Integrated Pest Management

INTRODUCTION TO CROP SCOUTING

Plant Protection Programs

College of Agriculture, Food and Natural Resources

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INTRODUCTION TO CROP SCOUTING

Crop scouting is an essential part of *Integrated Pest Management* (IPM). Integrated pest management uses field-specific information and improved decision-making to protect crop yield and quality while minimizing the risks associated with pesticide use. Through a regular and systematic field-sampling program, scouting provides field-specific information on pest pressure and crop injury. This information is essential to the appropriate selection and application of pest management procedures. Although scouting is most often thought of as being a method by which recommendations for in-season rescue treatments are made, scouting can also be used to determine whether replanting is appropriate and to make pest management recommendations for the next or succeeding growing seasons (Figure 1).

Pest management professionals will use information provided by the crop scout to select and implement a pest management program. Thus, the success of the recommended pest management procedures depends on the accurate and timely completion of all three crop-scouting activities. If an in-season rescue procedure is performed, crop scouts should continue monitoring the field to evaluate performance of the pest management program.

Pennsylvania State University

Figure 1. Information gained by scouting fields is crucial for making decisions on in-season pest management treatments as well as making decisions about pest management in future years.

A well-designed scouting program includes three main activities:

1. Sampling to provide an accurate estimate of pest densities and crop health.
2. Identification of pests or diagnosis of the cause of crop injury based on observable symptoms.
3. Comparison of observed pest pressure or crop injury to recommended economic injury levels or economic thresholds.

This publication explains the concepts of the *economic injury level* (EIL) and *economic threshold* (ET) and focuses on sampling procedures. Additional publications of the MU IPM series contain crop-specific information on pest identification, and, if available, recommendations for applying the EIL and ET to specific pests. Specific pest management recommendations can be found in other University of Missouri Extension sources.

ECONOMIC INJURY LEVEL AND ECONOMIC THRESHOLD

Fields are scouted to determine whether one or more pest management tactics are justified. The concept of an economic injury level (Figure 2) was developed to provide objective guidelines for making informed decisions about pesticide use. The EIL is the pest density or level of crop injury that will result in yield loss equal to the cost of managing the pest. It can be considered the break-even point, or the lowest pest density at which treatment may be economically justified. The EIL is

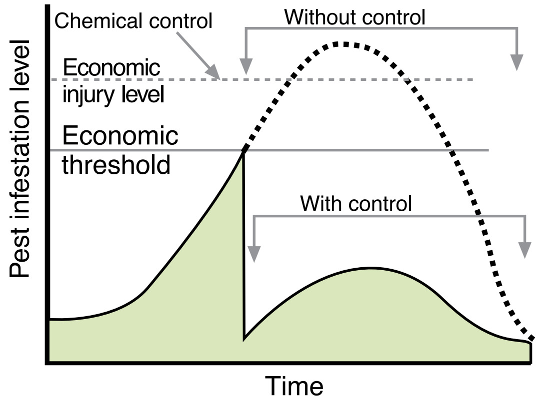

Figure 2. The economic injury level is the pest density or level of crop injury that will result in yield loss equal to the cost of managing the pest.

based on the economic loss caused by each pest and also the fluctuating values of crop market price and control costs. As the market value of the crop decreases, the EIL increases. Producers will be less inclined to control a pest as commodity prices drop. As the cost of pest control increases, the EIL increases. More expensive control measures require a higher level of pest infestation before treatment is justified. The EIL is independent of yield level, but estimated control percentages are affected by environmental conditions, stage of crop development, and age of the pest. Multiple pests may interact and influence the EIL of each pest.

The economic threshold is the pest density or level of crop injury at which controls should be applied to prevent an increasing pest population from reaching the economic injury level. The ET represents a pest density lower than that of the EIL so that the producer has time to implement the control measure before the EIL is reached. The ET is often set arbitrarily at 80 percent of the EIL to buffer the producer from preventable economic yield loss.

Considerable research is required to establish the relationship between pest density (or level of injury) and yield loss, so ETs are not available for all crop pests. When research-based ETs are lacking, guidelines (or nominal thresholds) may be gleaned from field observations of personnel with experience in making pest management decisions.

Economic thresholds are more often available for insect pests than for either diseases or weeds. Insect biology has been closely studied and relationships between infestation and yield loss are relatively easy to determine. Effective insecticides that control insect populations relatively quickly are available for most insects and crops, so treatment after pest identification is possible.

For most field crops, chemical controls of pathogens are rarely used for "rescue" treatments. Preventive measures such as seed treatments are more commonly used (Figure 3). Few pesticides for control of diseases caused by fungi, bacteria, or viruses are available for use after the disease has become established (Figure 4). For these reasons, ETs have been established for only a few diseases of field crops. However, in-season application of fungicides is much more common for high-value

Economic injury level (EIL) is the pest infestation point at which the *cost of control* equals the *loss of estimated crop yield*. It is necessary to calculate these two values and compare them to know whether the economic injury level has been reached.

EXAMPLE:

Cost of control = \$20/acre for material + \$5/acre for application
= \$25/acre

Loss of estimated crop yield:

- Crop market value = \$2.75/bushel
- Estimated yield loss = 10 bushels/acre
- Estimated control percentage = 75%

Crop market value × Estimated yield loss × Estimated control percentage
= (\$2.75/bu) × (10 bu/acre) × (0.75)
= \$20.63/acre

Because the cost of control (\$25.00) is greater than the economic loss of estimated crop yield (\$20.63), this field has not reached the EIL.

Laura Sweets

Figure 3. Preventive controls such as seed treatments are more commonly used to manage field crop diseases than in-season rescue treatments.

Laura Sweets

Figure 4. Pesticides for controlling diseases such as leaf rust of wheat should be applied before the disease is well established.

crops such as sweet corn, seed corn, and truck crops.

In weed management, research on threshold levels for major weed species and complexes of two or more species is expanding because of the development of herbicide-resistant crops and associated broad-spectrum herbicides. Soil-applied herbicides for control of annual grasses in corn are recommended because annual grasses such as giant foxtail, barnyardgrass, fall panicum, and others are present in most fields, and corn is sensitive to early-season grass interference (Figure 5). However, all weeds in soybeans and broadleaf weeds in corn can be managed effectively through scouting and postemergence herbicide selection.

EILs and ETs focus on the economic aspects of pest management and do not factor in costs once considered external to crop production. Environmental risks, such as groundwater contamination, pesticide residues in food, worker exposure to pesticides, and wildlife kills are difficult to quantify and therefore

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Figure 5. To reduce early-season grass interference in corn, soil-applied herbicides are commonly used to control annual grasses.

complicate treatment decisions. EILs may increase if potential environmental impacts were included in the equation as an additional cost for the producer. Use of the EIL and ET concepts in an integrated pest management system is a desirable approach to the selection, integration, and use of methods on the basis of their anticipated economic, ecological, and sociological consequences.

PREPARING FOR CROP SCOUTING

Careful preparation before traveling to the field improves the efficiency with which the field can be scouted and enhances the utility of the information gleaned from scouting. Scouting is part of an overall integrated monitoring plan and not a series of independent procedures (Figure 6). By focusing on a single pest, scouts may miss emerging problems or crop recovery from past injury. Scouts should actively observe and record information on environmental conditions, beneficial insects, pest insects, diseases, weeds, crop growth stage, and the general

William G. Johnson

Figure 6. The need for a postemergence herbicide application can be determined by scouting the field for weed species and densities.

health of the crop. An experienced scout knows that field and landscape characteristics affect pest distribution, symptom expression, crop injury, and crop recovery. An integrated approach with careful preparation helps to anticipate and measure the economic significance of pest and production problems and also provides a baseline for future evaluations. Preparation includes developing a thorough field history for each field on your route and assembling a comprehensive set of reference materials.

Developing a field history

A complete field history provides important clues to the accurate diagnosis of symptoms caused by pests, nutrient deficiencies and toxicities, chemical application (Figure 7) and unfavorable environmental conditions (Figure 8). Many signs of crop injury are ambiguous because similar abnormalities can have unrelated causes. For example, corn plants lodged or growing upward in a goose-necked shape can result from corn rootworm pruning, application of a growth regulator herbicide (Figure 9), or shallow rooting in wet or loose soil. A field record that includes the herbicides (and rates) applied and the previous season's crop might possibly eliminate one or more of these possible causes of lodged corn.

William G. Johnson

Figure 9. Goose-necked corn may be due to corn rootworm pruning, growth regulator herbicide injury, or shallow rooting in wet or loose soil.

In most situations, it is best to rely on written records (if available) so that the field history is not based on memory alone. The scout should prepare the field history well in advance of the first field visit. The initial field visit often occurs during the planting season, which is a hectic time for both the producer and the scout. Gathering all of the useful information will be more difficult at planting time than earlier in the season. Ask the grower to provide the following information for each scouted field:

- Specific field location and grower's preferred name or number for field identification. This information will also be recorded on the scouting report and is essential to accurate delivery of information. If the producer has GPS information, record coordinates for field.
- Crops for the previous 1 to 3 years. If the field had been planted with more than one crop or variety in the previous year, draw a map showing locations of the crops or varieties.
- Variety or hybrid. Specific information including name/number, company, and dealer will be required so that you can determine important characteristics (e.g., maturity, pest resistance or tolerance, herbicide tolerance).
- Other agronomic practices such as planting date, planting rate, row width, and tillage operations; timing of tillage (i.e., fall or spring) may also be useful.
- Pesticide names, rates, and application

Laura Sweets

William G. Johnson

Figure 7 (left). Root damage due to herbicide injury can resemble damage due to soil compaction (see **Figure 8, right).** A complete field history may help diagnose the problem and distinguish between possible causes.

dates. Note whether or not seed treatments were used and whether they were applied by the seed company or by the producer. Because of potential carryover of herbicide effects, record information for herbicides applied the previous season.

- Weather patterns of the present and previous season (including winter).
- Fertilizer and lime application rates and method of application.
- Soil test results, including N, P, K, percent organic matter, and pH.
- Soil type.
- Irrigation availability.
- Previous pest problems.

Diagnostic resources

Well-prepared scouts assemble a set of reference materials for interpreting the information collected during field visits. Some of these materials can and should be carried to the field site. Others are useful for study both before and after the field visit. Other publications that are part of the MU IPM series are particularly helpful for Missouri-based scouts.

Scouts must be able to recognize the appearance of a healthy crop plant, including the root system (Figure 10), before they can diagnose departures from the norm. It is also important to know how to stage a crop, because its susceptibility to, or its ability to recover from, pest damage is often influenced by its growth stage. For example, yield loss from defoliation of soybean plants is greater for R5 plants than for V4 plants (Figure 11).

William G. Johnson

Figure 10. The corn plant at left, injured by herbicide carryover, shows reduced above-ground and root growth. Healthy plant at right.

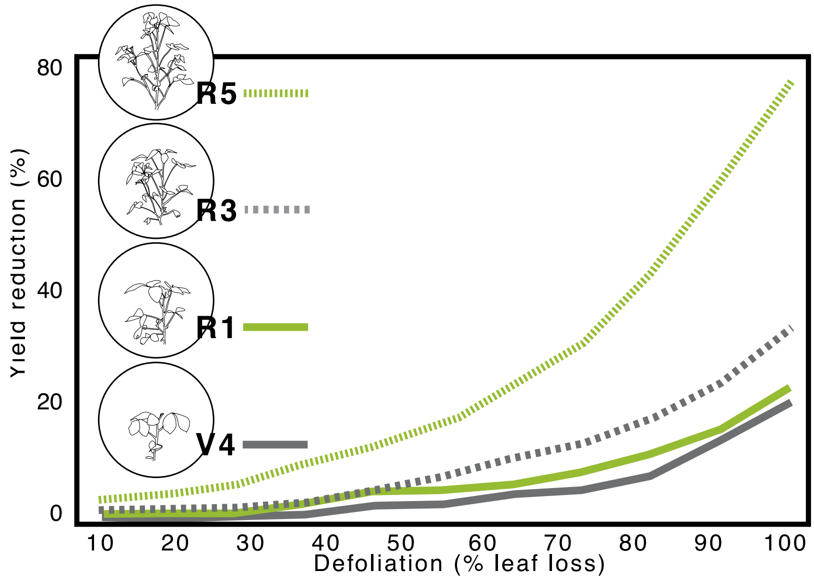
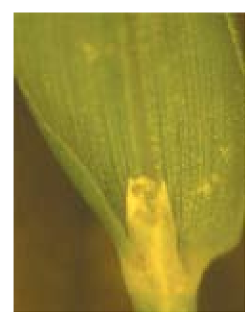


Figure 11. The stage of growth of a crop can influence its susceptibility to pest damage or its ability to recover. Yield loss due to defoliation is greater when defoliation occurs at the R5 growth stage than the V4 stage.

Conversely, the economic threshold for black cutworm damage to corn typically increases as the crop develops through the early vegetative stages so that black cutworm is rarely of economic consequence after the V5 (five leaf) stage.

References to be used in identifying pests or crop abnormality should contain high-quality photos and descriptive keys. Various stages of pest development should be illustrated. Weed references should focus important weed seedling characteristics such as ligules (Figures 12–15) and leaf shapes. Insect references should include progressive stages of growth. Many insect pests, especially larvae, change their color as they develop. Because an insect pest's feeding habits or coloration may



Fred Fishel

Figures 12–15. The collar region of grassy weeds contains subtle keys to their correct identification. Smooth crabgrass (top right) has a membranous ligule; fall panicum (above left) has ring of hair. Barnyardgrass (middle) has no ligule. Auricles are finger-like clasping structures in the collar region of quackgrass and the ryegrasses (above right).

make it difficult to find in the field, it is helpful to have diagnostic aids based on symptoms of crop damage. Insect references should also include beneficial insects.

Plant disease references should illustrate or describe symptoms on all affected plant parts. Many diseases exhibit both above- and below-ground symptoms. Signs, or evidence of the pest itself, may provide clues for the diagnosis of infectious diseases. Symptoms of nutrient deficiency or toxicity as well as diseases with other abiotic origins should be included (Figure 16). All references should include characteristics or diagnostic tips necessary to distinguish among abnormalities that exhibit similar symptoms or pests that appear similar. A "compare and contrast format" may help distinguish subtle differences in symptoms.

See MU publication MP730, A Guide to Diagnostic Services, for detailed instructions and forms for submitting samples to the following clinics and laboratories: Plant Diagnostic Clinic (diseases, insects, plants or weeds), Plant Nematology Laboratory, and Soil and Plant Testing Laboratory.

Fred Fishel

Figure 16. Scouts should make note of any abiotic disorder they encounter in the field, including lightning damage (shown here) or nutrient deficiencies.

SAMPLING PLAN, RECOMMENDED PROCEDURES

The purpose of scouting is to determine whether a pest is present and if the application of a pest management procedure is justified. Scouting is also beneficial to determine whether nutrient deficiencies, soil compaction or other disorders are affecting crop health. It is not practical to observe every plant within the field, so fields are sampled to estimate the level of infestation. The challenge of sampling is to balance the accuracy of estimates with the time and labor required to collect the samples. Although the reliability of estimates increases as sample size increases (up to a point), the collection of too large a sample is costly and inefficient and it wastes human resources.

The sampling plan is the procedure for obtaining a sample to estimate the population of one or more pests or the degree of crop injury in a field. The plan includes the timing of sampling and the directions for: (1) spatial distribution of survey stops, (2) the number of survey stops, (3) and the size or composition of the sampling unit at each survey stop. The magnitude or composition of subsamples from a single inspection or survey stop is called the "sampling unit." A "survey stop" is the area of the field in which a single sampling unit is inspected, counted, or collected. The total number of observations from all survey stops is referred to as the "sample." For example, if the sampling unit consisted of 20 sweeps with a sweep net, 10 survey stops would require 10 sets of 20 sweeps each, or a sample size of 200 sweeps in the field. Likewise, if the sampling unit consisted of inspecting 20 corn plants for black cutworm damage, 10 survey stops would require inspection of 10 sets of 20 plants each, for a sample size of 200 plants.

Timing and frequency of sampling

Sometimes it is challenging to determine when sampling for pests should begin. The inefficiency of sampling before sufficient numbers of pests are present must be balanced against the risk of sampling after an infestation has caused significant crop loss. Knowledge about pest biology and crop growth will help determine when sampling should begin and how frequently the field should be visited. Monitoring weather conditions will help in the prediction of both pest and crop development. Information included in the field history such as agronomic practices will help focus attention on key pests. Information from trapping programs (e.g., black cutworm or European corn borer) will also provide information on when to scout for specific pests.

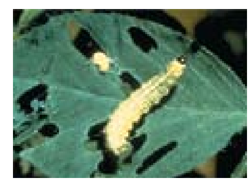
Pest biology

Recommendations for initiating sampling for some insect pests are based on calendar dates because the timing of important development stages of such pests are more or less consistent among years. For example, predictions regarding the adult emergence of corn rootworm and pecan weevil are often based on calendar dates because their development occurs in the soil at relatively constant temperatures. The development of other insect pests as well as most disease organisms and weeds is so dependent on weather conditions that calendar dates should be used only as rough guidelines for the initiation of sampling.

Some key insect pests and disease organisms overwinter in the coastal areas of the Gulf of Mexico and migrate north to the Midwest each spring. The timing and trajectories of annual pest migrations can be predicted by monitoring complex atmospheric circulation patterns or even persistent airflows from specific directions; but these relationships are complicated and beyond the practical applications for most scouts. Being aware of, and perhaps participating in, areawide trapping programs that monitor migration, as well as the seasonal emergence of overwintering insects will be useful in determining when fields should be scouted. For example, scouting for first-generation European corn borers in mid-Missouri should begin 200 degree-days, or approximately 11 to 12 days, after the first spring-flight moth has been detected by trapping or flushing from action sites in grassy field margins.

Crop stage of development

Monitoring of the crop growth stages most vulnerable to key pests may also be used to determine timing of sampling because there must be synchrony between the injurious stage of the pest and the vulnerable stage of the host crop. For example, the alfalfa weevil (Figure 17) is sampled before first hay-cutting because the larvae do not cause economic losses to subsequent growth. Some pests favor certain crop stages of development. Female stink bugs are highly attracted to soybeans once the plants start to bloom, so sampling of late-instar nymphs and adults should begin at that time. Spring-flight European corn borer females are more attracted to taller, early-planted corn, whereas summer-flight moths prefer to deposit their eggs during pollen shed in late-planted cornfields with fresh silks. Based on stage of development or planting date, those cornfields most likely to sustain injury should be given first priority for sampling European corn borers.



Lee Jenkins

Figure 17. Sample for alfalfa weevil before first hay-cutting; the pest does not cause economic losses on later growth.

Weather

Weather conditions not only affect the crop susceptibility to damage, but also influence the development of pests or the expression of symptoms from abiotic agents. Flushes of weed emergence for several species, including waterhemp, may occur after rainfall. The expression of sudden death syndrome symptoms in soybean fields is often tied to wet soil conditions 2 or 3 weeks previous. Potassium deficiency symptoms are most likely to occur in dry soils. Drought conditions increase the likelihood of injury from spider mites (Figure 18), corn leaf aphids, or grasshoppers (Figure 19). Rainfall or high humidity during anthesis of wheat is nearly essential to the development

Lee Jenkins

Figure 18. Drought conditions increase the likelihood of spider mite infestations.

USDA

Figure 19. Drought conditions may also lead to an increase in the number of grasshoppers.

of scab. Weather conditions the previous fall and winter may also be important. Winter annual weeds are most likely to be a problem after a warm winter. Insect and disease organism populations may also increase as a result of warm winters.

The growth rates of many insects and several crop plants depend on ambient temperature. Degree-day models, which relate temperature and pest population development, are an integral component of cost-effective scouting programs because they help to time sampling efforts accurately. Degree-day projections forecast when a population will reach a certain damaging stage, such as the "cutting" stage of black cutworm (Table 1) or the "tunneling" stage of European corn borers. An event in the insect's life cycle may trigger the accumulation of degree-days, such as the first significant flight of migratory pests into a locale (black cutworm) or first detection of emerging adults from an overwintering population (European corn borer). For other pests like alfalfa weevil, January 1 is the arbitrary base starting point for accumulating degree-days to predict larval hatch because eggs are laid in the fall over a prolonged period.

Table 1. Black cutworm development and activity as influenced by degree-days.

Stage	Activity	Degree-days
Egg hatch		90
1st – 3rd instar	Leaf pinhole feeding	91 – 311
4th instar	Initial cutting	312 – 364
5th instar	Plant cutting	365 – 430
6th instar	Cutting slows	431 – 640
Pupa – adult	Cutting stops	641 – 989

Sampling patterns

The sampling pattern will dictate where each of the survey stops will occur. Because sampling is performed in order to estimate the degree of pest infestation or the amount of crop injury, it may seem appropriate to use a completely randomized scheme in which each subdivision in the field would have an equal chance of selection, enabling the scout to obtain an unbiased estimate of the pest population or crop injury. However, a pattern of unrestricted random sampling could result in placement of the majority of the survey stops in the same area of a field. To correct for that possible error, restrictions to the sampling pattern are imposed. These restrictions help ensure that all areas of the field are sampled.

The most common pattern in scouting programs involves walking along a predetermined zigzag or M-shaped route through a field (Figure 20). This pattern is commonly used because it is easy to teach, convenient to use, and ensures that all regions of the field are visited.

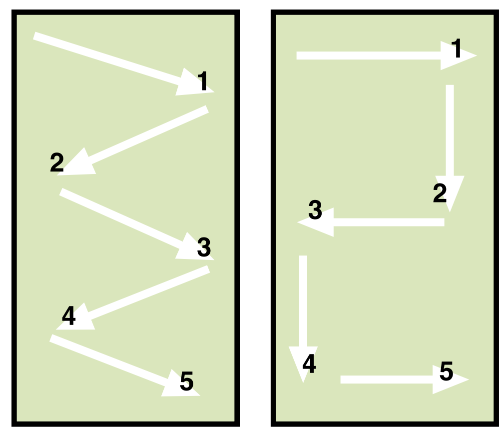


Figure 20. The most common pattern in scouting involves walking along a predetermined zigzag or M-shaped route through a field.

Before the scout arrives at the field, the pattern should be drawn on a field map. Each survey stop should represent approximately 5 to 7 acres. Use this relationship to determine the number of survey stops. For example, a 50-acre field would require 7 to 10 survey stops. The approximate placement of each survey stop should be marked on the drawing. However, these placements may change slightly to prevent too many of the survey stops from falling on some pattern resulting from an agronomic practice (e.g., sprayer overlap).

When approaching the first plant (or area) of each survey stop, the scout should not be looking at the crop. Many scouts are subtly biased toward selection of a damaged plant or area of the field. While looking away from the crop, walk 10 steps forward, and begin the sample unit with the plant nearest your right foot. Sample consecutive plants in each sample unit if the target insect will not be disturbed by sampling adjacent plants. If the pest is mobile or easily startled, take several steps between plants and sample randomly to avoid underestimating the pest population counts. For example, corn rootworm beetles are easily disturbed and may rapidly drop from the plant to the ground. Repeat the same selection process for each survey stop. When walking between survey stops, remain alert and make notes of observed pest problems, crop damage, and field conditions such as soil moisture.

Cover the entire field during each scouting trip. Avoid field margins and border rows unless there are specific reasons for monitoring the edges of the field. To counteract any "edge effect," go into the field at least 40 rows or 100 feet before inspecting, counting, or collecting the sampling unit. Edge effect is the tendency for several key insect pests to cluster near the field margin. Sampling near the edge of the field tends to overestimate the densities of many insect pests. Exceptions to the rule include deliberate survey stops in the outer rows of a cornfield adjacent to maturing small grains to monitor the invasion of true armyworms or chinch bugs (Figure 21).

On return visits to the field, change the sampling pattern so that all areas of the field are covered; for example, alternate a zigzag pattern with an M-shaped pattern. Avoid sampling in the same areas of the field or always entering the field at the same point on successive sampling visits.

Wayne C. Bailey

Figure 21. For pests such as chinch bugs, it may be necessary to sample near the edge of fields.

Number of survey stops and sampling units

The exact number of survey stops and sampling units inspected, counted, or collected at each survey stop may be influenced by the pest, its spatial dispersion, the type of crop injury, and other factors. Detailed sampling protocols for some key pests can be found in the MU IPM publication series. The following is a generalized scouting protocol, but keep in mind that unbiased population estimates for specific pests may require more intensive sampling. Conversely, labor-intensive or costly sampling methods may necessitate fewer samples.

A field size of 50 acres is generally accepted as the maximum land area to scout as a unit. Large fields should be divided into smaller subdivisions equal to or smaller than 50 acres for scouting. Landscape characteristics and information from the field history can be used to subdivide the field. Fields should be divided into even smaller subdivisions if areas of the field have been under different management systems. For example, if a 50-acre cornfield had been planted to 25 acres of corn and 25 acres of soybeans the previous season, the field should be scouted as two separate 25-acre fields divided according to last year's crop history. Regardless of size, fields planted with two or more varieties should be scouted as variety-specific subdivisions. If the field has considerable topographic or soil variation, the number of survey stops should be increased, especially if the pest population or percentage of crop injury approaches the economic threshold.

Characteristics of a pest and the manner in which the pest interacts with the environment determine how individuals of the pest population will be dispersed throughout the field. Because the microclimate varies within nearly every field, few pests are randomly distributed within a field. Both pest and field characteristics will affect the degree of aggre-

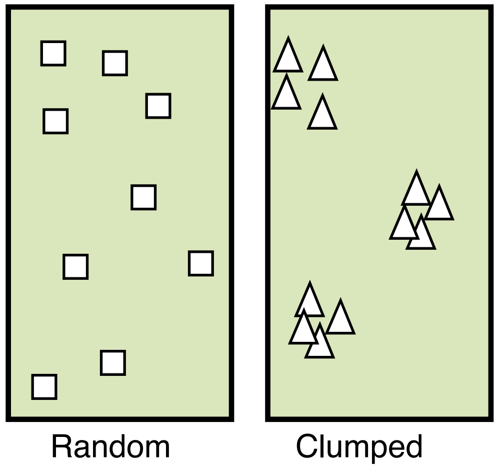


Figure 22. Pests may be present in different dispersion patterns within a field, affecting the success of detection.

gation (Figure 22). In general, as the degree of aggregation of the pest population increases, the number of survey stops required for a reliable estimate of the population increases. In addition, as aggregation increases, the number of survey stops exhibiting few pest numbers or minimal crop injury increases. This does not mean a pest is not present or is not causing injury.

Each sampling unit involves a specific number of plants, actions (e.g., 20 sweeps with a net), or land area (e.g., 100 square feet for weed scouting). Composition of the sampling unit is pest and often crop specific. Time and labor requirements help determine specific protocols. For example, visually examining 20 corn seedlings for black cutworm damage requires less time and effort than unfurling the leaves of 10 whorl-stage corn plants or splitting 10 stalks to assess the level of European corn borer infestation. As a general rule, it is better to make more survey stops consisting of fewer sampling units than smaller survey stops consisting of larger sampling units. For example, 10 survey stops of 10 sweeps each are superior to 5 survey stops of 20 sweeps each, even though the sample size would be equivalent.

Methods of sample collection

Procedures for sampling units are varied and are often pest/host specific. Many of the recommended procedures involve direct observation of the pest. Most weeds and many insect pests are sampled in this manner. Pest densities are counted and recorded on the survey form as the number of pests per plant, sampling activity (e.g., sweeps), row length, or unit land area. Some insects can be difficult to observe because of their small size, so a magnifying lens may be required. This lens is also useful for identifying closely related weeds.

Sometimes, to expedite sampling, only a specific portion of the plant is examined. Insects may be observed on a specific plant part because the pest has a preferred site on the plant for feeding or egg-laying (Figure 23). Scouting for second-generation European corn borers involves examining leaves in the "ear zone" (middle seven leaves of the reproductive-stage corn plant) for egg masses. In addition, if a pest typically injures an economically important product (e.g., corn earworm on sweet corn), that part of the plant is specifically observed (Figure 24).

Some insects are easier to count if they are dislodged from the plant by vigorous shaking and allowing the insects to fall into a bucket or onto a white "beat sheet." This technique is especially effective in counting insects with coloration that blends with the crop foliage. Soybean looper and green cloverworm, for example, can be counted far more easily if seen against the white background of the beat sheet

Ray Nabors, Inset: Wayne C. Bailey

Figure 23. Careful inspection may be needed to detect the presence of some pests.

Figure 24 (inset). Sampling may be targeted to the part of the plant most likely to be damaged by a certain pest; for example, checking sweet corn ears for corn earworm.

Harry Stockdale, Iowa State University

Figure 25. Some pests are easier to count if a "beat sheet" is placed on the ground before plants are shaken to dislodge the insects.

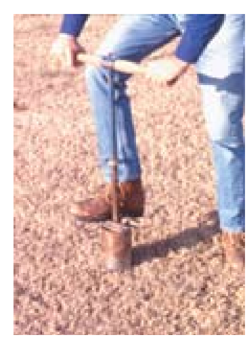
than on soybean foliage. The cloth should be carefully unrolled on the ground and placed between two 30-inch rows in a soybean field; plants on both sides of the row are then vigorously shaken to dislodge insects (Figure 25). Other pests are well concealed by parts of the host plant. The entire stem of an alfalfa plant or the head of a sorghum plant can be vigorously beaten into a large white bucket for dislodging and estimating the number of alfalfa weevils or sorghum headworms, respectively. The success of "beating methods" obviously depends on the extent to which the target pests release their grip on the infested plants. Another method of dislodging insects involves the use of an aspirator in which insects are sucked into a container for later identification.

A common method for "capturing" insects in the field for identification and counting is sweeping with a sweep or butterfly net. This technique is often used to estimate populations of potato leafhoppers in alfalfa or defoliating insects in drilled soybeans (Figure 26). Some scouts find it helpful to abruptly thrust the net upward on the final swing to force net contents into the bottom of the net, quickly turn the top (hoop) of the net sideways to block escape while grabbing the lowest quarter of the net from the outside, and force the swept contents into a gallon-size plastic bag. This technique minimizes escapes, allows easier counting of insects, and reduces the number of stings from agitated nontarget insects. Although sweeping can capture many insects with minimal labor and crop damage, the efficiency of this method varies with the insect species, crop height, time of day, weather, and sweeping technique. Sampling data are generally reported on the scouting report as the average number of insects per sweep.

Some pests live or cause damage underground, so digging up soil cores or a portion of the root mass may be required for observation. (Figure 27). Populations of plant-parasitic nematodes are sampled by collecting multiple soil cores with a cylindrical probe to a depth of 6 to 8 inches. Soil samples removed from close proximity to the plant are sometimes collected to detect the presence of corn rootworm larvae and to estimate the stage of development. The reliability of this technique is questionable because it is difficult to control the dimensions of the soil sample with a shovel. Custom-made and commercially available tools can increase sampling accuracy.

Laura Sweets

Figure 26. Sweeping with a sweep net or butterfly net is a common method of capturing insects in the field for identification and counting.



Fred Fishel

Figure 27. Soil cores are used to detect soil insects or plant parasitic nematodes.

Destructive sampling of plant tissue is not frequently required as part of the direct observation, but sometimes plant parts must be cut, split, or partially dug up to confirm the presence of a pest. Sampling for first-generation

European corn borers requires pulling the whorls from knee-high to pre-tassel stage corn and unfurling the leaves to count young larvae feeding between the unexpanded leaves.

The diagnosis of plant diseases is often based on symptoms and field distribution because the small size of the pathogen in infectious diseases and the absence of a pathogen in noninfectious diseases (e.g., frost injury or nutrient deficiency) make direct observation nearly impossible. For some infectious diseases, signs (i.e., evidence of the actual pathogen such as fungal fruiting bodies) are also important clues. Observations for diseases are recorded on the survey form as either the number of plants exhibiting symptoms or the proportion of plant parts affected by the disease (e.g., percentage of wheat flag leaf infected with rust).

When scouting for insects, the symptoms or signs of crop injury are often more conspicuous than the insect pest causing them. Several insect pests are primarily nocturnal feeders and so may not be visible during the day. During black cutworm surveys, for example, the scout should be alert for clues such as cut corn leaves partially buried in burrows. Occasionally, sample collection may include a unit measure of by-products of insect feeding or inhabitation; examples include the amount of frass (Figure 28), number of egg or pupal cases, or nests of colony-forming caterpillars such as the fall webworm.

University of Nebraska

Figure 28. When sampling for insect problems, it may be necessary to record levels of insect by-products such as insect frass.

Sometimes crop injury is the factor that is observed and upon which economic thresholds are based. Crop injury estimates are recorded on the scouting form as a description of the injury such as percent defoliation, number of pruned roots, percent of damaged stem terminals, or proportion of damaged reproductive structures. When the objective of sampling is to determine the need for a rescue treatment, direct estimates of pest density are also necessary to ensure that the pest is still damaging the crop. Even if the level of crop damage exceeds the economic threshold, avoid recommending a "revenge" treatment if the insect pest is not a current threat. The pest may have migrated from the field in search of a more suitable host plant, or may still be present but heavily parasitized (Figure 29) or near pupation.

North Carolina State University

Figure 29. Scouts should note whether pests are parasitized or near pupation. This hornworm is infested with parasites.

The recommended sampling method for a particular pest on a crop may differ according to the growth stage of either the pest or the crop and even the canopy structure of the crop. For instance, early in the season, direct counting over a measured length of row is the most practical method for sampling bean leaf beetles on soybeans. After the V4 stage, the sweep net in drilled soybeans or the "beat cloth" (with a row spacing of 30 inches) provides more reliable population estimates.

Uses of trapping

As described earlier, trapping of insects can help determine timing strategies for field scouting. In most instances, trapping is performed in conjunction with other scouts or with oversight by public agencies. Contact the local extension office for access to insect trap information. Trapping may help reduce the variation associated with the different sampling techniques of scouts and may reduce the diurnal and weather-related variation that affect sampling results from each weekly field visit. However, trapping should not replace in-field sampling.

The most common insect traps attract insects with visual clues, pheromones, or food odors. The short-wavelength light used in blacklight traps (Figure 30) is an example of attraction with visual clues. This method is especially effective for attracting several economically important nocturnal insects.

Blacklight captures do not provide sampling estimates, but indicate when to begin scouting based on initial or peak flight. First captures of European corn borer moths, for example, indicate that the females will soon begin to deposit egg masses in nearby fields. Blacklight traps are labor-intensive because they are non-selective. They indiscriminately capture many flying insects in large receptacles, and the target insects must then be hand-sorted from large numbers of others before counting. The strong attraction of many insect species to color has been exploited in the design of traps. Many aphids, Japanese beetles, and corn root-worm beetles are attracted to yellow. In corn-fields, yellow sticky traps may be placed at ear height to estimate populations of corn root-worm adults. These traps provide more reliable estimates than direct visual counts because of the propensity of the beetles to startle easily and drop to the ground when scouts approach an infested plant.

Traps that lure insects through the release of pheromones are highly selective to the target insect. For this reason, sorting before counting the target pest is rarely necessary (Figure 31). Insects for which pheromone traps have been successfully used include black cut-worm, European corn borer, gypsy moth, and boll weevil. Solar bait stations (Figure 32) are used to monitor wireworm populations and are an example of attraction with odors associated with food.

Wayne C. Bailey

Figure 30. A blacklight insect trap uses a short-wavelength light to attract insects.

Bruce Barrett

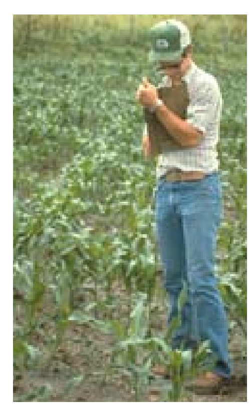
Figure 31. Wing-style pheromone traps can be used to monitor coddling moths or other lepidopterous pests in orchards.

Benton Naylor

Figure 32. Solar bait traps can be used to detect wireworms.

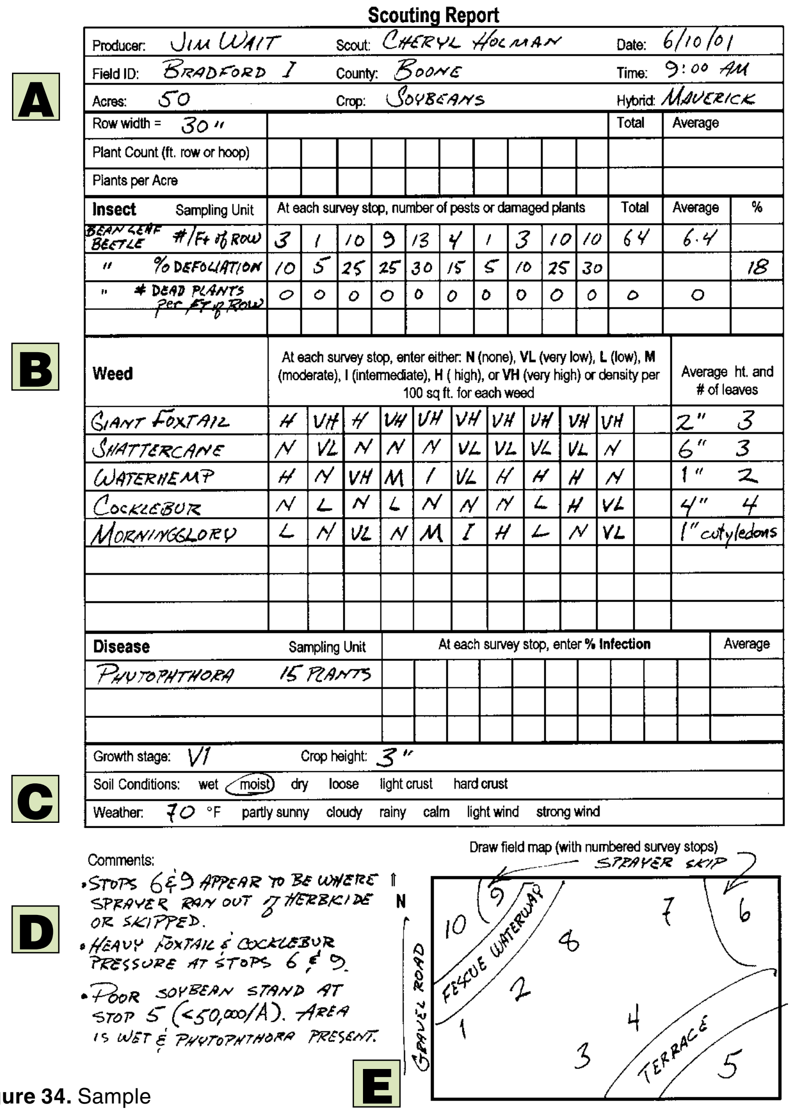
THE SCOUTING REPORT

The scouting report is often the only record of the field sampling survey. Although scouts may have the opportunity to report sampling information orally, the scouting report can be filed and saved whereas oral comments cannot. It is imperative that the scouting report accurately communicates what was found and the methods used to obtain the information (Figure 33). A complete and legible scouting report is the essential "road map" guiding pest management decisions. Over the course of several growing seasons, scouting reports provide a permanent record and time line of pest activity and crop growth. Such detailed records can lead to improved management strategies for the entire field and site-specific locations within the field. An example



Jim Jarman

Figure 33. Detailed scouting reports are needed for judicious pest management.



Scouting Report

Producer: JIM WAIT	Scout: CHERYL HOLMAN	Date: 6/10/01
Field ID: BRADFORD I	County: BOONE	Time: 9:00 AM
Acres: 50	Crop: SOYBEANS	Hybrid: MAVERICK

Row width = 30"											Total	Average
Plant Count (ft. row or hoop)												
Plants per Acre												

Insect	Sampling Unit	At each survey stop, number of pests or damaged plants										Total	Average	%
BEAN LEAF BEETLE	#/Ft of ROW	3	1	10	9	13	4	1	3	10	10	64	6.4	
"	% DEFOLIATION	10	5	25	25	30	15	5	10	25	30			18
"	# DEAD PLANTS Per Ft of Row	0	0	0	0	0	0	0	0	0	0	0	0	

Weed	At each survey stop, enter either: **N** (none), **VL** (very low), **L** (low), **M** (moderate), **I** (intermediate), **H** (high), or **VH** (very high) or density per 100 sq ft. for each weed										Average ht. and # of leaves
GIANT FOXTAIL	H	VH	H	VH	VH	VH	VH	VH	VH	VH	2" 3
SHATTERCANE	N	VL	N	N	N	VL	VL	VL	VL	N	6" 3
WATERHEMP	H	N	VH	M	I	VL	H	H	H	N	1" 2
COCKLEBUR	N	L	N	L	N	N	N	L	H	VL	4" 4
MORNINGGLORY	L	N	VL	N	M	I	H	L	N	VL	1" cotyledons

Disease	Sampling Unit	At each survey stop, enter **% Infection**	Average
PHYTOPHTHORA	15 PLANTS		

Growth stage: V1 Crop height: 3"

Soil Conditions: wet moist dry loose light crust hard crust

Weather: 70 °F partly sunny cloudy rainy calm light wind strong wind

Comments:

- STOPS 6 & 9 APPEAR TO BE WHERE SPRAYER RAN OUT OF HERBICIDE OR SKIPPED.
- HEAVY FOXTAIL & COCKLEBUR PRESSURE AT STOPS 6 & 9.
- POOR SOYBEAN STAND AT STOP 5 (<50,000/A). AREA IS WET & PHYTOPHTHORA PRESENT.

Figure 34. Sample scouting report. Letter blocks refer to the following paragraphs.

of a scouting report that has been properly completed is shown in Figure 34; boldface capital letters in the following paragraphs are keyed to specific areas of the completed form. A blank report form is provided in the Appendix. The Missouri Scouting Form contains five categories of information: field description, crop field observations, pest observations, comments, and field map.

Field description (A)

The top portion of the scouting report should be filled out before entering the field. Some of this information was gathered when the field crop history was developed. The field ID should be understandable to both the scout and the producer. If the producer has GPS information, record the coordinates for the field. If the information will be entered into a database for record keeping, add a unique ID in addition to the field descriptor for the farmer and a customer ID. If the field was divided into two or more portions fill out a separate survey form for each portion and record the acreage of each. In this instance use similar or linked identifications so that multiple reports can be reviewed together. Information for the variety or hybrid should be specific and include the company name as well as the variety name or number. After arriving at the field, record the date and time.

Pest observations (B)

The pest or description of crop damage should be reported with the sampling unit — for example, square feet of area inspected, number of plants dissected, or sweeps collected. The counts or estimates should be entered separately for each survey stop. Accurately calculate the average or percentage of pest density or crop damage in the insect and disease sections of the scouting report. The procedure for weed scouting and yield loss tables based on weed density and crop and weed height are included in *Practical Weed Science for the Field Scout: Corn and Soybeans* (IPM 1007). Enter the stage of pest development (if it may factor into a management decision) and the average height and number of leaves for the weeds that are recorded. If there is doubt as to the correct identification or diagnosis, collect samples of pests or damaged plants for later confirmation of the pest or cause of the symptoms.

Crop and field observations (C)

As the sampling plan is followed, record the following information in the area provided near the bottom of the form: crop growth stage; crop height (useful for weed control recommendations); soil conditions (moisture, crusting, etc.); weather conditions (approximate temperature and wind speed; sunny, cloudy, or rainy).

Record all plant counts so that the number of plants per acre can be estimated. Wait to count plants for this purpose until most seedlings have emerged, about two weeks after emergence was first noted. Refer to MU publication G4091, *Corn and Soybean Replant Decisions*, for recommended methods for estimating plant populations. For crops planted in 15- to 40-inch rows, record the row length used for each plant count. For row spacings less than 15 inches, use hula-hoops or some other rigid frame. Record the diameter or area of the hula-hoop.

Comments (D)

Use the comments section to record additional information that may be useful to either the producer or pest management professional. This additional information could include: other pests and the approximate level of crop injury between survey stops; beneficial insects and their abundance; more details on recorded pests (e.g., "25% of armyworms parasitized"); or unusual field conditions (e.g., "standing water in NE corner").

Field map (E)

Before arriving at the field, the sampling pattern including the location of each survey stop should have been drawn in the space provided. Record landmarks, roadways and other pertinent information to help with orientation on this map.

SUMMARY and RESPONSIBILITIES of the SCOUT

Crop scouting is an integral part of integrated pest management; the crop scout is an essential partner in programs designed to protect crop yield and quality while minimizing the risks associated with pesticide use. Scouts should not make pest management recommendations. Pest management professionals will use the scouting report to select and implement pest management programs. Thus, the success of the recommended pest management procedures depends on timely field sampling and accurate communication of gathered information. It is the responsibility of the scout to

- Be familiar with the concepts of *economic injury level* and *economic threshold* and be able to apply these concepts to important crop pests.
- Use advance planning to prepare for field visits including developing field histories gathered through interviews with producers.
- Be knowledgeable of self-limitations and know locations of information sources required to make accurate diagnoses; these sources include written documents, electronic documents, and diagnostic laboratories.
- Understand the purposes of field sampling and the limitations of recommended protocols.
- Follow recommended procedures, but be flexible in response to site-specific variables.
- Understand the manner in which pest biology, crop plant development, weather, field characteristics, and agronomic practices interact to influence pest development and expression of injury.
- Use the best sampling methods and be aware that these methods are often pest/host specific.
- Know how trapping can benefit field sampling.
- Accurately complete the field scouting report.
- Use language that accurately communicates information to producers and pest management professionals.
- Keep records for future reference.

APPENDIX

Identifying crop growth stages

When determining the growth stage of a crop, be sure to observe plants throughout the field, because variation occurs within any field. A field or sample is said to be at a certain stage of development when 50 percent of the plants in the field are at that stage. Corn, soybean, and rice development is divided into vegetative (V) and reproductive (R) stages.

Corn

Subdivisions of the vegetative stages for corn are designated numerically as VE (emergence), V1 (one visible leaf collar), V2 (two leaf collars visible), and so forth. The last vegetative stage (VT) occurs when the last tassel branch is completely visible.

Reproductive (R) stages are designated R1 through R6. R1 (silking) occurs when silks are visible outside of husks. R2 (blister) is when the liquid in the kernel is the color and consistency of a blister. The endosperm turns white and becomes thicker as solid starch is deposited. R3 is designated as the milk stage, and R4 is designated as the dough stage. A dent (R5) forms at the tip as the center of the kernel collapses because of shrinkage. After R5, a "milk line" forms and marks the layer between solid and liquid starch in the endosperm. Physiological maturity (R6) occurs when kernels have obtained their maximum dry weight and an abscission layer (black or brown) forms near the bottom of the kernel.

Soybeans

VE designates soybean emergence and occurs when cotyledons are visible above the soil. VC designates the cotyledon stage and occurs when the unifoliolate leaves are fully extended. To determine all other vegetative stages, counting the node where the unifoliolate leaves are or were attached and continue counting until you reach the uppermost node with a fully developed leaf. A fully developed leaf is one that has a leaf above it with unfolded leaflets. A V2 plant has unfolded leaves on three nodes (1 unifoliolate and 2 trifoliolate).

Reproductive stages are designated R1 through R8, which describe flowering (R1 and R2), pod development (R3 and R4), seed development (R5 and R6), and maturity (R7 and R8). At R1, one open flower is found on the main stem while a plant with an open flower at one of the two uppermost nodes on the main stem with a fully developed leaf is in R2. An R3 plant has a 3⁄16-inch-long pod at one of the four uppermost nodes on the main stem with a fully developed leaf. When one of the uppermost nodes has a pod that reaches ¾ inch long, the plant is in R4. The R5 stage has pods with seeds ⅛ inch long in one of the four uppermost nodes on the main stem with a fully developed leaf. However, when the green seed fills the pod cavity at one of the four uppermost nodes, the plant is in R6. Physiological maturity (R7) occurs when one pod on the main stem has reached its mature (brown or tan) color. Full maturity is attained (R8) when 95 percent of the pods have reached their mature color.

Wheat

Feeke's scale is commonly used to describe the developmental stages of wheat. It consists of 11 leaf stages of grain development. One shoot (stage 1) and tillering (stage 2) up to erect leaves with three tillers (stage 5) encompass leaf and tiller development. Wheat is dormant during stages 2 and 3. Stem elongation occurs from stage 6 to stage 10. At stage 6, the first node is visible (jointing), followed by the second node (stage 7). When the last leaf (flag leaf) is visible (just the leaf, not the ligule), wheat is at stage 8. When the ligule of the last (flag) leaf is visible, it is at stage 9. The boot stage (10) concludes the stem elongation development of wheat. Flowering occurs at stage 10.5, and stage 11 is grain development.

Grain sorghum

Grain sorghum stages of development have been assigned numbers from 0 to 9. Stage 0 is when the shoot (coleoptile) is visible at the soil surface. Stages 1 and 2 designate a visible leaf collar at the third and fifth leaves, respectively. Stage 3 (growing point differentiation) occurs when the growing point changes from vegetative to reproductive and there are 7 to 10 leaves visible. At growth stage 4, the final or flag leaf is visible in the whorl and all but the final three to four leaves are fully expanded. At growth stage 5 (boot), the sorghum head is nearly full size and enclosed in the flag leaf sheath. Growth stage 6 (half-bloom) occurs when half the plants in a field or sample are in some stage of bloom. Stage 7 (soft dough) and 8 (hard dough) are similar to that described for corn or rice. Stage 9 (physiological maturity) can be determined by the presence of a dark spot on the opposite side of the kernel from the embryo. Grain moisture is 25 to 35 percent at maturity.

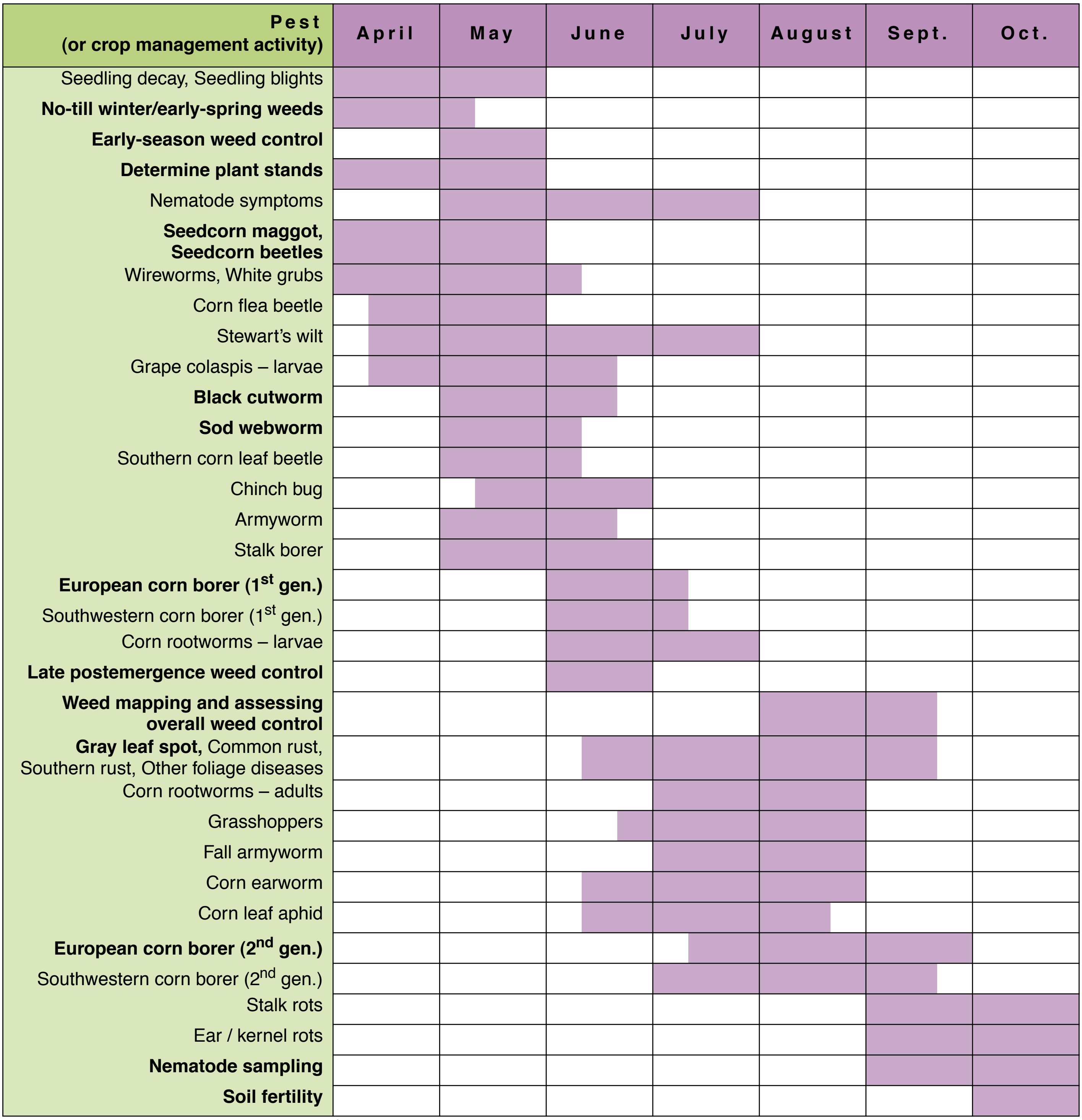
Cotton

Cotton vegetative growth is designated by leaf stages. The cotyledon stage is when only the cotyledon leaves are present. A leaf stage occurs when there is a fully unfolded leaf at least 1 inch in diameter (or roughly the size of a quarter). The fifth leaf stage has no squares present and five fully unfolded leaves at least 1 inch in diameter above the cotyledon leaves. For the reproductive stages, first square is when there is a square ⅛ inch in diamter at the fifth to eighth node. First flower occurs when there are 12 to 16 nodes. Cutout typically occurs when there are five nodes or less above white flower (NAWF). First open boll occurs 45 to 60 days after first flower. Cotton is harvest ready when 95 percent of the harvestable bolls are open.

Rice

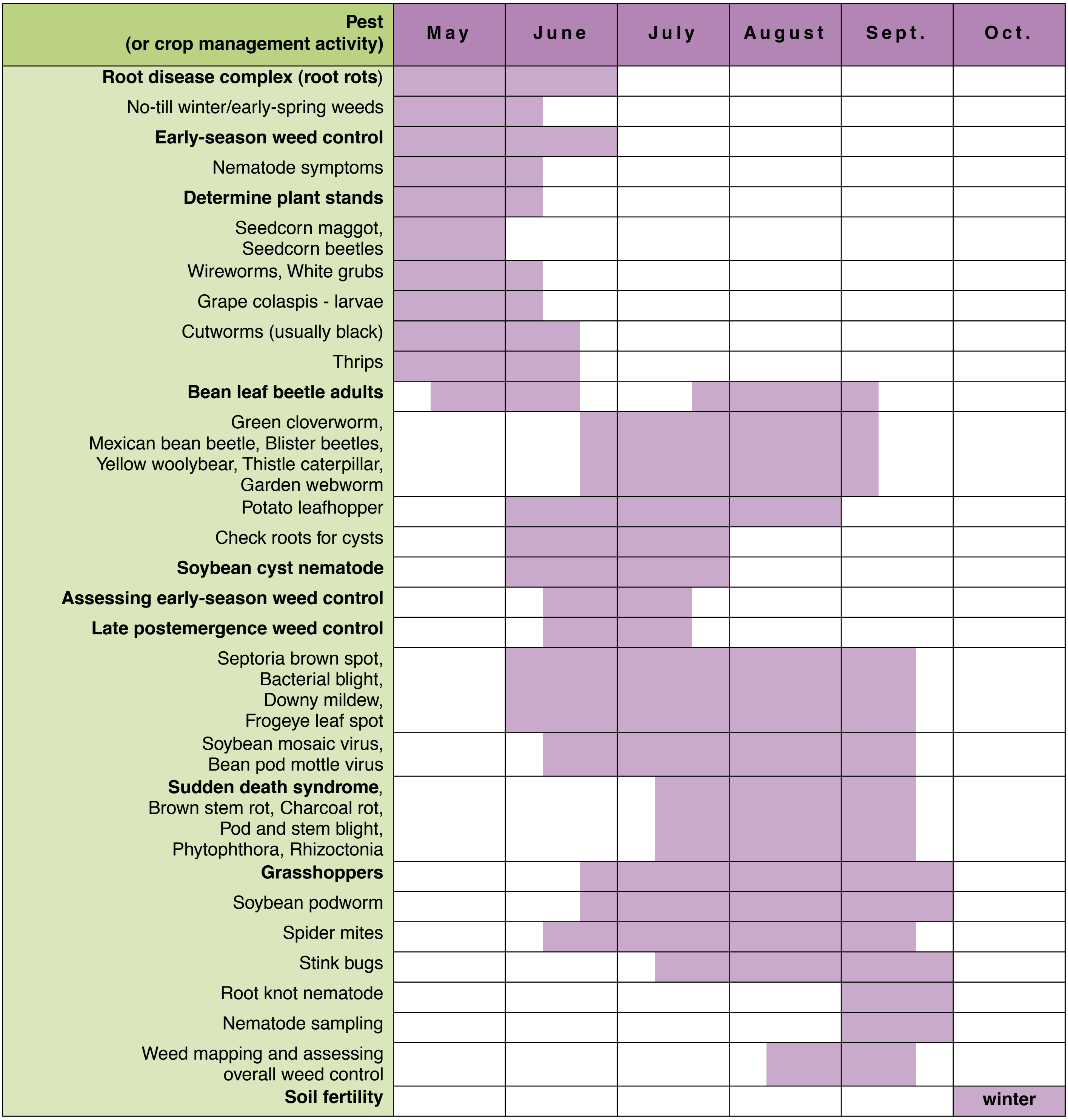
Rice growth stages are designated as seedling (S), vegetative (V), and reproductive (R). Seedling growth stages (S0 to S3) occur before rice emerges. Vegetative: Emergence is when the coleoptile is visible above the soil surface. Formation of the first leaf collar on the main stem signifies the V1 stage. V stages continue as new leaf collars are added to the main stem until V13, which is usually the flag leaf stage. There are 10 reproductive stages. Reproductive stages R0 (panicle initiation) and R1 (branches on panicle) begin before flag leaf development (V13) V13 and R2 both signify that the flag leaf collar is visible. At R3, the tip of the panicle is visible above the collar of the flag leaf. At R4, one or more of the florets on the main stem panicle has reached anthesis. R5 and R6 indicate caryopsis elongation on the main stem panicle. At stages R7 and R8, one grain on the main stem panicle has , respectively, a yellow or brown hull. At R9, all grains that have reached R6 have brown hulls. A DD-50 computer growth model is often used to predict growth stages.

Timeline for Corn Pests or Pest/Crop Management Activities for Central Missouri [1]



[1] This timeline is estimated for central Missouri. For the northern third of the state, advance timeline by 2 to 3 days. For the southeastern "Bootheel," move the timeline back by 10 days.

Timeline for Soybean Pests or Pest/Crop Management Activities for Central Missouri [1]



[1] This timeline is estimated for central Missouri. For the northern third of the state, advance the timeline by 2 to 3 days. For the southeastern "Bootheel," move the timeline back by 10 days.

Timeline for Cotton Pests or Pest/Crop Management Activities for Southeastern Missouri

Pest (or crop management activity)	April	May	June	July	August	Sept.
Cutworms	Seedling-4" leaf					
Thrips	Seedling-4" leaf					
Soil applied herbicides						
Armyworms	Seedling-4" leaf					
Early post weed control		3–8" tall				
Seedling diseases		Seedling-4th leaf stage				
Plant bugs		1st 4 weeks of squaring				
Aphids		Seedling-open boll				
Boll weevils		Seedling-open boll				
Cotton bollworm and Tobacco budworm		Squaring-post bloom				
Spider mites		Squaring-harvest				
Whiteflies		Bloom-harvest				
Mid post weed control			8–14" tall			
Wilts				Bloom-1st open boll		
Lay by weed control						
Foliar diseases				1st open boll-defoliation		
Root-knot nematode				Bloom-harvest		
European corn borer				Bloom-harvest		
Boll rots					1st open boll-harvest	
Cabbage loopers					Bloom-harvest	

Scouting Report

Producer:	Scout:	Date:
Field ID:	County:	Time: am/pm
Acres:	Crop:	Hybrid:

Row width =											Total	Average
Plant Count (ft. row or hoop)												
Plants per Acre												

Insect Sampling Unit	At each survey stop, number of pests or damaged plants										Total	Average	%

Weed	At each survey stop, enter either: **N** (none), **VL** (very low), L (low), **M** (moderate), I (intermediate), **H** (high), or **VH** (very high) or density per 100 sq ft. for each weed											Average ht. and # of leaves

Disease Sampling Unit	At each survey stop, enter **% Infection**										Average

Growth stage:	Crop height:
Soil Conditions: wet moist dry loose light crust hard crust	
Weather: °F partly sunny cloudy rainy calm light wind strong wind	

Comments:

Draw field map (with numbered survey stops)

⇑
N

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