AN IPM PROGRAM FOR SOYBEANS IN PENNSYLVANIA

A COMPREHENSIVE APPROACH TO CONTROLLING INVERTEBRATE PESTS, WEEDS, AND DISEASES

Following hay and corn, soybeans are the third most valuable crop to the economy of Pennsylvania. In 2019, soybeans had a production value of $253 million, which was harvested from 610,000 acres planted across the Commonwealth (USDA NASS 2021). While not a leader in the acreage of soybeans grown, Pennsylvania consistently ranks among state leaders in soybean yield per acre; in 2019, Pennsylvania farmers averaged about 50 bushels of soybean per acre (USDA NASS 2021).

To maximize profits from soybean production, farmers need to manage pests. Pests can interfere with crop productivity, and pest management costs, particularly unnecessary costs, can erode profits. While pests can colonize every acre of soybeans in Pennsylvania, they do not invade every field annually. Rather, pest distributions tend to be patchy, dynamic, and difficult to predict. Therefore, treating every field each year with the same insecticides, fungicides, and herbicides can often be unnecessary and waste resources. Instead, fields can benefit from individualized attention to determine which of them are going to benefit from particular pest management inputs.

Decades of research have established integrated pest management (IPM) as an effective framework that can be used to combat pests while minimizing input costs. Two key principles of IPM are that (1) management decisions should be based on field-specific information collected while scouting and (2) pesticides should be used only as necessary. By using IPM, pesticides can be deployed where and when they can be most effective, decreasing concerns about nontarget effects and the possibility that pest species will evolve resistance to the pesticides. More important, using IPM can improve profits by removing unnecessary input costs.

The purpose of this publication is to provide details of an IPM program that can effectively control weeds, diseases, and invertebrate pests typical of Pennsylvania soybean fields, while minimizing input costs.

Soybean Pest Management

The *Penn State Agronomy Guide* provides detailed coverage of the specific pesticides (i.e., herbicides, fungicides, and insecticides) and their formulations that are available for controlling pests in Pennsylvania soybean fields. We, therefore, do not address those details here. Rather, in the following three sections, we explain how to implement IPM in soybean fields to manage weeds, diseases, and invertebrate pests (i.e., insects, mites, and slugs).

Weeds

Herbicides are the foundation of weed control programs in most Pennsylvania soybean production systems, particularly where farmers use no-till or conservation-tillage practices. Most farmers in Pennsylvania plant glyphosate-resistant (Roundup Ready) soybean varieties, allowing for postemergence use of glyphosate during the soybean growing season. Widespread adoption of glyphosate-resistant crops across the United States, coupled with repeated glyphosate use and simplification of herbicide control programs, has led to widespread glyphosate-resistant weed species and increased herbicide costs. Adopting IPM principles for weed control is a beneficial course correction that offers a more sustainable and cost-effective approach. Integrated weed management (IWM) borrows from IPM principles in several ways while recognizing certain unique features of weed management decision-making.

Scouting

Developing an effective weed scouting program is the foundation of IWM. Field scouting at multiple time points within a crop rotation sequence is the only way to accurately characterize any problems and choose appropriate weed control tools. Regular scouting helps identify the diversity of weed species present, their growth stage, and infestation severity. *Spending resources on weed scouting has the potential to provide cost savings by improving selection, timing, and efficacy of chemical and nonchemical weed-control tactics.* In no-till production systems, there are four key timings to scout weeds:

1. Spring green-up (mid-April). Scouting weeds after plant growth resumes in spring will provide an indicator of which weed control tactics or herbicide inputs will be necessary to achieve a clean seed bed prior to planting. At this timing, weed species will include overwintering winter annuals (e.g., marestail, common chickweed, henbit, deadnettle, various mustard species) and perennials (e.g., dandelion, dock). A guiding principle of weed management decision-making is that preplant burndown herbicides and tillage tools used prior to soybean planting will be more effective on small weeds. Glyphosate-resistant marestail is a notable example. Large overwintering marestail rosettes will be increasingly difficult to control when left to grow until soybean planting but can be easily controlled with cost-effective herbicide programs in late fall or early spring while in the seedling-to-small-rosette growth stage (Table 1).
2. After soybean planting (three to five weeks). Most no-till farmers control weeds for the first four to five weeks after soybean planting by using one of two types of programs: first, a one-pass program that relies on a postemergence herbicide application to control weeds that emerge after soybean planting; or second, a two-pass program that utilizes soil-applied residual herbicides near planting to control emerging weeds for several weeks, and a postemergence application to control weed escapes. Summer annual broadleaf and grass weed species can vary widely in emergence timing and competition for resources; therefore, scouting early in the soybean growing season is necessary to determine if additional control tactics are needed and to ensure that postemergence herbicide applications target small weeds that are more susceptible to herbicides (smaller than 4 inches in height; e.g., the "soda can rule"). Understanding key characteristics of common summer annual weed species can improve scouting efforts and development of integrated control tactics (see Table 1).
3. In-crop weed control assessment (six to eight weeks). Scouting after in-crop weed control tactics have been employed but before canopy closure is useful for evaluating efficacy of weed control tactics and to identify which weed species escaped control. At this point, additional control tactics are unlikely to be cost-effective but adjustments to weed control programs can be made for future crop rotation sequences based on understanding of why certain weed species escaped control.
4. Late season (prior to frost). Scouting soybean after leaf drop is useful for identifying which weed species will produce seed and contribute to weed control problems in future years. Scouting at this time is likely to reveal weed patches and other patterns that occur in the field, which may allow for site-specific prevention or control measures. One goal for late season scouting is to determine the best harvest sequence so fields or areas within

Table 1. Scouting tips for troublesome weed species in soybean. Weed species are ordered in sequence of when they are relevant for the growing season.

Weed Species	Scouting Recommendations
Marestail (or horseweed)	Winter annual that can emerge in fall through late spring. Consider herbicide control in early spring and use of winter cover crops.
Common ragweed	Earlier emerging summer annual. Consider delayed planting if dealing with high infestation levels to allow for additional control methods.
Palmer amaranth and waterhemp	Highly competitive summer annuals that emerge from May through August. Resistant to multiple herbicide sites of action. Consider a "zero-tolerance" control strategy to reduce weed seedbank.
Burcucumber	Large-seeded summer annual with long emergence window. Include alfalfa, small grains, and corn silage in rotation to prevent seed production. Prevent seed spread when harvesting infested fields.
Common pokeweed	Perennial with deep, persistent taproot and spreads by seeds. Scout field edges that contain bird habitat to identify new infestations.

a field that contain higher weed infestation levels are harvested last to limit weed dispersal and spread from the combine and other harvest equipment.

Economic Thresholds

Within the IWM framework, weed control decision-making based on economic thresholds has not been emphasized. Most fields support a diverse weed community with species that differ in their competitive ability at various densities, and making decisions based on economic thresholds is challenging with diverse weed communities and uncertainty about the size and composition of weed seedbanks in soil. Moreover, identifying the level of weed control needed to prevent soybean yield loss or optimize net returns is a short-term economic decision that does not represent the benefits and costs associated with weed control tactics over the long term. For example, low densities of some annual weeds are unlikely to reduce yields but may contribute significantly to future weed control problems if left to produce seed. For this reason, a goal of zero seed rain is recommended for Palmer amaranth and waterhemp, which are resistant to multiple herbicide sites of action. These species may not affect soybean yields at low densities, but a single plant can produce over 200,000 seeds, which will likely create significant weed pressure in subsequent crops. When using herbicides against these and other weed species, it is best to use full label rates and target weeds of an appropriate size; this approach will maximize the likelihood of successful weed control while decreasing chances for evolution of resistance.

Nonchemical Control Tactics

Integrating nonchemical weed control tactics into weed management programs is necessary to reduce herbicide inputs but requires understanding of the traits, or characteristics, of problematic weed species. To realize reductions in total herbicide inputs, no-till producers must integrate effective cultural practices with judicious use of herbicides. Some cultural practices can significantly enhance weed suppression, but agronomic and pest management tradeoffs should be considered when developing IWM strategies.

Due to competition for resources, sowing a winter cereal (that is, a cover crop of cereal rye, winter wheat, or triticale) in the fall preceding soybean can reduce winter annual weed infestations and their spring growth rates. Penn State research has demonstrated that cereal rye can reduce marestail populations by 45 to 85 percent and decreases the number of large individual weeds that would be targeted with preplant burndown herbicides. After planting soybeans, farmers are also likely to realize weed suppression benefits from winter cover crops, particularly if spring termination of the winter cereal is delayed to allow for more biomass production; cover crop residue left on the soil surface can interfere with early season recruitment and growth of small-seeded summer annual weeds.

Many farmers plant soybean on 30-inch row spacing to align with corn planter configurations; however, drilling soybean on 7.5-inch row spacing or planting in narrower 15-inch spacing can enhance weed suppression due to faster canopy closure. Increasing crop competition with use of alternative row spacing configurations holds potential to decrease need for late season herbicide applications and also helps limit weed seed production of late emerging weeds.

Diseases

Similar to management of weed and insect pests, proper disease management requires use of an integrated approach, starting with cultural practices that focus on prevention. While several foliar fungicides are currently labeled for soybean, no single disease management tactic alone will adequately protect soybeans from yield loss due to disease.

Disease management tactics can be divided into those implemented before the pathogen infects the plant (preventative) and those implemented after an infection is detected to reduce disease severity and/or spread of the pathogen (reactive). It is important to know what diseases are most likely to affect your crops and familiarize yourself with their associated symptoms and signs (Table 2). It is also important to know what environmental conditions favor development of individual diseases and what plant growth stages are susceptible. Early detection via scouting is critical for making in-season management decisions. Making maps of disease outbreaks on your farm each season will, over time, help to inform your crop rotation decisions and direct your scouting to areas or fields on your farm that are more favorable for the development of certain diseases.

Scouting

It is important to be familiar with characteristics of a healthy host crop at all crop growth stages. Soybean should be scouted regularly, ideally every 7 to 10 days. If multiple soybean varieties are present in the same field, scout those individually by variety. When symptoms are observed, determine the prevalence of the problem by looking for distribution patterns. Check all parts of the plants, including digging up the roots, for symptoms and signs.

In general, the following are questions you should ask when scouting fields:

1. Are all plants in a large area affected by the disease, or are they scattered randomly across the field or localized along one edge or corner of the field?
2. Do multiple varieties show the same symptoms?
3. When was the problem first observed (during which growth stage)?

Table 2. Common soybean diseases in Pennsylvania.

(Under "Pathogen Type," diseases are ordered in their importance for Pennsylvania soybean fields.)

Pathogen Type	Common Name	Image
Fungi or oomycetes	Seed rots and damping off	 Penn State
	Septoria brown spot	 Penn State
	Frogeye leaf spot	 Penn State
	Downy mildew	 Penn State
	White mold	 Penn State

Table 2. Common soybean diseases in Pennsylvania. *(Continued)*

(Under "Pathogen Type," diseases are ordered in their importance for Pennsylvania soybean fields.)

Pathogen Type	Common Name	Image
Fungi or oomycetes *(continued)*	Stem rots	 Penn State
	Seed decay	 Penn State
	Sudden death syndrome	 Penn State
Bacteria	Bacterial leaf spot	 Penn State
Viruses	Soybean vein necrosis	 Penn State

Table 2. Common soybean diseases in Pennsylvania. *(Continued)*

(Under "Pathogen Type," diseases are ordered in their importance for Pennsylvania soybean fields.)

Pathogen Type	Common Name	Image
Nematodes	Soybean cyst nematode	 Edward Sikora, Auburn University, Bugwood.org
	Root knot nematode	 Greg Tylka, Iowa State University, The SCN Coalition

4. Was the damage sudden or did it develop over time?
5. How old (what growth stage) are the affected plants?
6. What percentage of the field is affected?
7. What other practices have been used in the field?
8. What were the weather conditions or were there any extreme weather events that may have contributed to the onset of the problem?

Preventative Disease Management Tactics

Crop Rotation

Crop rotation is one of the oldest practices used for managing pathogens in agroecosystems. It helps to achieve diversity above and below ground and is best implemented preventatively to reduce the buildup of pathogen inoculum that occurs when susceptible hosts are planted year after year. Successful use of crop rotation to reduce pathogen pressure will depend on how well pathogens survive in absence of their hosts and the host range of the pathogen. Keep in mind that the effect of crop rotation will differ based on the pathogen in question; for example, the fungus that causes frogeye leaf spot on soybeans is unable to infect corn or forage crops. Thus, rotation between these crops is an effective control strategy for this soybean leaf disease. In contrast, the white mold pathogen *Sclerotinia sclerotiorum* has a host range of over 400 plant species, including many agronomic crops, cover crops, and common weed species such as lambsquarters, mustard, nightshade, pigweed, ragweed, velvet leaf, and vetch. Once established in fields, it is very difficult to "rotate" your way out of this problem without considering extended rotations with nonhost crops.

Field Selection, Sanitation, and Preparation

Field selection and soil and nutrient management are important for crop yield, but they are also key for disease prevention. It is important to select fields without a history of high pathogen pressure or avoid areas that are inherently conducive to disease development. Examples of disease-conducive areas include low areas of fields where water may stand, bottomlands where dew lingers, weedy fields that can serve as reservoirs of pathogen inoculum and insect vectors, and shaded areas of fields due to hedge rows or wooded borders that restrict air movement and promote extended periods of leaf wetness.

Removal or destruction of diseased crop residues will reduce primary inoculum available to initiate disease the following year. For some pathogens, deep tillage that buries overwintering structures such as sclerotia and crop residue is important for disease management. These decisions must be balanced with the benefits of having the soil covered overwinter to prevent erosion. While no-till and reduced-till systems are known to provide benefits like enhanced water infiltration, moisture retention, nutrient retention, and higher organic matter levels, many pathogens also thrive in these systems. The majority of leaf pathogens in soybeans survive from season to season in the residue from the previous crop. Tillage is one method to reduce the amount of inoculum that is capable of infecting subsequent crops.

Some cover crops, namely those in the mustard family, have been shown to reduce the level of some soilborne pathogens in vegetable systems. This has not been researched for Pennsylvania field crops, but if you choose to use a cover crop or green manure for this or other soil health benefits, be sure to select carefully. You will want to choose a cover crop that is not in the same family as your main crop, since many pathogens can infect plants of the same family. For instance, do not choose a legume cover crop to precede or follow a soybean crop, as they both provide a host for many of the same pathogens.

Planting Dates

Susceptible crops may escape significant damage by adjusting the planting time to avoid conditions that favor the pathogen. For example, delaying the planting date until soil temperatures are warmer will reduce the incidence and severity of damping-off and seedling blights caused by *Pythium*, *Phytophthora*, *Fusarium*, and *Rhizoctonia* species. Planting too deep or in saturated or compacted soils can also leave seedlings more susceptible to these damping-off diseases, as can using poor-quality or old seed.

Use of "Pathogen-Free" Seed or Planting Material

If available, every effort should be made to secure seed that has been tested and certified. Seed should be free of sclerotia and other overwintering structures that could potentially become mixed into the seed when it is harvested from symptomatic fields. Many pathogens are seedborne and capable of surviving on the seed coat and inside the seed. It is impossible to certify seed to be completely free of pathogens; however, use of certified seed provides some assurance that practices have been implemented to reduce potential infection by pathogens.

Further, seed should not be saved from a field with high levels of disease and replanted a subsequent season. If you must plant seed saved from an infected field, take care during harvest to avoid the areas of greatest infection, and adjust combine fan speed to help blow out the lighter affected grains. Reduction of pathogen levels can occur during long periods of seed storage; however, cool, dry storage conditions favor seedborne pathogen survival. Cleaning seedlots mechanically can reduce, but will not completely eliminate, sclerotia and infested seed.

Selection of Resistant Cultivars

Use of resistant cultivars is one of the most important and economical components of an integrated disease management program. The term "resistance" is used to describe the ability of the host plant to hinder the ability of the pathogen to infect a plant. Resistance does not imply immunity. Resistant cultivars may still develop symptoms, but they may not be as severe or may develop later in the season. Resistant cultivars are useful because they can reduce reliance on in-season use of chemicals and other management tactics. Some cultivars may be characterized as tolerant, which has a slightly different meaning from resistant. Tolerant cultivars will develop symptoms, sometimes severe; however, there is minimal negative impact on yield. When selecting resistant cultivars, it is important to be familiar with the most common soybean diseases found in your region. Unfortunately, resistant cultivars are not available for all pathogens or all races/strains of a pathogen. For example, hybrid resistance has not been documented for charcoal rot of soybeans. Also, resistant cultivars can fail due to new strains of the target pathogen. This can happen over time as we have found for soybean cyst nematode, where the primary source of resistance (PI 88788) has begun to lose efficacy in several areas of the Midwest.

Proper Culture and Nutrition

Reducing stress generally improves the ability of plants to cope with or resist disease. Any growth condition (e.g., moisture, nutrition, pH) that is outside the ideal range can cause stress and may make plants more susceptible to many diseases. Soil tests should be taken regularly (a minimum of every three years, but one to two years is ideal) to determine the proper nutrient and pH levels for your soybeans. You can obtain soil test kits from your local Penn State Extension office or by visiting the Penn State Agricultural Analytical Services Lab website at **https://agsci.psu.edu/aasl**.

Environmental Modification

The goal of environmental modification is to create conditions that are favorable for the host crop and unfavorable for the pathogen. Implementation of practices that promote leaf drying will reduce incidence and severity of many diseases. To infect plants, most foliar pathogens require either leaf wetness or high relative humidity for a specific length of time. Practices such as maximizing row spacing, adjusting row orientation to promote drying, and optimizing crop fertility to avoid overly dense crop canopies will reduce leaf wetness. Keep in mind that often the conditions that favor pathogen infection and disease development occur early in the morning after a long dew period. Excellent weed control is also key to preventing a high-humidity environment within the canopy and eliminating possible other sources of inoculum from alternate hosts.

Environmental Monitoring

When managing diseases, especially foliar diseases, it is important to understand the weather conditions that favor development of specific diseases. For soybeans, several disease forecasting programs are available that use knowledge about pathogen biology coupled with forecasted weather to predict the likelihood of disease development for a given period of time. Some programs will use this information to aid in the timing of fungicide applications. However, these programs are based on the primary assumption that the pathogen is present in the field or region, so scouting your soybean fields to determine actual presence of an infection is still critical for decision-making. Some disease forecasting programs are coupled with real-time observational data. Even if you choose not to use fungicides, knowledge of in-season disease risk can help with management decisions, such as your choice to harvest an affected field. Some of the more useful monitoring systems for soybeans include those for white mold (e.g., Sporecaster) and Asian soybean rust (**https://soybean.ipmpipe.org/soybean rust/**). Soybean rust has never reached Pennsylvania since its arrival in the United States 2004, but the potential exists for it to become problematic in certain years.

Fungicide Applications

Disease management of soybean is best achieved through the approaches mentioned above (i.e., crop rotation, balanced fertility, and the use of certified seed to reduce potential issues in the field). In Pennsylvania, many foliar diseases of soybean do not cause an economic impact. With that said, there have been severe epidemics of frogeye leaf spot in fields where soybeans followed soybeans in no-till conditions. The more economically important diseases are those of the roots and stems, such as charcoal rot, stem canker, and brown stem rot, which are unaffected by fungicide applications. These diseases cause early death of the plants, resulting in reduced pod fill and small seed size. Diseases that directly affect the seeds, such as downy mildew, purple seed stain, and Phomopsis seed decay, can reduce the size, quality, and appearance of the soybean seed, but they are usually not responsive to foliar fungicides. *In general, disease levels in Pennsylvania typically do not warrant a foliar fungicide application and an economic return from application is not likely, except where fields have a history of infection by white mold, sudden death syndrome, or soybean cyst nematode.* In these cases, preventative foliar or seed treatments may be prudent.

Use of fungicidal seed treatments is also beneficial when planting early in the season into cold, wet soils or no-till planting into heavy residue. In these conditions, the fungicide will help protect the seed and seedling from seed decay and other early season diseases. In early planted soybeans, successful use of fungicide seed treatments may take precedence over thoroughly inoculating the seed with nitrogen-fixing bacteria. As the soil warms, proper inoculation should be considered more beneficial than fungicide seed treatments due to reduced threat of seedling diseases and less time the seed is in the soil before emergence. It is helpful to mix modes of actions to increase protection on the seed.

Invertebrate Pests (Insects, Mites, and Slugs)

Historically, soybeans grown in Pennsylvania and the rest of the northern United States have been relatively free of insect pests. As a result, the need for regular use of insecticides has been uncommon. However, some recently arrived exotic insect species (e.g., soybean aphid, brown marmorated stink bug) have changed this scenario because their populations can grow to economically damaging numbers, necessitating insecticide use in some years and some parts of Pennsylvania, particularly in southeastern counties. Beyond insects, in recent decades slugs have become a threat to soybeans grown in no-till fields, and this threat has expanded as no-till adoption has increased in Pennsylvania and the Mid-Atlantic region. Slugs can be problematic in spring for no-till soybean fields because the absence of disturbance provides a stable habitat where slug populations can grow, and relatively small amounts of slug feeding can kill young seedlings. Further, in many years Pennsylvania tends to get enough rain in spring and early summer to create favorable conditions for slug populations to thrive.

One reason for the historical lack of economically important insect pests of soybeans is that soybeans have a great capacity to tolerate damage inflicted by foliage-feeding pests. Vegetative-stage soybean plants, including newly emerged plants, can tolerate up to 30 percent defoliation until bloom, about 15 percent while pods are small and soft, and about 30 percent when pods start hardening (Figure 1). Below these levels, defoliation does not adversely affect crop yield, so insecticide use is not recommended. However, Pennsylvania soybeans can occasionally be challenged by large populations of soybean aphids or stink bugs (particularly brown marmorated stink bug), which are not defoliators. These insect species—populations of which can vary greatly from year to year—are phloem feeders that use their needlelike mouthparts to extract sap from plants, so plant tolerance based on tissue removal simply does not apply. Moreover, populations of these sucking insects can grow quickly, making their management even more challenging.

Currently in Pennsylvania, 10 or so insect species can occasionally be abundant enough to cause economic losses in soybean production (Figure 2 and Table 3). Most are found on the foliage, such as bean leaf beetle, green cloverworm, grasshopper, Japanese beetle, Mexican bean beetle, potato leafhopper, and soybean aphid. Stink bugs, particularly brown marmorated stink bug, will feed on foliage and pods. A field usually reaches economic thresholds when more than one of these foliage-feeding pests are present at the same time. Soybean aphid can spread from the Midwest into eastern states, usually arriving in late June to mid-July. These invasions were common between 2001 and 2014, when populations routinely exceeded the economic threshold of 250 aphids per plant. From 2015 onward, however, relatively few aphids have

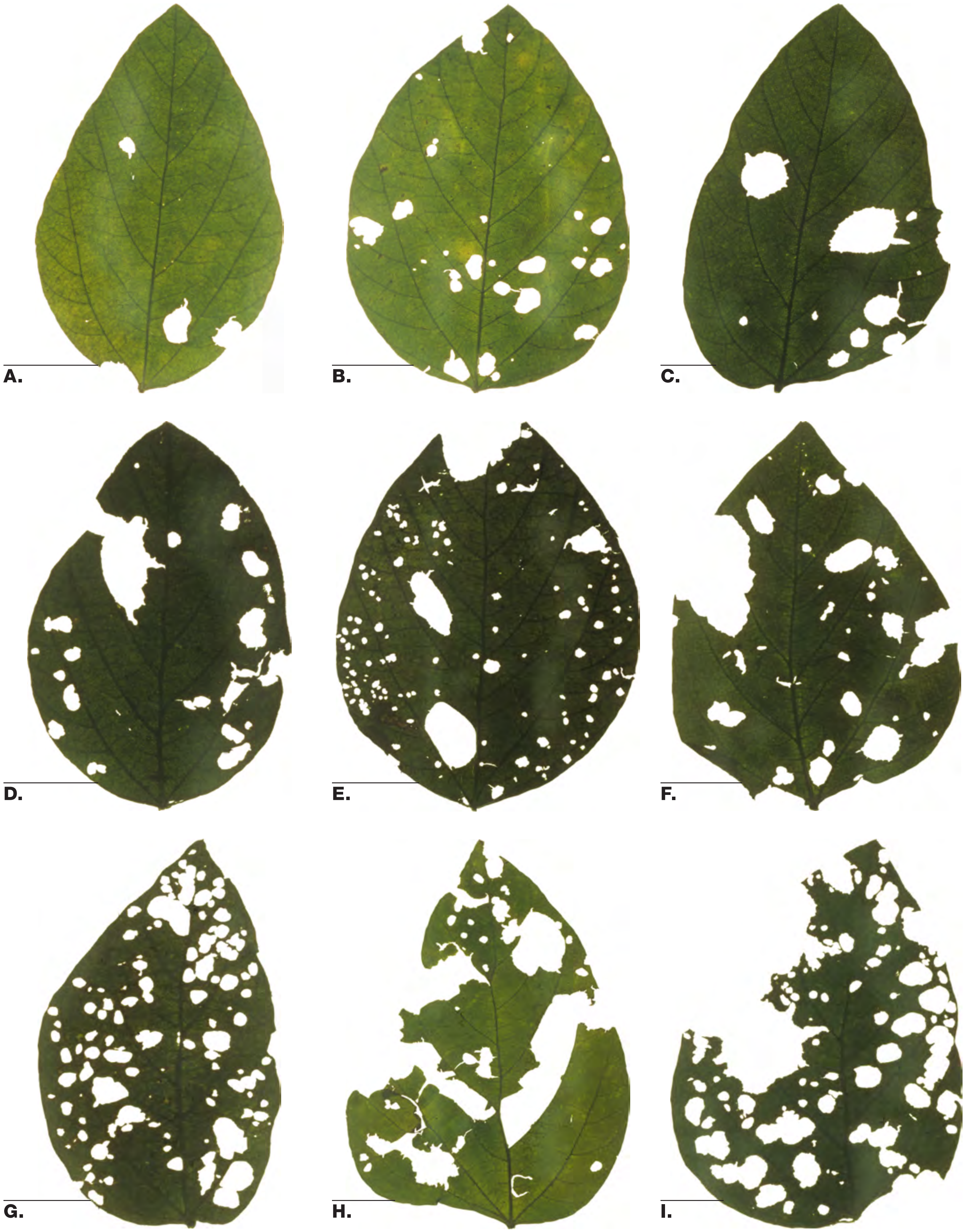

Figure 1. Percent defoliation of soybean leaflets: (A) 3.3, (B) 7.1, (C) 10.0, (D) 13.8, (E) 16.2, (F) 20.6, (G) 23.9, (H) 30.8, (I) 41.6.
Source: Used with permission from the Purdue Pest Management Program.

materialized in Pennsylvania soybeans, and it is difficult to predict what will happen in coming years. Seedcorn maggot is a seed-feeding insect that can reduce stands, especially in tilled systems and when a living green cover crop is incorporated into the soil prior to planting and conditions are cool and moist for long periods after the seed is planted. Under extended hot, dry periods, the two-spotted spider mite can cause severe damage. Slugs, which are mollusks and not insects, can cause serious stress to plants before V3.

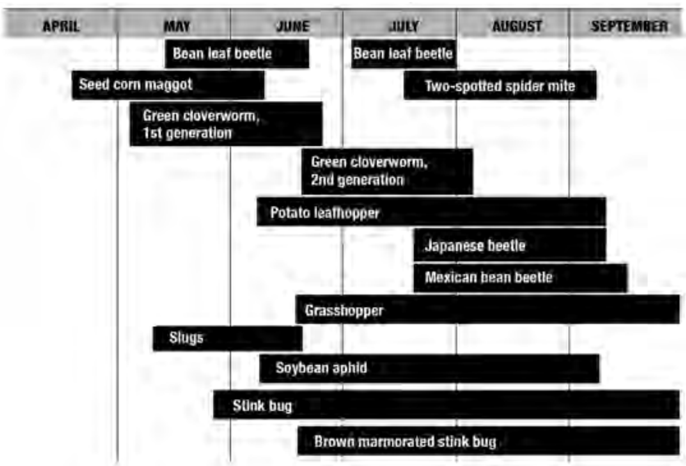

Figure 2. Key periods of soybean insect and mollusk pests in Pennsylvania. Source: Figure 2.4-1 in the *Penn State Agronomy Guide (2021–2022)*.

Because all of these pest species can only occasionally cause problems in soybeans and none are guaranteed to colonize fields every year, the best approach for managing them is IPM. The starting point for IPM is regular scouting of fields. Scouting fields regularly (every 7 to 14 days) will reveal which pest species are active and whether their populations are large enough to cause economic loss. By scouting and comparing pest populations and the amount of damage that plants receive to published economic thresholds, farmers can determine whether their fields will benefit economically from insecticide use (see Table 3).

Insecticide and Soybeans

From the 1970s and into the early 2000s, less than 2 percent of U.S. soybeans received insecticides because there were so few pests of concern. In recent years, however, while the suite of insects that attack soybeans has remained mostly the same (soybean aphids and stink bugs are notable exceptions), soybean production has intensified and it is now common for soybeans fields to receive one or more preventative insecticide applications per year. These preventative applications come in two forms: foliar sprays and insecticidal seed coatings. *Foliar insecticide sprays tend to be applied as part of tank-mixes with postemergence herbicide applications or mid-season applications of fungicides. This approach tends to be inefficient for con-*

Table 3. Economic thresholds for frequently encountered soybean pests in Pennsylvania.

<table>
<tr><th>Invertebrate Pest</th><th>Economic Threshold</th></tr>
<tr><td>Bean leaf beetle*</td><td>30 percent defoliation until bloom, about 15 percent while pods are small and soft, and about 30 percent when pods start hardening.</td></tr>
<tr><td>Caterpillars (including green cloverworm, silver-spotted skipper, thistle caterpillar, velvetbean caterpillar, and others)*</td><td rowspan="4">Same as above.</td></tr>
<tr><td>Grasshoppers*</td></tr>
<tr><td>Japanese beetle*</td></tr>
<tr><td>Mexican bean beetle*</td></tr>
<tr><td>Potato leafhopper</td><td>V1, one per plant; V2, three per plant; V3, six per plant; R4, nine per plant; or four per sweep if plants are moisture stressed, and eight per sweep if plants not moisture stressed.</td></tr>
<tr><td>Seedcorn maggot</td><td>None; good idea to use a seed treatment if soil typically is cold and wet after soybean is planted, especially if a green living cover crop has been tilled.</td></tr>
<tr><td>Slugs</td><td>If using shingles to track populations, an average of one to two slugs per shingle over a few weeks; otherwise, heavy feeding on cotyledons and unifoliate leaves that is causing plant death.</td></tr>
<tr><td>Soybean aphid</td><td>250 aphids per plant with an increasing population. Counting can be made easier by estimating the number of aphids per leaf and the number of infested leaves per plant; assess at least 10 plants spread across the field to find an average.</td></tr>
<tr><td>Stink bugs, including brown marmorated stink bug</td><td>3.5 stink bugs per 15 sweeps in 30-inch-row soybeans; 2.5 stink bugs per 15 sweeps in narrow-row beans; or one stink bug per foot of row.</td></tr>
<tr><td>Two-spotted spider mites</td><td>Treat when plants along field margin or within field show discoloration and mites are present.</td></tr>
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*Chewing insects whose damage can be combined into an overall economic threshold for defoliation.

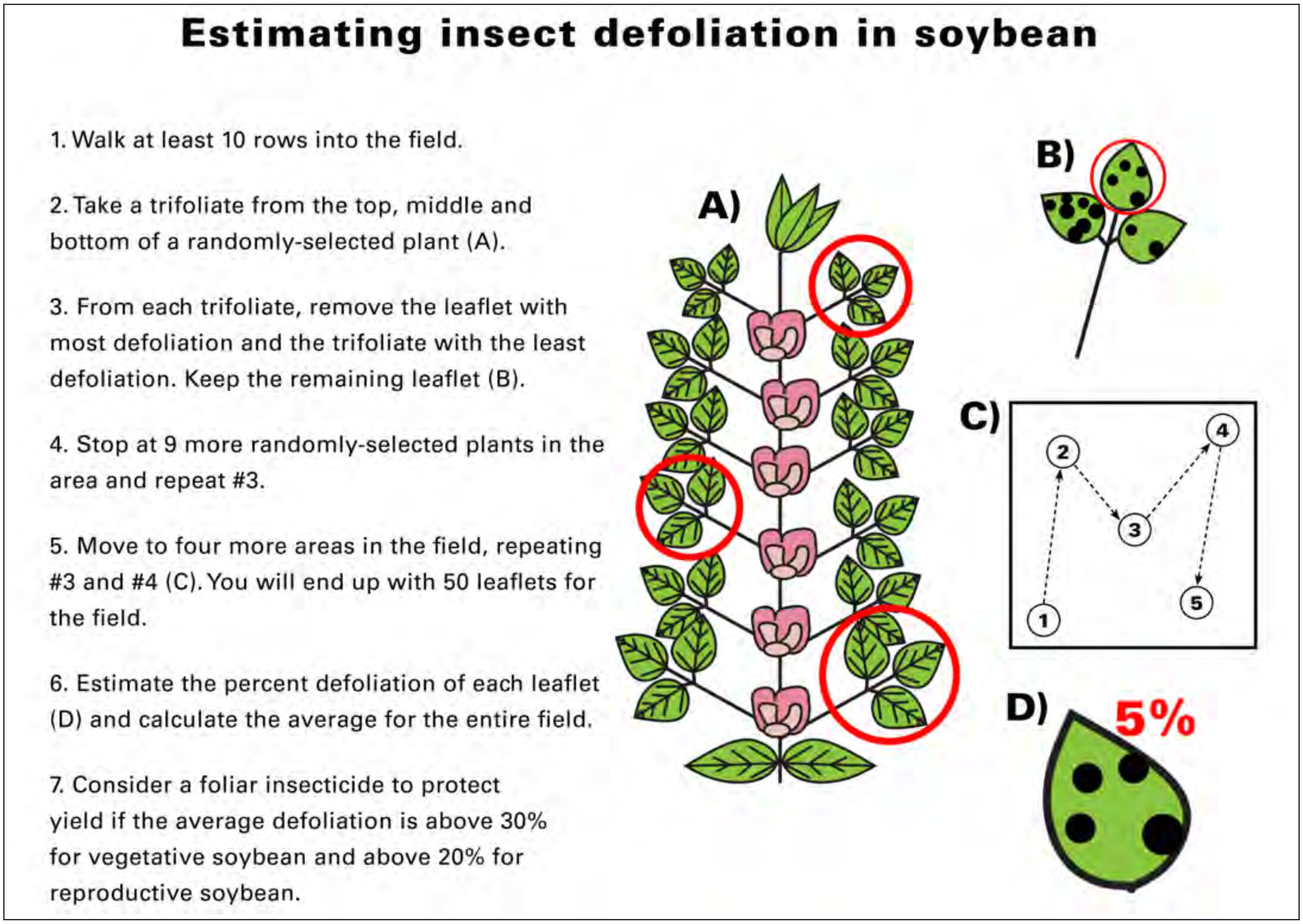

Figure 3. Scouting recommendation for estimating insect defoliation in soybean. Source: Shanovich et al. (2019), used with permission from Erin Hodgson, Department of Entomology, Iowa State University.

trolling insect populations because it is rarely based on scouting and is often poorly timed to target particular insect populations. Coatings of neonicotinoid insecticides are becoming increasingly popular on soybean seed, but their value to production in Pennsylvania is low because the insect pests they target are not very common and rarely cause economic damage (Tooker et al. 2021). Moreover, recent research has revealed that neonicotinoid seed treatments can exacerbate damage from other pest species, particularly slugs and spider mites. Slug damage can be worse in presence of neonicotinoid seed coatings because the insecticide decreases populations of predatory insects that typically contribute to slug control; therefore, one step toward improving slug control is removing insecticidal seed treatments from slug-prone fields. Neonicotinoid seed coatings can also make plants more vulnerable to spider mites because their chemical structure resembles a common hormone in plants that suppresses plant defenses, allowing more mite feeding than usual.

Because of these limitations, the value of preventative insecticides in soybeans is low, and we recommend against using preventative insecticide applications (foliar sprays or seed coatings) in Pennsylvania soybeans. To increase the value of insecticides, it is best to scout fields regularly and apply insecticides only if pest populations or the damage they cause exceed economic thresholds (see Table 3).

Soybean and Natural Enemies

Beyond their tolerance of herbivory, another reason that soybeans have historically had few problems from insects is that soybeans tend to host robust populations of natural enemies that can kill a wide range of plant-feeding pests. These natural enemies (e.g., lady beetles, predaceous bugs, lacewings) can be abundant in soybean fields because the canopy provides a comfortable microclimate (i.e., higher humidity, shade) and a consistent supply of food in the form of insects that do not threaten yield. In Pennsylvania, no-till production provides an additional benefit for natural enemies because no-till fields harbor larger populations of natural enemies than tilled fields because natural enemies do well in the stable, undisturbed habitat of no-till fields. Therefore, by using no-till practices and avoiding preventative insecticides, Pennsylvania soybean farmers can build natural-enemy populations that can help protect fields if pest populations arrive. Should pests arrive, they are likely to be controlled by natural enemies; if not, they will be detected with regular scouting and can be controlled with insecticides if they exceed the economic threshold.

Insect-Resistant Varieties

In other crop species, like corn and alfalfa, insect-resistant varieties (transgenic or conventionally bred) are readily available. For soybeans, there are few varieties available with insect-resistant traits. One exception is RAG genes (e.g., Rag1 and Rag2), which provide resistance to soybean aphid, but thus far they have not been widely available in Pennsylvania and are more common in the upper Midwest.

Scouting Soybeans for Insects, Slugs, and Mites

Begin scouting soybeans for insects and slugs shortly after emergence. Walk fields looking for damage to emerging plants, their cotyledons, and young leaves, and notice any insects feeding on plants. If you find damage or insects, identify the culprits—there is relatively small suite of insect, slug, and mite pests that damage soybeans in Pennsylvania. Keep in mind the time of the season that pests tend to be active (see Figure 2). If you are unable to identify the pest species or different types of damage, contact your local Penn State Extension office. Identifying what is causing the damage is vital because its identity will reveal if it can cause yield loss and how it could be controlled.

If a pest population is concerning, quantify the number of insects or amount of damage they are causing; your quantification will allow you to compare your values with acknowledged economic thresholds (see Table 3). Let the units of the economic threshold (i.e., number of insects per plant or amount of defoliation) guide your quantification method. Quantifying the number of insects in a defined portion of a row can be done visually by inspecting individual plants or using a sweep net (i.e., conduct the appropriate number of sweeps in different parts of the field and count the number of insects in your net after each bout of sweeping). Sweep nets are made from durable fabric and are used to collect insects from foliage by swinging them through plant canopies. Sweep nets can be purchased from agricultural supply stores. Butterfly nets are made from lightweight fabrics, and are not appropriate for sweeping foliage.

To quantify defoliation by chewing insects, collect leaves from 10 plants at five widely separated spots in a field and estimate the amount of leaf area removed (Figure 3). Estimating the defoliation of leaves is not hard, but it takes some practice because people have a tendency to overestimate defoliation damage. To get some experience, consider taking a training lesson from the Crop Protection Network; see **https://severity.cropprotectionnetwork.org/crop/soybeans/soybean-insect-defoliation-training**.

Continue to scout soybean field every 7 to 14 days to detect other pest species when they become active. Continue scouting fields until soybeans reach the R6 stage, when soybeans become less susceptible to insect pests.

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