvae; these petioles will wilt, and they often fall off the plant eventually. Splitting open infested stems will reveal the tunneling larvae. As soybeans mature, girdled stems often have a pile of sawdust at the base of the plant. The appearance of these sawdust piles can be an indication that lodging will soon occur. The most effective management is timely harvest of infested fields. Destruction of soybean residue through tillage or another means can reduce overwintering survival, but is unlikely to provide effective control of dectes stem borer alone.

Slugs. Slugs (primarily the grey garden slug, *Deroceras reticulatum*) are associated with high levels of moisture and residue, and can be a troublesome pest of soybean and corn during the seedling stages. Most of our slug problems in recent years have occurred in the southern third of Illinois, where no-till and conservation tillage are common. The wet springs that have occurred more frequently in recent years have driven slug issues. Slugs are especially damaging to soybean stands when they feed on germinating seeds and cotyledons (Fig. 25). Slugs are a mollusk, not an insect, and insecticides are ineffective for slug control. In addition to the reduced activity you might expect given the many biological differences between insects and mollusks, slugs are often able to “slime off” chemical control agents by producing

Fig. 25. A soybean cotyledon damaged by slug feeding (Image: Jennifer Jones, University of Illinois Extension)

excess mucus. There are bait products available for slug control. While these materials can provide effective control, they are expensive and are often not widely available. Additionally, baits containing metaldehyde are not labeled for use in soybean in Illinois (though they are labeled for use in corn).

Approach slug management with a multi-pronged strategy, as no single tactic is likely to eliminate an established slug problem. High slug densities are most likely during wet springs that follow mild winters. Wet, cool conditions after planting slow plant growth and leave them vulnerable to slug damage for a longer time, exacerbating the damage. Residue management (such as row cleaners) and other strategies that improve early season growth can help plants to "outrun" slug damage. Insecticides, including seed treatments and broadcast sprays, have no effect on slugs, but can eliminate natural enemies that provide some level of natural control; as always, an insecticide should be reserved for those fields where it is justified based on the likelihood of economic damage (i.e., where an economic threshold has been exceeded). Slug-specific baits (assuming they are labeled for use in soybean; see above) can provide effective control, especially in hard-hit portions of the field. In fields where a damaging slug population has been confirmed (and especially in those that have already been replanted once), the most effective control is to wait for a warm, dry seedbed that will facilitate rapid growth and deter slugs.

Wheat

Insect problems in wheat are variable from year to year, but are generally less common than in corn and soybean for much of Illinois. Control strategies in wheat include host plant resistance (primarily for Hessian fly), planting date, and seed-applied and foliar insecticides.

Planting after the "fly-free" date has been recommended for decades as a way to mitigate insect pest issues. The fly-free date for a given area (Fig. 26) indicates the average date when temperatures become cool enough to prevent Hessian fly egg-laying activity. While the Hessian fly has not been an issue in Illinois for several years, planting after the fly-free date also reduces the risk of early infestations of aphids and subsequent barley yellow dwarf virus (BYDV).

Insect pests of wheat

Aphids. Four different species of aphids occur in wheat fields in Illinois – bird cherry-oat aphid (*Rhopalosiphum padi*), corn leaf aphid (*Rhopalosiphum maidis*), English grain aphid (*Sitobion avenae*), and greenbug (*Schizaphis graminum*). Aphids are known for rapid population development, and their feeding results in the removal of phloem from the plant. For aphids that arrive in wheat in the fall, the potential for transmission of BYDV by aphid feeding is more concerning than the stress of the feeding itself. Management decisions are complicated by the fact that not all aphid populations are positive for BYDV, and not all wheat varieties react the same to this disease. While control guidelines (i.e., economic thresholds) for aphids in the fall have not been well established in Illinois, foliar insecticides or seed treatments are viable control options.

Aphid populations begin to increase when temperatures warm in the spring. During this period, they have the potential to reduce yields through fluid removal and subsequent stress on the plant in addition to BYDV transmission. A good rule of thumb is to spray an insecticide if numbers reach or exceed 25-50 aphids per stem (25 greenbugs, 30 corn leaf or bird cherry-oat aphids, 50 English grain aphids) through the boot stage. Once dough stages have been reached, insecticides are no longer recommended for aphid control.

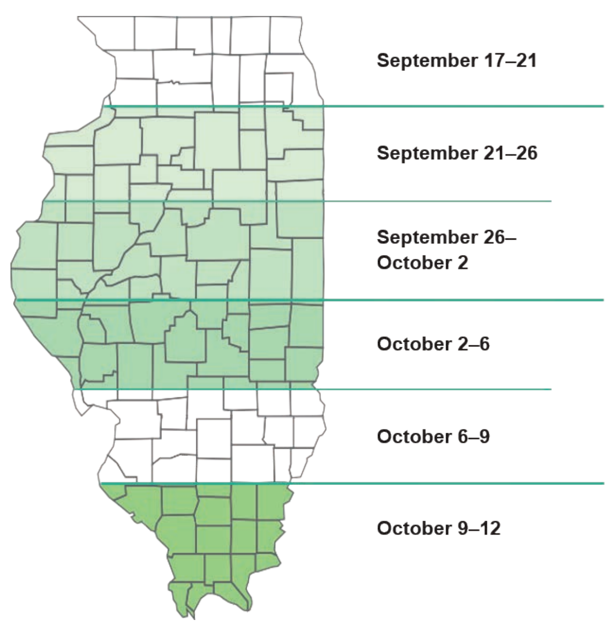

Fig. 26. Hessian fly-free date ranges in Illinois

Armyworm. True armyworms (*Mythimna unipuncta*) feeds on wheat foliage in the spring. There is limited overwintering of this insect in southern Illinois, and most armyworm infestations originate when the moths migrate into Illinois from southern states, usually beginning in April. The key to effective management of armyworms in wheat is regular field scouting in the spring.

Armyworm moths are attracted to dense, grassy vegetation to lay their eggs. Wheat, particularly areas of wheat fields with dense stands, is an attractive egg-laying site, and moths deposit many eggs in rows or clusters on the lower leaves. Young larvae scrape tissue from the surface of the leaves, while older larvae feed from the edges of the leaves and consume the tissue in its entirety. The larvae usually work their way from the bottom of the plants upward through the canopy as they feed. Injury to the lower leaves does not cause economic damage; however, injury to the upper leaves and especially the flag leaf can reduce yields. After larvae remove the flag leaves, they will often chew into the tender stem just below the head, which can cause the grain head to fall off ("head clipping"). After their initial hosts dry down (whether this is wheat, another small grain, or a cover crop), armyworm larvae will migrate into adjacent grasses including cornfields; this migration, which sometimes occurs "en masse," is the reason for the name "armyworm." While there are two to three generations per year in Illinois, only the first generation threatens wheat production. (Note that, rarely, the related fall armyworm [*Spodoptera frugiperda*] can affect stands of early-planted wheat in the fall). Armyworms are susceptible to diseases and several parasitoids, which often keep their populations in check.

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 are usually found on the ground under plant debris. If the number of armyworms exceeds 6 non-parasitized larvae per foot of row, consider an insecticide application.

Hessian fly. Hessian flies have not caused economic damage to wheat in Illinois in many years. Use of fly-free dates and destruction of volunteer wheat are cultural control methods that help to keep this insect in check.

The Hessian fly overwinters as a full-grown maggot inside a puparium (a brown capsule, commonly referred to as a "flaxseed"). In the spring, the maggots pupate inside of the puparia (pl.), then 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 pupate (again forming puparia). These puparia can be found behind leaves next to the stem; Hessian flies remain in this stage throughout the summer within the wheat stubble. The flies emerge again in late summer to seek egg-laying sites – typically volunteer wheat or fall-seeded wheat seedlings. After hatch, the fall generation will feed on these seedling plants until it is time to overwinter.

Wheat infested in the fall is usually stunted; the leaves of infested plants appear 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.

Foliar-applied insecticides are generally not practical or reliable for control of Hessian flies in Illinois. The best preventative tactics are destruction of wheat stubble and volunteer wheat, planting after the fly-free dates, and using a hybrid with full or partial resistance to Hessian fly. Where wheat is seeded on or after the fly-free date in Illinois, the adults usually emerge and die before wheat emerges, thus protecting the crop from infestation.

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