PEST MANAGEMENT

Content

Competency Areas:

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CA1: Integrated Pest Management (IPM)

1. Define pesticide resistance.

Pesticide resistance can develop over time when pesticides with the same mode of action (same way of affecting pests) are repeatedly applied in the same area. Resistance occurs when a pesticide exhibits reduced effectiveness or no longer controls the pest population at the formerly effective rate. If the pesticide or others with the same mode of action continue to be applied, eventually not even higher rates or more frequent applications provide control. At this point the pest population becomes dominated by individuals that are not susceptible to pesticides of that particular chemical class or mode of action (https://ipm.ucanr.edu/agriculture/floriculture-and-ornamental-nurseries/managing-pesticide-resistance/#gsc.tab=0).

2. Describe how pesticide resistance develops in a pest population.

Pesticide resistance develops when repeated exposure to the same mode/mechanism of action selects for individuals with traits that allow survival. Sublethal doses, poor application and applications made at the wrong life stage can increase the survival of resistant pests. Over time, these survivors reproduce, changing the population towards resistance.

3. Know examples of resistant field crop pests in the Northeast.

- **Horseweed**
- **Corn Rootworm**
- **Frogeye Leaf Spot**
- **Water hemp**

4. Know the definition of integrated pest management (IPM) and the major IPM strategies.

Integrated Pest Management (IPM) is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health, and environmental risks (https://ipmdata.ipmcenters.org/). As defined in the National IPM Roadmap ((https://www.nifa.usda.gov/sites/default/files/resources/National%20Road%20Map%20for%20Integrated%20Pest%20Management.pdf), IPM is a long-standing, science-based, decision-making process that identifies and reduces risks from pests and pest management related strategies. It coordinates the use of pest biology, environmental information, and available technology to prevent unacceptable levels of pest damage by the most economical means, while posing the least possible risk to people, property, resources, and the environment. Integrated pest management provides an effective strategy for managing pests in all areas from developed residential and public areas to wild lands and serves as an umbrella to provide an effective, all encompassing, low-risk approach to protect resources and people from pests.

- Integrated: A broad interdisciplinary approach taken using scientific principles of crop protection to fuse into a single system with a variety of management strategies and tactics. Strategies are overall plans to reduce a pest problem. Tactics are the actual methods used to implement the strategy, including such things as chemical, biological, cultural, physical, genetic and regulatory procedures.
- Pest: Defined as any organism that interferes with production of the crop. Pests are thought of as insects, diseases and weeds, but there are many other types including nematodes, arthropods non insects, and vertebrates.
- Management: The decision-making process to control pest populations in a planned, systematic way by keeping numbers or damage at economically acceptable levels.

Key components of IPM include:

- Determine the risk of the pest.
- Integrates management of all pests.
- A way of dealing with pest problems while minimizing economic, human health, and environmental risks.
- Reduces pests to tolerable levels – does not emphasize pest eradication or elimination.
- Prevention vs. reactive pest control.
- Holistic approach ecologically based.

What does IPM integrate?

- Multiple pest management tactics (chemical, biological, cultural, mechanical, host plant resistance).
- Management of multiple pests (insects, diseases, weeds, vertebrates, etc.).
- Pest Management tactics on an area-wide basis (many pest control situations are better handled on a large-scale or regional basis).

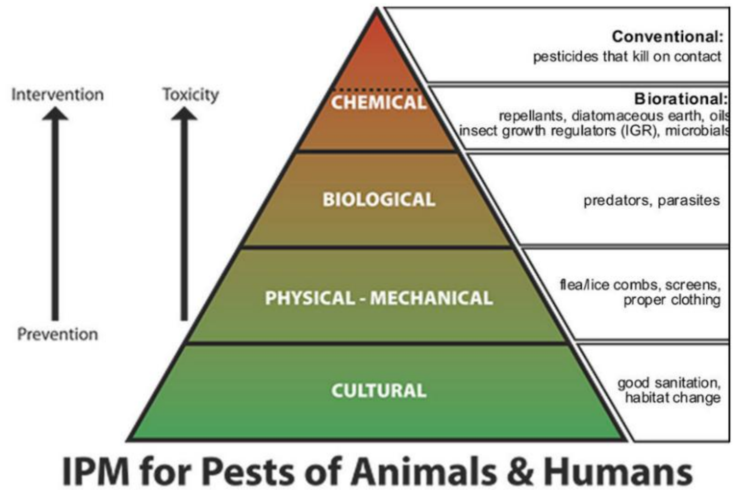
General IPM strategies:

- Do-nothing – Is the pest economically significant? Use sampling and knowledge of economic thresholds to decide; if the population is below the economic threshold, if not, the control is not justified.
- Reduce Numbers – Implement on a treat-as-needed basis when the economic injury level is reached, or as a preventative tactic based on history of a pest problem. Examples of tactics pesticides, release of natural enemies, cultural practices such as cultivation, sanitation, etc.
- Reduce-crop/host/ecosystem susceptibility – rely on changes made in the host (plant or animal) or ecosystem that make it less susceptible to the pest (i.e., raise the economic injury level). Examples of tactics host plant (or animal) resistance, tolerance, cultural

practices such as fertilization (reduce stress) and altering the synchrony between pest and susceptible host, etc.

- Combined strategies – Diversification is often helpful in improving consistency of a pest management program.

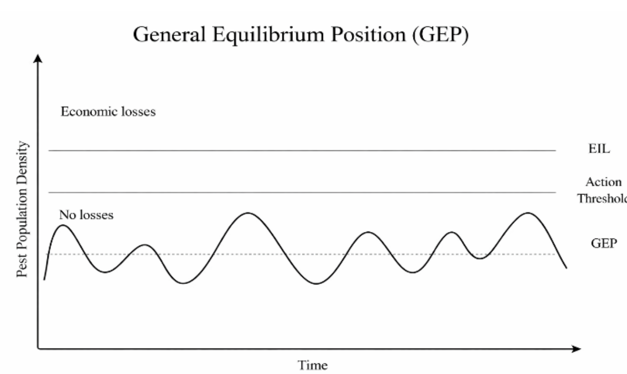
Another way of looking at selecting pest management options is to view them as a pyramid. The pyramid illustrates a least toxic approach to pest management. The foundation contains practices such as crop rotation that enhance crop health and help prevent or avoid pest population build up or reduce pest impacts. As one climbs the pyramid towards the top different options are employed as necessary interventions to pest population buildup or impact.

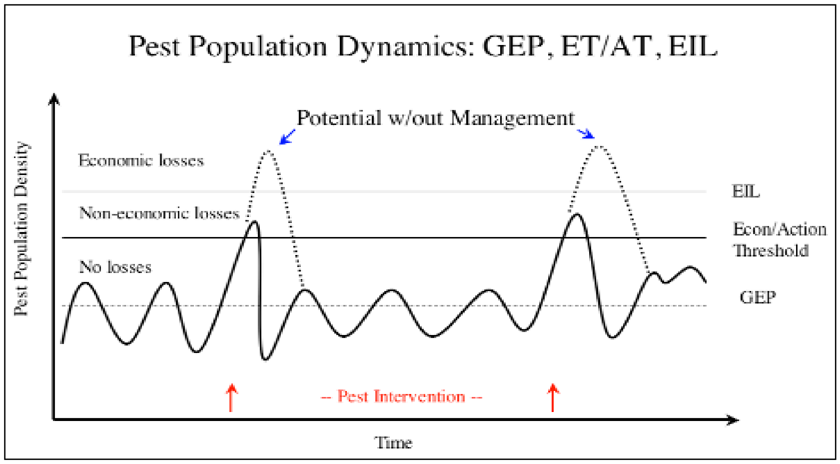


Integrated pest management helps reduce management risks and optimize the economic efficiency of pest control decisions through (1) early detection of pests, (2) proper identification of pests, (3) accurate assessment of potential for economic impact, and (4) timely employment of appropriate, economically efficient, and environmentally sound management strategies.

5. Know the relationship between the economic injury level, economic threshold, action threshold and general equilibrium position of a pest population.

In most crops, and most seasons, a pest species that feeds on or otherwise affect the crop will be present at some point in the plant life cycle. However, just because the pest is present does not necessarily mean that the farmer needs to act against the pest. In seeking to reduce a pest's long term average density, the general equilibrium position (GEP), is low compared with the economic threshold (problems are not particularly severe), the best strategy would be to dampen pest population peaks. This action would not change the GEP appreciably yet would prevent economic damage from occurring during outbreaks. By contrast, severe pest problems call for more drastic population reductions. With these pest problems, the GEP lies close to or is above the economic threshold. What is required for these populations is a general lowering of the GEP so that highest population peaks never reach the economic threshold. How does the farmer know when the number of pests in his/her crop is too many? Is this number the same every year in all fields?





To help farmers decide when there are too many pests, the concept of the "Economic Injury Level (EIL)" is used. The EIL allows the farmer to compare the value of the damage, and what the number of pests in the field might do to the crop with the cost of taking action against a pest. In other words, is the cost of taking action (e.g. spray) more or less than the value of crop lost to the pest if no action is taken? The point where the cost of control equals the value of loss is called the EIL.

Economic Injury Level (EIL):
The EIL represents the pest density at which the cost of control equals the value of crop loss. It helps farmers compare the potential damage pests may cause with the cost of taking action. When the expenses of control match the expected loss from pest damage this defines the EIL.

Economic Injury Level (EIL) = P

$$P = \frac{C}{V \times I \times D}$$

where:
- P = Density or intensity of pest population (for example insects/acre)
- C = Pest Management Costs ($/acre)
- V = Market Value per unit of produce (for example, $/acre)
- I = Injury units per production unit (e.g., % defoliation/insect/acre, expressed as a proportion)
- D = Damage per unit injury (for example, bushels lost/acre/percent defoliation)

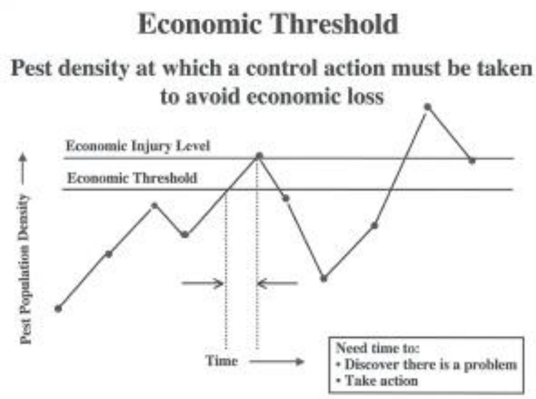
In instances where some loss from a pest is unavoidable, for example, if injury can be reduced by 80%, the relationship becomes:

$$P = \frac{C}{V \times I \times D \times K}$$

Where K = proportionate reduction in injury (for example, 0.8 for 80%)

By the time that the farmer determines that the pest population is getting to unacceptable levels and finds the time, equipment and labor needs to act, the pest population may have had a chance to exceed the EIL and reduce the farmer's profit. To account for this management 'lag' another measure, the Economic Threshold, sometimes called Action Threshold, is calculated.

- Economic Threshold (ET):
  The level of pest infestation at which management action is justified. At or above the ET, the likely loss from crop damage is greater than the cost of control. Below the ET, cost of control exceeds savings from crop protection.
- Action Threshold:
  The density at which control measures should be initiated to prevent the population from reaching the EIL.



Thresholds are set through research, so all the farmer has to do is take a proper sample of the pest to answer the question: Are we above or below the ET for pest X?

To calculate ET, you must:

1. Know how to identify the pest.
2. Know how to sample the crop environment to assess level of infestation.
3. Know the stage of crop development and how that relates to severity of damage.
4. Know approximate ET levels (available by your state University Extension)
5. Consider how action threshold may vary with stage of crop development, value of crop and cost of control.

For more information see: http://paipm.cas.psu.edu/fldcrop/part3.htm.

6. Know the typical steps in the IPM process. These include:

a. Proper identification of problems
b. Sampling to determine the extent of the problem
c. Analysis to assess problem importance
d. Selection of appropriate management alternative
e. Proper implementation of management action
f. Evaluation of effectiveness of management action

The IPM approach promotes "proactive" rather than "reactive" management. Careful use of these principles in the order presented will maximize the advantages of using the IPM approach. This IPM approach can be applied to a wide variety of pest management situations. With some modifications these IPM steps can be effectively applied to help manage pests of crops, turf, landscapes, pests of pets, livestock, stored products and pests in/around structures. The following steps can help to detect pest problems before they become significant, to prevent losses, and to avoid unnecessary pest management actions:

Key issues/questions.

- What should you expect?
- Crop agronomy, growth and development?
- Pest management needs, options?

- Previous field history? Common (annual) pest problems for the crop being produced?
- When and how to look at the pest or signs of pest / damage?
- Identification – what are key characteristics to correctly identify the pest?
- New problems – are there new, emerging, invasive pest species of potential concern?

Other factors to consider?

- Field history – Is there a documented field history with information on previous crop and pest management actions or concerns?
- Farm management – understand farm resources, strengths, opportunities/constraints.

Resources: where can you find information?

- Cornell Cooperative Extension
- Certified Crop Advisor
- Company representatives and other growers
- Cornell Guide for Integrated Field Crop Management: https://cropandpestguides.cce.cornell.edu
- Cornell IPM: https://cals.cornell.edu/integrated-pest-management
- Trade Journals, etc.

a. Proper identification of problems

Correct identification is the first and most important step in controlling a field problem as incorrect diagnosis leads to mismanagement. What is causing the problem? A pest? An environmental stress? A nutritional deficiency? Mistaking a disease problem for an insect problem can lead to unnecessary use of an insecticide or continued planting of disease-susceptible crop varieties. Confusing a nutritional deficiency for herbicide injury or a disease ailment can likewise lead to incorrect actions. Learn to identify parasites and predators that help keep harmful pests in check. Many insects and other organisms can be observed in fields, relatively few harm crops. Obtain as much information about the problem as possible to determine its cause. What type of damage is observed? Check field history information to determine if it is a historical problem. Is the problem found only in particular locations, rows, soil types, drainage patterns, or at certain times during the growing season? What part or growth stage of the plant is affected? A first steps is to dig up plants showing symptoms. Check roots and the surrounding soil for evidence of pests. If in doubt about correct identification of the problem, collect representative samples and field information to share with other knowledgeable people or submit to a diagnostic clinic. There are many resources available to provide helpful information on identification of common pest problems of crops.

Key issues/questions

- Misidentification = mismanagement
- Who is your enemy and who is your friend?
- Be familiar with common, expected problems.
- Know where on/in the plant/in the field and when (growth stage of crops, time of the season) to anticipate common pests.

- Know how to distinguish pest damage from other injuries (soil compaction, nutrient deficiencies, frost)
- Know vulnerable stages of crop and pest, compensation and yield capabilities, potential pest impacts.
- Know when and how pests can hurt crops thmost.st
- Be proactive. What crop conditions might favor pest problems?
    - Wet soils = Phytophthora root rot
    - Continuous corn – corn root worm, foliar diseases
    - Poor weed control – armyworm, stalk borer
    - High crop residue - foliar diseases
- Knowing key beneficial and indicator species, signs of crop health and stress

b. Sampling to determine the extent of the problem.
Once the pest is correctly identified, the next step is to determine whether it poses a risk of significant loss. Consider if the problem is occasional, localized or common thorough the field, and evaluate the extent and progression of damage. Scientific sampling and crop monitoring techniques help assess the damage potential of many pests and remove guesswork by quantifying ongoing or emerging problems. Use sampling information along with pest and crop biology, to make better management decisions. For example, alfalfa weevil in the Northeast typically pupates around first harvest, naturally reducing its impact. Accurate sampling or scouting is systematic and methodical, examine and quantify all the key field information needed for sound pest management decisions. Specific sampling strategies for individual pests and crops can be found in resources such as the Cornell Guide to Integrated Field crop Management or the Cornell IPM website https://cropandpestguides.cce.cornell.edu/.

Pest forecasting: For some pests forecasting methods have been developed to aid in determining when a pest is likely to be a problem. Weather data and other information help predict when these specific pests will most likely occur. Weather-based pest forecast models for diseases and insects of many crops have been developed in the Northeast. For field crops, information on an alfalfa weevil prediction model based on accumulated heat units is available in the alfalfa insect section of the Cornell field crops guide. Actual growing degree calculations for predicting estimated alfalfa weevil growth stage across Northeast during the growing season can be found at: https://newa.cornell.edu/alfalfa-weevil/. Another forecasting model is available to help predict critical times to manage of Fusarium Head Blight of Winter Wheat at Penn State: https://www.wheatscab.psu.edu/.

Access to a computer network to obtain weather, regional insects, and disease forecasts is useful but not essential. The Northeast Weather Association (NEWA: https://newa.cornell.edu) provides automated local weather information and the results of pest forecasts daily. Simple weather-recording equipment such as thermometers, hygrometers, and rain gauges will assist the prediction of pest outbreaks. Information on the potential for pest outbreaks can be obtained from Cooperative Extension offices, newsletters, and crop advisors.

Key issues/questions.

- How many pests are there and general crop condition?
- What is the extent of the damage (few spots or excessive plants/areas)?
- Is the problem associated with any obvious field factors?
- Are you quantifying an old problem or discovering a new one?
- Are pests a "growing" threat?

Make sure to examine and quantify all the necessary parameters to make a sound decision. Refer to IPM Guidelines for sampling recommendations and monitoring techniques

c. Analysis to assess problem importance

The third step in the pest management process is analyzing the identification and sampling information and evaluating the need for pest control action. How bad is the problem? Is the potential control measure more costly than the potential damage? Weigh economic, environmental and time concerns. What impact will current pest control decisions have on future crop management decisions? Compare the observed frequency of a pest to its action threshold.

During the analysis stage, consider the relative vigor of the plants, plant populations, and value of the crop and potential yield, depending on the crop and pest type. Light pest populations may increase yields by causing the plant to compensate. Poor stands (less than 75% alfalfa) may not return management dollars since thresholds are based on research with clear stands. For alfalfa stands, crowns should have many lush stems, and little or no signs of root or crown injury, and clear stands should have a minimum of five healthy crowns per square foot to justify pesticide application. Clear seeded alfalfa is usually more economical to treat for a given pest problem than mixed stands, and some pesticides cannot legally be applied to mixed stands.

Key issues/questions

- Evaluate risk. Is there a significant problem? If so, how bad?
- Consult threshold guidelines that are built on research and experience with similar problems
- Weigh economic, environmental, & time concerns. Is damage potential more costly than the control? What happens if you do nothing? What happens if you apply control(s)? Which would cost more - damage or control?

Decision aids (see PO#2 for more information):

- Economic Injury Level (EIL): pest densities (number of pests per unit area) at which control measures are economically justified.
- Cost of pest control = savings from damage avoided / crop protected (break-even point).
- Economic threshold (ET): pest density at which action must be taken to prevent an impending pest outbreak.
- Action threshold: the level of pest infestation at which management action is justified. At or above this level, the likely loss from crop damage is greater than the cost of control. Below this level, the cost of control is greater than the savings from crop protection.

d. Selection of appropriate management alternative

When action is required, select a strategy that fits the farm's short- and long-term plans, labor, equipment and finances. Evaluate the cost, benefits and risks of each management option and look for opportunities to integrate multiple tactics. Consider cultural, mechanical biological and chemical controls and determine which approach is the most practical, economical and effective.

Management tactic	Example
Biological	Parasites, predators, pest
Chemical	Pesticides, pheromones, baits, attractants
Cultural	Rotation, planting date, site selection, fertility, pH, plant populations, sanitation
Host resistance	Resistant varieties, transgenic crops
Mechanical	Cultivation, tillage, rotary hoe, fly swatter, traps, screen, fence
Physical	Rain, freezing, solar radiation

Information on short- and longer-term pest management strategies can be found in the Cornell Guide to Integrated Field Crop Management (https://cropandpestguides.cce.cornell.edu/) or the Cornell IPM website (https://cals.cornell.edu/integrated-pest-management).

Key issues/questions.

- What can be done to control this pest problem?
- Cultural, mechanical, biological, and chemical control options? Economics?
- Are there windows of opportunity to disrupt the pest's life cycle or potential impact?
- Does the total management system allow for some options such as: will early alfalfa harvest to control weevil interfere with crucial corn planting?
- Given time and the farm's resources what's the optimum IPM option(s)?
- Re-evaluation needed? - influence of weed size, insect age, crop growth stage, etc.

e. Proper implementation of management action.

Implement the control carefully and at the right time. If pesticides are used, always follow label recommendations. Cultivation or using herbicides on weeds must be done at the right stage of weed and crop development for greatest impact. Pay close attention to the quality control of pest control actions, such as correct calibration of the application equipment and label recommendations. If appropriate, leave small, untreated areas to evaluate control effectiveness. Conduct management action with precision and thoroughness.

Key issues/questions

- Timely application of management procedures. Such as using herbicides on weeds at the right stage of development
- Use quality control. Correct calibration of the sprayer.
- Integrated approach. Avoid the tendency to use chemicals when effective cultural controls or natural enemies are present
- Keep records of actions taken.
- Once a course of action is chosen: Be precise, thorough, timely, and use quality control.

f. Evaluation management action(s) effectiveness

After a control action, evaluate what worked and what needs to improve. Re-scout the field and compare pest levels before and after treatment. Confirm correct pest identification, unbiased sampling and proper use of thresholds. Assess whether the control choice was based on sound judgement and identify system changes that could improve outcomes, recording findings.

Key issues/questions

- Review what went wrong - what went right
- Did you trip up the steps, or climb gracefully? Was the “problem” identified correctly?
- Sampling unbiased? Threshold guideline followed?
- Choice of control based on sound judgment or salesperson pressure?
- What changes to the system would make it better?
- Check (no treat) plots to evaluate the action.

7. Recognize the importance of using appropriate sampling methods to determine presence or absence, and to estimate population density of a pest species. Know the components of proper sampling including method, location, timing, and sample size.

Scientific sampling techniques vary by crop and pest type. Methods to assess the damage potential of important common pests can generally be found in state crop and IPM guides. Sampling techniques and protocols strive to collect information representative of the whole field condition on which to make management decisions. Correct sampling helps eliminate the guesswork in pest control by providing a means to quantify the pest problem. Use sampling knowledge and information on pest and crop biology to make better management decisions. To most effectively use IPM guidelines, use the sampling methods and threshold guidelines recommended by your state.

Common methods for sampling: Visual Inspection of insects, diseases, weeds, vertebrate or other plant damage. Assessments are made while walking throughout the field. Data are generally recorded as the number of individuals per plant or plant part or percentage of plants or area affected. Weed assessments include species identification, type (annual, perennial, grass, broadleaf, etc.), and the relative abundance of important species in the field. Weed populations can be evaluated using the rating scheme provided in the weed assessment section.

Insects:

- Sweep net or beat cloths – For mobile insects such as potato leafhopper sampling protocols call for using a 15-inch diameter sweep net. Samples are taken from numerous locations within the field. Assessments are made by counting the number of individuals collected in the net per “X” number of sweeps. Beat cloths are another method of collecting information on less mobile insects in row crops, such as spider mites and aphids. The beat cloth is used to collect insects shaken from plants in a sample area such as a square foot. The number of individuals collected per unit area is compared to recommended guidelines.
- Trapping – Several types of trapping devices are used in collection of insect information.
- Light traps – used to determine relative abundance of insects in a defined region. Information on the number of adults caught in the trap over time is used to help predict potential pest outbreaks.

- Sticky traps – Used to collect small flying insects such as aphids, leafhoppers, flies, and beetles. Relative abundance and type of insect collected is recorded.
- Pheromone traps – chemical attractant traps used to determine if a particular species is in the area. Also used to detect initial flights of insects such as European corn borer and the relative abundance of insects like western corn rootworm.

Identification, sampling and management guidelines for specific insects and their damage can be found in state crop and IPM guidelines. Information on specific sampling strategies for specific pests on crops of interest can be found in resources such as the Cornell Guide to Integrated Field Crop Management (https://cropandpestguides.cce.cornell.edu/) or the Cornell IPM website (https://cals.cornell.edu/integrated-pest-management .

Disease sampling: As different diseases are favored by different environmental conditions, scout for diseases throughout the entire growing season in conjunction with other scouting activities. Diseases may become more obvious during certain times of crop development such as crop emergence, or during times of stress (e.g., drought or flood), and pre- or post-harvest. Look for areas of stunted, yellow, discolored, wilted, contorted or dead plants.

Symptoms of different diseases often appear similar and can at times be confused with other ailments such as nutritional deficiencies and abiotic problems. If a problem cannot be diagnosed in the field, dig up several plants that show typical symptoms. For many diseases it is important to include above and below ground plant parts when submitting samples for diagnosis. For example, when submitting alfalfa samples include as much of the crown and taproot as possible. Submit the samples to a diagnostic laboratory. Estimate the percentage of plants affected by the disease throughout the field. Record information concerning particular problem areas, noting location, size of area affected, drainage pattern, etc.

Weed sampling: Scout for weeds in the spring and fall. As always, take care to obtain a representative sample of weed conditions throughout the field, although weed infestations may not be uniform across the entire field. Document the weed type rather than taking detailed counts of weed species. Observe at least five random areas of a forty-acre field; divide larger fields into two equal parts for scouting. Base these divisions on previous field history, soil type, topography, or other factors that might affect weed populations. Scout for weeds in conjunction with other monitoring activities. See the comments above for "Visual Inspection". Record weed type (annual, biennial, perennial, grass, sedge, and broadleaf) and relative importance from all parts of the field. Note any areas with significant weed problems. Map weed locations on the scouting form. Check special terrain features such as droughty slopes, poorly drained areas, field borders, and fence rows for weeds. These areas can be major sources of weed contamination and differ significantly from the rest of the field. Specific economic thresholds have not been established for weeds in alfalfa in New York. Instead, use the rating scale provided below and knowledge of the weed type (annual, biennial, perennial, grass, sedge, or broadleaf) to design a weed management program. After rating the weeds, rank the most prevalent weed species in each field in order of severity.

Determine the presence of each weed species according to the following rating scheme:

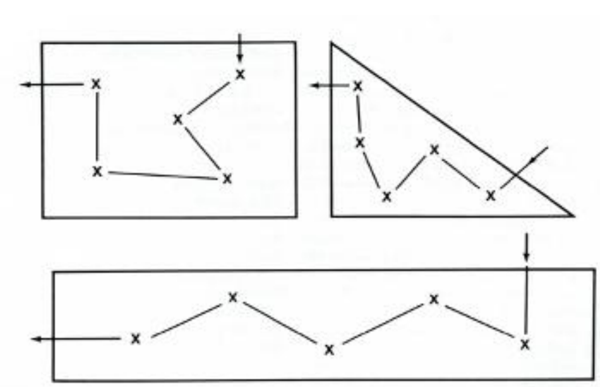
None	No weeds are present.
Few	Weeds are present, but there are very few plants in the field. There are enough plants to produce seed but not enough to cause significant loss.
Common	Plants are dispersed throughout the field. There are: a) up to 5 grassy or 3 broadleaf annual weeds per square foot, or b) 0.3 perennial or biennial weeds per square foot (3/sq. yd), or c) scattered spots of severe infestation.
Abundant	There are fairly uniform concentrations of: a) 6 to 20 grassy or 4 to 10 broadleaf annual weeds per square foot, or b) 0.5 to 1.0 perennial or biennial weeds per square ft (6-20/sq yd), or c) scattered spots of severe infestation.
Extreme	There are: a) concentrations of more than 2 grassy or 1 perennial or biennial weeds/square foot (20 grassy or 10 perennial or biennial/sq yd), or b) large areas of severe infestations.

8. Outline methods for sampling plant and pest material.

Pest sampling must be based on an understanding of pest biology. You need to know how to identify the pest, what to sample (plant parts, % injury, insect counts, weed density) when and how to sample and what defines a sample (e.g. 10 sweep net sweeps per site). Some pests require specialized sampling techniques. Scouting calendars for common New York pests in alfalfa, corn soybeans, and small grains are provided in the IPM literature.

Correct sampling is the key for obtaining useful field information. It is important to randomly select plants for sampling. Do not examine only the "best" and "worst" plants. A random sample is taken by walking to the general area to be sampled, and looking up to the sky, walk forward five paces. Begin the inspection procedure with the plant nearest to the toe of your right foot.

Selecting an appropriate subsample method will depend on the mobility of the pest being scouted. Two subsample methods are recommended. Consecutive plants are examined when the pest will not be disturbed by sampling procedures on adjacent plants. This method is appropriate for scouting pests such as cutworms, stalk-boring insects, weeds, and diseases. Random plants are examined when mobile insects are being surveyed. In this case, the next plant examined should be some



Pattern I example. Sampling pattern for pests expected to have uniform distribution in the field. X = sample area.

distance away to remove any possibility of recounting insects that may have moved from plants sampled earlier. Random sampling is the preferred sampling method for insects such as corn rootworm adults.

Note: More than one pest may be present in fields at the same time. For this reason, combinations of the sampling procedures described may be necessary to accurately detect presence of all pests.

- Sampling for specific NY Field Crop Pests can be found in the Cornell Guide to Integrated Field Crop Management (http://fieldcrops.cals.cornell.edu/) and the IPM field crop website (http://nysipm.cornell.edu/agriculture/livestock-and-field-crops).
- Field Crops Pest Management Manual, Purdue University, Agricultural Communication, Media Distribution Center, 231 S University St, West Lafayette, IN 47907-2094, (https://extension.entm.purdue.edu/fieldcropsipm/), 1-888-EXT-INFO (398-4636), Fax: (765) 496-1540.
- Cornell University Integrated Crop Management Guidelines: http://ipmguidelines.org/.
- Penn State Field Crop Integrated Pest Management Training and Reference Manual http://paipm.cas.psu.edu/fldcrop/.
- Pest Sampling and Management Tactics, High Plains Integrated Pest Management Guide for Colorado, Western Nebraska, Wyoming, Montana and Western South Dakota (http://highplainsipm.org/).
- Radcliffe's IPM World Textbook. The University of Minnesota's electronic textbook of Integrated Pest Management (IPM) featuring contributed chapters by internationally recognized experts. (http://ipmworld.umn.edu/).
- Northeast Region Integrated Pest Management Center. Links to IPM information and resources from northeastern US states (CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT, WV) and throughout the United States: http://neipmc.org/index.cfm.

9. Outline basic methods for submitting plant and pest material for diagnosis and laboratory analysis.

Cornell University's Insect Diagnostic Lab can help identify pests and provide pest management suggestions (http://idl.entomology.cornell.edu/). Guidelines for sending specimens:

- Collect and send 10 or more insects, if possible, and all life stages present.
- Household/structural pests: describe the problem: where found, in what room, approximately how many, extent and type of damage/concern, history of past infestation.
- Plant pests: collect progression of symptoms and pests. Include or identify plant material on which the insects were found -- this is useful and sometimes necessary for pest identification.
- For plant material, collect fresh samples, wrap in paper towels, and then in a plastic bag with a few holes. Place in a padded envelope/box. Send early in the week to avoid weekend delays.
- For small plants, you may want to ship the entire plant. Package it so the soil doesn't spill out -- wrap pot with soil in a plastic bag tied about the base of the stem.
- Dead, hard-bodied insects such as beetles, wasps, flies, moths, and butterflies should be placed in layers of tissue paper and packaged in a sturdy container for shipping.

- Soft-bodied insects (aphids, spiders, mites, grubs, and caterpillars) will break down quickly, so should be prepared and mailed as quickly as possible. It would be best to choose next day delivery if shipping these insects. To kill the insects, small insects such as aphids can be placed directly in a freezer in a bag with a bit of tissue paper to absorb moisture when they defrost. Larger ones such as grubs or caterpillars require preparation to prevent discoloration. They should be dropped into gently boiling water for about 30 seconds; then they may be wrapped in tissue paper and sent. Please indicate original color of specimen.
- Securely wrap the sample and package in a container acceptable to the post office.
- Provide complete collection data: When collected, where collected (town or city or nearest post office), and by whom. Send sample early in the week to avoid weekend delays. Insect Diagnostic Laboratory, 2144 Comstock Hall, Cornell University, Ithaca, NY 14853-2601. idlDiagnosticLab@Cornell.edu.

To have the laboratory identify a pest, download, print, and fill out a Diagnostic Lab Information Sheet available in Adobe Acrobat PDF format. http://idl.entomology.cornell.edu/sample-directions/. Collect and package a few of the insects following the guidelines listed below. Insects are identified as quickly as possible. You should have a response within one to three days by e-mail or fax, or one to two weeks by regular mail. For any questions about sample submission or sample results, contact: IDLDiagnosticLab@cornell.edu.

Collection and submission of plant disease samples
The Plant Disease Diagnostic Clinic at Cornell University provides diagnostic services: http://plantclinic.cornell.edu/. For factsheets: http://plantclinic.cornell.edu/factsheets.html.

How to submit a field crop sample:	
Most samples	Nematode samples
• The sample to be submitted should contain all parts of the plant when possible. • Wrap the sample in a paper bag and package it in a sturdy box. • Try to mail the sample as quickly as possible. • If the sample can not be mailed immediately, keep it refrigerated or out of direct sunlight. • It is important that you try to collect the sample prior to any pesticide applications. Once pesticides have been applied it may be difficult to obtain an accurate diagnosis. • It is helpful if the sample is taken from an area that has early symptoms of the problem. Areas that are completely dead often contain a number of secondary organisms that may hinder the detection of the primary pathogen.	• The best time of year for nematode analyses is during the active growing season. • A minimum of 6 soil subsamples, approximately 1" in diameter and 4" in depth, should be collected from an area that is approximately one acre in size. • The sub-samples should be collected randomly throughout the area. • The subsamples should be mixed together thoroughly and about a pint of soil transferred to a plastic bag. • Samples should be shipped as soon as possible. If the sample cannot be mailed immediately, keep it refrigerated or out of direct sunlight.

10. List types of pest monitoring methods and the advantages and disadvantages of each.

Monitoring techniques fall into 3 types: absolute methods, relative methods, population indices.

- Absolute methods: estimates of pest population density are expressed as a level per unit of crop area or as a percentage of the sampling units affected. Examples are direct visual counts per plant or per foot of row or per unit of area.
    - Advantages: broad range of applicability, less influenced by spatial patterns and changes in pest behavior. Efficient sampling. Easier to predict potential crop damage.
    - Disadvantages: more time-consuming.
- Relative methods: Estimates of pest population activity per unit of effort or time but not expressed with units of the crop area. Examples include visual searches, sweep net sampling, beating or shake cloth estimates, blacklight traps, pheromone traps, visual sticky traps, and bait traps.
    - Advantages: yield more data given the same effort, less time consuming, easier to implement.
    - Disadvantages: efficiency is affected by pest behavior, diurnal activity, weather conditions, crop habitat being sampled, and variations in methods; requires more information to relate relative estimates to potential crop damage.
- Population indices: estimates of crop damage or the frequency of pest infestations which indirectly reflect the size of the pest population. Examples are percentage of plants infested or diseased, percentage of defoliation, percentage of damaged fruits, visual ratings of root or foliage injury, etc.
    - Advantages: less time-consuming, easy to implement, more directly related to crop yield losses.
    - Disadvantages: can not be used alone to make control decisions, may not allow enough time to take management actions.

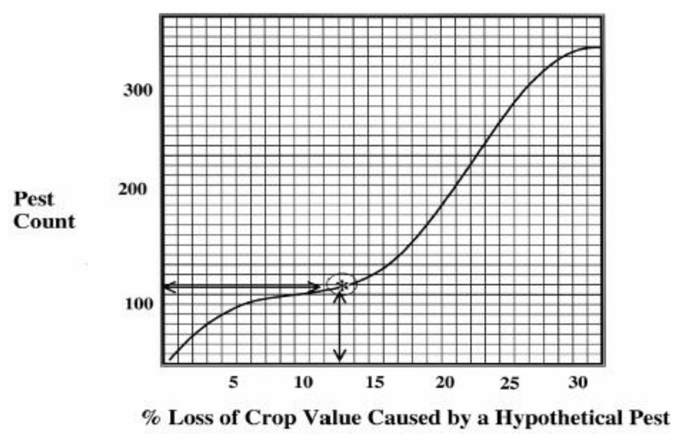
11. Define and distinguish between the following classes of plant response to injury: resistance, tolerance, and susceptibility.

- Resistance: ability of an organism to overcome, completely or in some degree, the effect of a pathogen or other damaging factors.
- Tolerance: ability of a plant to sustain the effects of a disease without dying or suffering serious injury or crop loss. Also, the amount of toxic residue allowable in or on edible plant parts under the law.
- Susceptibility: inability of a plant to resist the effect of a pathogen or other damaging factor.

12. Recognize how variables including the following are used to calculate the economic injury level (EIL), and how the EIL changes with a change in any of the variables:

a. **Pest density/crop damage relationship**
b. **Market value**
c. **Cost of Control**
d. **Effectiveness of management action**

a. Pest density/crop damage relationship.



b. Crop value

Information needed:

Value ($) per bushel, ton, salable unit, etc. = $ _____

Expected yield (bu., ton, salable unit, etc.) per acre = _____

Calculation:

Value ($) per salable unit X expected yield / acre = crop value ($) / acre

c. Cost of control

Estimate control cost (primary + secondary costs)

Primary cost (pesticide cost)

Information needed:

Pesticide use rate (lb., oz, etc.) / acre, i.e. ____(lb., oz, etc.)

Pesticide price / (lb., oz, etc.) $ _____

Calculation:

Pesticide use rate (lb., oz, etc.) / acre, i.e. ____(lb., oz, etc.)

Pesticide price / (lb., oz, etc.) $ _____ =

Pesticide cost / acre, i.e. $_____ / acre

Secondary cost

Information needed:

Pesticide application cost $_____ / acre

Primary pesticide cost + secondary cost = Total pesticide application costs / acre

i.e. Total control cost $ _____ / acre

Calculate maximum allowable crop Loss (%)

Total control cost $ ____ / acre divided by crop value $____ / acre =

Maximum allowable crop loss ____%

d. Effectiveness of management action

See PO#2.

13. Understand how weather-based computer models can be utilized to predict pest arrivals and outbreaks, and how they can be useful in management decisions. Also understand the limitations of computer-based pest models.

Computer models are built from biological features of the pest and weather parameters. They aim to predict when a pest will be active and close to the economic thresh hold so that growers can be better prepared to take management practices. Limitations include: (1) we do not know all of the parameters so there is a margin of error; and (2) models typically give a short window (2 weeks) of forecasting.

CA2: Weed Management

Weed Biology

14. Demonstrate familiarity with life cycles (annual, biennial, perennial) and growth habits (dicotyledons and monocotyledons) of weeds and how these characteristics affect weed management.

Annuals: Complete life cycle in one year:

- Summer annuals: Germinate from seed in spring or early summer then flower and set seed before the end of the growing season, i.e. common ragweed and large crabgrass.
- Winter annuals: Germinate from seed in late summer or fall, then flower and set seed the following spring or early summer, i.e. corn chamomile, shepherd's-purse and purple deadnettle.

Biennials - Take two years to complete life cycle:

- They make vegetative growth in the first year. Then after additional vegetative growth in the second year, they flower and set seed, i.e. common burdock and bull thistle.

Perennials: Live for more than two years

- Perennials reproduce from seed only or from seed and vegetative organs.
- Perennial plant forms include:
  - Simple - from seed only, i.e. dandelion and curly dock.
  - Bulbous - from seed, aerial and underground bulblets, i.e. wild garlic.
  - Tuberous - from seed and tubers at tips of rhizomes, i.e. yellow nutsedge.
  - Creeping - from seed and either stolon's (prostrate stems or runners that root at the nodes) or rhizomes (underground creeping stems). Rhizomes may be either shallow "rooted" (quackgrass and wirestem) or deep "rooted" (common milkweed, horsenettle).

Growth habits are important because of herbicide selectivity and type/location of growing points (meristems).

- Dicotyledons or broadleaf weeds have two seed leaves and apical/axial meristems, so stem elongation is from tip(s).
- Monocotyledons have one seed leaf and basal or intercalary meristems, so stem elongation is from the lower portion of internodes.
- Grass have hollow round or flattened stems. The parts of grass leaves are:
- Blade - part of a leaf above the sheath
- Sheath - lower part of grass leaf that encloses the stem/younger leaves
- Collar - outer side of a grass leaf at the junction of the blade and sheath

- Ligule - thin membranous appendage or ring of hairs on the inside of a leaf at the junction of the blade and sheath
- Auricle - a small projecting lobe or appendage found where the blade meets the sheath
  - Rushes have solid, round stems
  - Sedges have solid, triangular stems

15. Understand the survival mechanisms of weeds, i.e., how they reproduce, spread, and the role seed dormancy plays in survival.

a. Reproductive capacity:
   - Sexual: Weeds are prolific seed producers and average about 20,000 seeds/plant (250 from wild oat and 6 million from tumble pigweed).
   - Asexual: Vegetative means of reproduction, i.e. bulbs, tubers, stolon's, rhizomes, rootstocks.

b. Dissemination of propagules is by wind, water, and animal, especially humans

c. Dormancy or extended viability is the inability of propagules (seeds or vegetative reproductive structures) to germinate when provided with proper conditions:
   - Innate - inherent in mature seed, i.e. mechanically restricted seed coats, impermeable seed coats, germination inhibitors, immature embryos, etc.
   - Induced - become dormant after exposure to environment
   - Enforced - limitations of environment prevent germination

16. Demonstrate the ability to classify each of the following weeds by life cycle and growth habit, i.e., recognize whether they are broadleaf weeds, grasses, or sedges.

Summer Annuals	*Summer/Winter Annual*	*Perennials*
Velvetleaf	Horseweed*	Common Milkweed
Redroot/smooth pigweed*	Chickweed	Hedge bindweed
Common ragweed	Shepherd's purse	Canada thistle
Common lambsquarters*	Italian ryegrass*	Field bindweed
Hairy galinsoga	*Biennials*	Smooth bedstraw
Wild mustard	Common burdock	Horsenettle
Eastern black nightshade	Bull thistle	Dandelion
Large crabgrass	Cow parsnip/wild parsnip	Quackgrass
Barnyardgrass	Spotted Knapweed	Wirestem muhly
Fall panicum		Johnsongrass
Giant foxtail		Yellow nutsedge
Yellow foxtail		Poison Ivy/poison oak
Green foxtail		
Palmer amaranth*		
Water hemp*		
Powell Amaranth*		
Sowthistle		
Prickly lettuce	*Some of the species exhibit herbicide resistance	

17. Recognize how weed life cycle and growth habit impact choice and timing of control measures.

Weed control measures (methods) limit weed infestations so that crops can grow profitably and operations can be conducted efficiently. Control efforts exploit biological differences between crops and weeds and should increase competitiveness of crops in comparison with weeds. A successful control program should involve two or more methods of control.

18. Mechanical – Understand the advantages and limitations of mechanical control measures, especially those associated with tillage, cultivation, mowing, and the impacts on soil health and pest populations.

Mechanical control forms include mowing, burning, smothering, and tillage.

a. Advantages
- Reduce or eliminate herbicides
- Control weeds that escape herbicide applications, i.e. delay or prevent development of herbicide-resistant weed populations.
- Sometimes there is a "cultivation effect" that is not related to weed control, i.e. cultivation may improve soil aeration, water infiltration, etc.

b. Limitations
- Timeliness is critical. Weather/soil moisture conditions may prevent timely cultivation.
- In-row weed control is difficult with many cultivators.
- Increased labor costs.

19. Cultural – Understand the advantages and limitations of cultural practices that influence the competitive relationship between crops and weeds including the role of the following in weed management:

  a. Choice of crop and variety/hybrid selection including the advantages and disadvantages of herbicide-resistant crops.
  b. Crop rotation
  c. Soil management – pH, fertility, soil water
  d. Planting date
  e. Seeding rate/plant populations/row spacing
  f. Nurse crops/cover crops
  g. Minimize introduction of weed seeds via use or incorporation of feed, bedding, cover crop mixes, or buying equipment from other regions
  h. Sanitation

Cultural or managerial practices favor the crop over the weeds.

a. Choice of crop and variety or hybrid, including herbicide-resistant crops (HRCs)

Advantages or potential benefits of HRCs
- New control options for hard-to-control weeds (i.e. perennials)
- Increase success and adoption of conservation tillage
- Encourage use of thresholds for weed management decisions
- Aid resistance management

- Use of environmentally and toxicologically friendly herbicides
- Minimize herbicide carryover problems
- Options for limited acreage crops

Disadvantages or potential risks of HRCs

- Unintentional application to, and/or spray drift on susceptible crops
- HRCs could become weeds in rotational crops
- Increase selection pressure for herbicide-resistant weeds
- HRC pollen movement to organically grown crops
- Invasive potential of HRCs into natural ecosystems
- HRCs could outcross with closely related weedy relatives

b. Crop rotation

Advantages

- Management of tough to control weeds
- Breaking Life cycle of weeds, insects and disease
- Helps to diversify pesticide mode of action
- Effective herbicide resistance management strategy

Disadvantages

- Cary over effects of chemicals/pesticide
- Crop volunteers especially with herbicide resistant crops

c. Soil management

Advantages

- Better soil water management improves herbicide efficiency
- Soil organic matter can determine the use rate of soil applied herbicides
- Propper soil pH increases herbicide performance

Disadvantages

- Poor drainage or excess moisture reduces herbicide activity
- High organic matter may require higher herbicide rates
- Unfavorable pH lowers herbicide effectiveness

d. Planting date

Advantages

- Optimum crop planting dates can help proper application timing of soil and foliar applied herbicides
- It can benefit crop establishment and growth better than weeds (Crop weed competition)

Disadvantages

- Lack of optimum weather conditions can limit proper planting dates

e. Seeding rate/plant populations

Advantages

- Increasing seeding rate provides a competitive advantage to crops than weeds
- Can benefit preventing late weed seedling emergence
- Can increase crop yield

Disadvantages

- Resource (Nutrient, moisture, space) competition

- Increasing cost of crop seed and other inputs

f. Row spacing

Advantages

- Narrow row spacing can benefit crops competition over weeds
- Early crop canopy development can prevent late season weed emergence
- Suppress overall weed growth by crop shading

Disadvantages

- Lack of proper equipment for crop planting
- Narrow row spacing can result in resource competition

g. Minimize introduction of weed seeds via use or incorporation of feed, bedding, cover crop mixes, or buying equipment from other regions

h. Sanitation: proper cleaning of farm equipment (tillage, planter, combine. Etc.) after use in a contaminated field

20. Biological – Understand how biological control measures can play a role with intensively or extensively managed production systems.

Biological control involves use of natural enemies (insects, diseases, animals, other plants). Understand that biological control measures do not work as well with intensively managed crops or natural areas where you are targeting one weed.

21. Chemical – Be familiar with EPA's certified conservation practices menu to protect endangered and threatened species while using certain types of herbicides.

Chemical control had its' start in the 1940s with development of 2,4-D. The rapid development of herbicides since then has led producers to think of herbicides as a panacea for their weed problems. They are not a panacea; they should be used as part of an integrated weed management program. They can be selective or nonselective.

Foliar applied herbicides

- Contact - act mainly by touching weeds rather than by being absorbed and moved to the site of action.
- Trans-located - moved from point of entry to site of action within the plant.

Soil applied herbicides

- Works through application on soil surface and incorporation through soil moisture or precipitation preventing weed seeds to germinate and emerge.

Site of action classification.

Mode of action refers to the sequence of events from herbicide absorption into a plant to its' final effect at the site of action. Herbicides with similar chemical structures and herbicidal activity are grouped into families. Two or more herbicide families may have the same site of action within plants and express similar herbicidal activity and injury symptoms. The Weed Science Society of America (WSSA) has approved a numbering system to classify herbicides by their site of action. A Group Number is given to all herbicides with the same site of action.

22. Chemical – Know time(s) of application (pre-plant incorporated, pre-emergence, or post emergence) for different types of herbicides, crops and how soil (texture, organic matter, pH) and weather (rainfall/soil moisture, temperature, etc.) affect herbicide performance.

a. Preplant - applied before crops are planted
  - Early preplant - surface applied before crop is planted
  - Preplant incorporated
    - Some herbicides require mechanical mixing with soil because they are volatile or subject to photodecomposition.
    - Used to place herbicide near germinating propagules
    - Improve dependability of control

b. Pre-emergence applied to soil surface prior to emergence of crop and weeds; depend on rainfall or irrigation for incorporation and activation.
  - Factors affecting performance:
    - Amount of rainfall or irrigation
    - Herbicide solubility
    - Amount of herbicide adsorbed on soil affects application rates
    - Herbicide chemistry
    - Soil texture
    - Organic matter
    - Soil pH

c. Post-emergence - applied after emergence of crop and weeds.
  - Factors affecting performance:
    - Time of application - should be applied when weeds are young and/or actively growing
    - Summer annuals - young plants in spring or early summer
    - Winter annuals - rosettes in fall or early spring
    - Biennials - fall growth or rosettes in fall or spring
    - Perennials - bud stage in spring or summer or vigorous fall growth
  - Application factors
    - Spray volume
    - Pressure
    - Spray adjuvants - additives that aid or modify the action of the active ingredient(s)
  - Environmental factors
    - Light
    - Temperature
    - Relative humidity
    - Wind
    - Rain

23. Chemical – Be familiar with problems associated with herbicide use.

   a. Herbicide resistant weeds – Know weeds that have developed herbicide resistant populations in the northeast and the practices involved in herbicide resistance management.

b. Problems of off-site movement of herbicides and being able to recognize symptoms of common types of off target herbicide injury.
c. Causes of crop injury by herbicides.
d. Advantages and disadvantages of herbicide persistence as it relates to weed control, crop rotation, and water quality.
e. Herbicides as potential sources of non-point pollution of surface- and groundwater.

a. Herbicide resistance: Defined by WSSA as "the inherited ability of a species to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. In a plant, resistance may be naturally occurring or induced by such techniques as genetic engineering or selection of variants produced by tissue culture or mutagenesis. http://weedscience.org/Summary/SOASummary.aspx.

Related definitions include:
- Cross resistance is resistance to other herbicides within a similar chemical group such as to atrazine and to other triazines.
- Multiple resistance is the evolution of populations resistant to herbicides not chemically related and having different sites of action.

Factors that increase the potential for herbicide resistant weed populations include:

Weed characteristics that favor resistance
- Annual weeds
- High germination rates
- Produce large numbers of seed
- Germinate over a long period of time
- Very susceptible to a herbicide

Herbicide characteristics that favor resistance
- Single site of action in weeds
- Highly effective on a species
- High frequency of use
- High use rate compared to amount needed
- Long residual activity in soil with noted exceptions

Cultural practices that favor resistance
- Continuous cropping with one crop or type of crop, i.e. RR crops
- Using a single herbicide to control specific weeds
- No cultivation or tillage for weed control
- Continuous/repeated use of a herbicide or herbicide group with the same site of action

Triazine-resistant weeds in New York State
- Common lambsquarters (*Chenopodium album*) – 1977
- Smooth pigweed (*Amaranthus hybridus*) – 1980
- Common groundsel (*Senecio vulgaris*) – 1989
- Common ragweed (*Ambrosia artemisiifolia*) – 1993

Herbicide resistance management

- Rotate crops or type of crop, i.e. RR or LL crops
- Cultivate to control weeds that escape other measures
- Use herbicides with little soil activity and/or short residual
- Rotate herbicide sites-of-action, especially in continuous cropping rotations
- Use tank mixtures or sequential application with different sites-of-action

b. Problems of off-site movement of herbicides**.**

- Spray drift - physical movement of spray particles to non-target areas.
- Vapor drift - volatilization of herbicides from plant and soil surfaces with subsequent vapor movement and injury of non-target species.

c. Causes of herbicide crop injury

- Excessive application rates
- Improper application methods
- Synergistic mixtures/sequential applications
- Susceptible hybrids/varieties
- Abnormal soil/climatic conditions

d. Advantages and disadvantages of herbicide persistence as it relates to weed control, crop rotation, and water quality.

Carryover affecting rotational crops depends on:

Herbicide decomposition

- Microbial
- Chemical
- Photodecomposition
- Plant metabolism

Availability for breakdown altered by

- Volatilization
- Plant uptake
- Adsorption on soil colloids
- Leaching or movement of water through a soil profile may move herbicides

Avoid herbicide carryover

- Read and follow label
- Use minimum dose
- Calibration and application
- Rotate herbicides
- Use short residual herbicides
- Integrate with other control measures

e. Pesticides are potential sources of non-point pollution of surface and groundwater.

Pesticide database - provides pesticide surface runoff and leaching potential based on:

- Half-life - days for concentration to decrease by one-half.
- Soil sorption index – Koc is measure of tendency to be attached to soil particles.
    - Pesticide chemistry
    - Organic matter content of soil
    - Clay content of soil
- Water solubility – ppm that will dissolve in water at room temperature

- Soils database - soils are ranked according to their potential for pesticide loss through leaching or surface runoff: Potential 1 - has a high probability of being lost to leaching or runoff; and Potential 2 - has the possibility of being lost to leaching or runoff.

CA3: Management of Infectious Plant Diseases

Biology of Infectious Plant Diseases

24. For each of the following crop diseases, classify by type of pathogen:

a. **Know the type of symptoms produced and plant parts affected**
b. **Know what conditions favor disease development**
c. **Know how the pathogen survives between crop seasons**
d. **Know other crop/weed species attacked by the pathogen**
e. **Know how the pathogen is spread**

Alfalfa	Corn
Anthracnose -F	Anthracnose leaf blight and stalk rot-F
Brown root rot - F	Common rust-F
Common leaf spot -F	Common smut-**F**
Fusarium crown and root rot- **F**	Carbonum leaf spot **-F**
Leptosphaerulina (halo) leaf spot **- F**	Eyespot-**F**
Phytophthora root rot **- O**	Gibberella stalk and (red) ear rot**-F**
Pythium damping-off**- O**	Goss's wilt**- B**
Sclerotinia stem rot **-F**	Gray leaf spot**-F**
Spring black stem and leaf spot **-F**	Northern leaf blight**-F**
Verticillium wilt **- F**	Seed decay/seedling blights **- B, F, O**
	Stewart's bacterial leaf blight and wilt**- B**
	Southern rust **-F**
	Tar spot **-F**
Wheat	**Soybean**
Barley yellow dwarf- V	Anthracnose -F
Fusarium head blight (scab) **- F**	Bacterial blight**- B**
Leaf rust**- F**	Bacterial pustule**- B**
Loose smut**- F**	Brown stem rot**- F**
Powdery mildew**- F**	Downy mildew **- F**
Septoria tritici blotch **- F**	Frogeye leaf spot **-F**
Soil-borne wheat mosaic- V	Pod and stem blight**- F**
Stagonospora nodorum blotch**- F**	Sclerotinia stem rot (white mold) **- F**
Stripe rust**- F**	Septoria brown spot**- F**
Wheat spindle streak mosaic- V	Soybean cyst nematode- N
	Soybean mosaic- V
	Stem canker
	Sudden death syndrome**- F**

Pathogen type: **B = bacterium**; **F = fungus**; **N = nematode**; **O = oomycete**; **V = virus**

Diseases of Alfalfa

Pathogen type: B = bacterium; F = fungus; N = nematode; O = oomycete; V = virus

Disease, type Symptoms; Host plants	Survival & Spread	Favored by	Control measures and effectiveness (1=high to 3=slight)
Anthracnose - F Stem lesions, wilt; Alflalfa, clover	Rain-splashed spores (from debris/plants)	Warm, moist weather	Resistant varieties (1) Remove debris from equipment (2)
Brown root rot - F Root/crown rot; Legumes, grasses	In soil	Stresses that weaken plants	Reduce plant injury/stress (3)
Leaf and stem blight complex - Fungi Leaf, stem lesions; Small-seeded legumes	Rain-splashed or airborne spores from infected debris or plants	Moist conditions	Harvest early to reduce leaf loss (3) Foliar fungicides (2)
Fusarium crown and root rot - F Root/crown rot; Many hosts	In soil	Stressed plants; clover root curculio; injured crowns	Reduce plant injury/stress (3)
Phytophthora root rot - O Root rot; Alfalfa	In soil	Wet soils	Resistant varieties (1) Anti-oomycete seed fungicides (2) Soil drainage (2)
Pythium damping-off - O Root/shoot rot Many hosts	In soil	Cool, moist soil	Anti-oomycete seed treatments (1) Good seedbed preparation (2) Soil drainage (2)
Verticillium wilt - F Systemic wilt; Many dicot plants	Soilborne, contaminated harvest equipment	Cool, wet weather	Resistant varieties (1) Rotation with cereals/grasses (3)

Diseases of Corn

Pathogen type: B = bacterium; F = fungus; N = nematode; O = oomycete; V = virus

Disease, type Symptoms; Host plants	Survival & Spread	Favored by	Control measures and effectiveness (1=high to 3=slight)
Anthracnose – F Leaf blight, stalk rot; Corn	Rain-splashed spores (local) from corn debris	Mild, wet; reduced-till, continuous corn; European corn borer injury to stems	Resistant hybrids (1-2) Crop rotation (2) Clean plowing (2) Corn borer-resistant (Bt) hybrids (1-2)

Common rust – F Leaf rust; Corn	Airborne spores (long distance)	Humid; thunderstorms	Resistant hybrids (1) Timely planting (2)
Common smut – F Galls on ears, tassel, leaves; Corn	Airborne and rain-splashed spores (in soil)	Injuries; dry conditions	Resistant hybrids (1) Fertilize based on soil test (2)
Eyespot – F Leaf lesions; Corn	Rain-splashed spores (local) from corn debris	Cool, wet; reduced-till, continuous corn	Resistant hybrids (1) Crop rotation (2) Clean plowing (2)
Gibberella (red) ear rot – F Ear rot, mycotoxins; Cereals, grasses	Airborne spores (regional) from corn debris	Moisture at silk emergence	Adapted, less susceptible hybrids (2) Timely planting + harvest (3) Fertilize based on soil test (3) Reduce stresses (3)
Gibberella stalk rot – F Stalk rot Cereals, grasses	Invasion through roots (soil) or wounds	Stressed plants	Adapted, tolerant hybrids (2) Timely planting and harvest (3) Fertilize based on soil test (3) Reduce stresses (3)
Goss's wilt – B Leaf blight, systemic Corn, grasses	Infected corn debris; seed; grass weeds	Rain; reduced tillage; continuous corn	Resistant hybrids (1) Crop rotation (2)
Gray leaf spot – F Leaf lesions; Corn	Airborne spores (regional) from corn debris	Persistent dew, fog; reduced-till, continuous corn	Resistant hybrids (1) Foliar fungicides (2) Crop rotation (2) Clean plowing (2)
Northern leaf blight – F Leaf lesions; Corn	Airborne spores (long distance) from corn debris	Humid, wet	Resistant hybrids (1) Foliar fungicides (2) Timely planting (2)
Northern leaf spot – F Leaf lesions; Corn	Airborne spores (long distance)	Humid, wet	Resistant hybrids (1) Foliar fungicides (2) Timely planting (2)
Seed decay/ seedling blight – F, O, B Seeds, seedlings; Many hosts	In soil; seed	Cool , moist soil; poor quality seed	Protectant seed fungicides (1) Good seedbed preparation (2) Timely planting (2)
Stewart's leaf blight – B Leaf blight, systemic; Corn	Corn flea beetle	Mild winter preceding crop	Resistant hybrids (1)

Diseases of Wheat

Pathogen type: B = bacterium; F = fungus; N = nematode; O = oomycete; V = virus

Disease, type Symptoms; Host plants	Survival & Spread	Favored by	Control measures and effectiveness (1=high; 3=slight)
Fusarium head blight (scab) – F Head, kernel blight, mycotoxin contamination; Cereals and grasses	Airborne spores (regional) and rain-splashed spores (local) from corn and cereal debris	Moisture at crop flowering through early grain filling	Follow a non-cereal crop (3) Plant less susceptible varieties (2) Stagger planting dates (3) Systemic foliar fungicides at flowering (2)
Leaf rust – F Leaf rust; Wheat only	Airborne spores (long distance)	Warm, humid; thunderstorms in June	Resistant varieties (1) Timely planting (2) Foliar fungicides (2)
Loose smut - F Kernel replacement by spores; Wheat only	In seed (embryo)	Bin-run seed	Certified seed (1) Systemic seed fungicides (1)
Powdery mildew – F Mildew on all plant surfaces; Wheat only	Airborne spores (regional)	Humid; moderate temperatures	Systemic seed fungicides (2) Systemic foliar fungicides (1) Resistant varieties (2)
Septoria tritici blotch – F Leaf blotch Wheat	Wheat debris; windborne	Splashing rain; extended leaf wetness	Foliar fungicides (1)
Stagonospora nodorum blotch – F Leaf/glume blotch; Wheat	In seed; wheat debris; windborne	Splashing rain; extended leaf wetness	Seed fungicides (3) Foliar fungicides (1)
Tan spot – F Leaf spot; Wheat	Wheat debris; in seed; windborne spores	Wheat after wheat; humid, moderate temp.; rainfall	Seed fungicides (2) Partially resistant varieties (2) Foliar fungicides (1)
Soilborne wheat mosaic – V Foliar mosaic, stunting; Wheat, triticale	Transmitted by protozoan; per-sists in soil for many years; limi-ted distribution	Soil moisture at seedling stages; cool spring temperatures	Resistant varieties (1)

Stripe rust – F Leaf rust; Wheat only	Airborne spores (long distance)	Warm/humid;June thunderstorms	Resistant varieties (1) Foliar fungicides (1) Timely planting (2)
Wheat spindle streak mosaic – V Spindle-shaped yellow streaks on leaves in spring; Wheat	Transmitted by protozoan; persists in soil for years; wide-spread	Soil moisture at seedling stages; extended cool spring temperatures	Resistant varieties (1)
Yellow dwarf - V Yellowing of leaves, stunting of plants; Many cereals and grasses	Transmitted by aphids (short + long distance)	Early planting; high aphid pop.; nearby infected grasses	Plant after Hessian fly free date (2) Systemic seed insecticides (2)

Pathogen type: B = bacterium; F = fungus; N = nematode; O = oomycete; V = virus

Disease, type **Symptoms; Host plants**	**Survival & Spread**	**Favored by**	Control measures and effectiveness (1=high; 3=slight)
Asian soybean rust – F Rust on leaves; Soybean, kudzu, perhaps other legumes	Windborne spores (long-distance)	Early arrival of windborne spores; moderate temps.; rain	Application of protectant fungicides prior to infection (1-2) Timely application of fungicides with systemic, curative activity (1)
Bacterial blight – B Lesions on leaves and pods; Soybean	Rain-splashed bacteria from soybean debris; cultivation in wet conditions	Cool, wet weather	High quality seeds (2) Crop rotation (2) Avoid highly susceptible varieties (2)
Bacterial pustule – B Lesions on leaves and pods Soybean	Rain-splashed bacteria from debris or soil; cultivation in wet conditions	Wet conditions	High quality seeds (2) Crop rotation (2) Avoid highly susceptible varieties (2)
Brown stem rot - F Stem rot; premature plant death Soybean	Infected soybean debris; in soil	Cool, moist at seedling stage; hot, dry during pod fill	Resistant varieties (1) Crop rotation (2)

Disease, type **Symptoms; Host plants**	**Survival & Spread**	**Favored by**	Control measures and effectiveness (1=high; 3=slight)
Downy mildew – O Mildew on leaves, pods, seeds; Soybean	Windborne sporangia; sys-temic infection from infected seeds	High humidity; moderate temperatures	Crop rotation (2) Anti-oomycete seed treatments (2)
Northern stem canker – F Stem cankers, stem rot; premature plant death Soybean	Infected soybean debris; in soil	Cool, moist at seedling stage; hot, dry during pod fill	Crop rotation (2)
Pod and stem blight – F Pods and stem lesions; Soybean	Rain-splashed spores from infected soybean debris	Prolonged moist periods during pod maturation	Crop rotation (2) Adapted varieties (2) Timely harvest (2) Late season foliar fungicide application if warranted by disease pressure (1)
Sclerotinia stem rot (white mold) - F Rot of stems; Many dicot plants	Windborne spores from sclerotia on soil surface; in soil	Dense canopy; moisture at flowering; disease in previous crop	Tolerant/resistant varieties (2) Crop rotation (2) Wide row spacing (2) Foliar fungicides (2)
Septoria brown spot - F	Infected soy-bean debris; seedborne	Splashing rain; moist conditions; soybean after soybean	Crop rotation (2) Foliar fungicides, if warranted by disease pressure (1)
Soybean cyst nematode – N Colonizes roots, stunts plants; Soybean only	In soil; movement on equipment, unclean seeds	Infested local soil from which nematode may be introduced into new fields	Avoid introduction (1) Resistant varieties (1) Crop rotation (2)
Soybean mosaic – V Mosaic on leaves, stunts plants; Soybean	Aphid-transmitted (non-persistent) from infected live hosts; seed-transmitted	High aphid populations when plants are young	Plant virus-free seed (1) Timely planting (2) Resistant varieties (strain specific) (2)

Disease, type **Symptoms; Host plants**	**Survival & Spread**	**Favored by**	Control measures and effectiveness (1=high; 3=slight)
Sudden death syndrome – F Root rot; foliar discoloration; premature plant death	Infected soybean debris; in soil	Cool, moist at seedling stage; hot, dry during pod fill	Seed fungicide (1) Crop rotation (2) Control of soybean cyst nematode (2)

Compiled by Gary C. Bergstrom, Cornell University.

Control of Infectious Plant Diseases

25. For the crop diseases listed under (21) above, know the availability and relative usefulness in disease management under Northeast conditions of:
   a. Seed-, foliar-, and soil-applied fungicides
   b. Resistant or tolerant crop varieties
   c. Use of certified seed
   d. Other cultural practices such as rotation, tillage, site selection, soil drainage, planting time, harvest time, fertility, weed and insect control

See tables in PO#4.

Biology, Detection, and Prevention of Mycotoxins

26. Define 'mycotoxin' and be acquainted with specific mycotoxins: aflatoxins, deoxynivalenol, zearalenone, fumonisins, and ochratoxin.

- Mycotoxin is a general term for a poison produced by a fungus that is harmful to humans and/or animals. Only certain strains of certain fungi produce mycotoxins, and only under certain environmental conditions. Corn and small grain cereals are especially prone to accumulate mycotoxins in their seed tissues, although the stem (stover) fraction of these crops may also be invaded by toxin-producing molds. Molds may continue to grow and produce toxins in stored commodities under aerobic, high moisture conditions. However, our most prevalent problems in the Northeast have been with mycotoxins produced in standing crops prior to harvest. Mycotoxins are only problematic when they occur in commodities and feeds above levels of concern established for individual animal species. Mycotoxin contamination is measured in parts per million (ppm) and parts per billion (ppb).
- Aflatoxins: Produced by the fungus Aspergillus flavus, a golden-colored mold; cause liver damage and cancer; tolerances set by U.S. Food and Drug Administration for levels of contamination allowed in milk and other food commodities. Not commonly found in commodities produced in the Northeast but are found in commodities produced in warmer growing regions and shipped to the Northeast.
- Deoxynivalenol (vomitoxin): Produced by certain species of the fungus Fusarium (Gibberella), a pink to red-colored mold; cause feed refusal, vomiting, and digestive disorders in swine, dogs, and other species with simple stomachs; chronic symptoms include loss of productivity and lowered immunity; poultry and ruminant animals are less sensitive. USDA recommends less than 1 ppm deoxynivalenol in finished food products and less than 2 ppm in unmilled

grain destined for human consumption. Occurs commonly in wheat, barley, and corn grain and silage produced in the Northeast.

- Zearalenone: Produced by certain species of the fungus Fusarium (Gibberella), a pink to red-colored mold; an estrogenic compound that causes reproductive disorders in swine and other species. Occurs commonly in corn grain and silage in the Northeast.
- Fumonisins: Produced by certain species of the fungus Fusarium, a whitish-colored mold, and differing from the species that produce deoxynivalenol and zearalenone; cause a fatal brain disease in horses, lung damage in swine, liver damage in several animals, and linked to human esophageal cancer. Occur commonly in corn grain in the Northeast but at fairly low levels. Occur at higher levels in corn produced in warmer regions.
- Ochratoxins: Produced mainly by the fungus Penicillium, a blue to green-colored mold, and produced mainly under poor storage conditions rather than in a standing crop; cause damage to the liver and kidneys. Found occasionally in stored commodities in the Northeast.

27. Know the mycotoxins found in Northeast grain and silage, the fungus genera they are produced by, why they are important, and how they are detected.

Main Mycotoxins occurring in corn grain and silage produced in the Northeastern United States.

Mycotoxin:	Predominant toxigenic mold:	Lowest level of concern:	Common effects on animals:
Deoxynivalenol (vomitoxin)	*Fusarium graminearum* (*Gibberella zeae*) Causal fungus of Gibberella ear rot and stalk rot of corn; and Fusarium head blight of wheat and barley	1-3 ppm <1 ppm	Feed refusal and gastrointestinal upset and vomiting in animals with simple stomachs; severity increases with level. Swine and dogs are most sensitive; adult cattle and poultry tolerate >10 ppm. USDA guideline for human food product
Zearalenone	*Fusarium graminearum* (*Gibberella zeae*) Causal fungus of Gibberella ear rot and stalk rot of corn; and Fusarium head blight of wheat and barley	1-5 ppm	Hyperestrogenism and infertility. Swine (gilts) are most sensitive; adult cattle tolerate 50 ppm.
Fumonisins	*Fusarium verticilloides; F. proliferatum.* Causal fungi of Fusarium ear rot and stalk rot of corn	5-10 ppm >100 ppm	Brain deterioration, death (horses); liver damage (horses, swine, cattle, poultry). Lung damage in swine

28. Know strategies for minimizing contamination of commodities by mycotoxins.

Field practices that reduce the risk of mycotoxin contamination in corn:

- Timely planting of locally adapted hybrids of appropriate maturity with partial resistance to Gibberella ear rot
- Avoiding continuous planting of corn under conservation tillage, especially where Gibberella/Fusarium stalk rot is prevalent
- Fertilizing based on soil test and avoiding excessive nitrogen
- Avoiding stress from insects, weeds, and excessively high plant populations
- Planning for harvest and subsequent grain handling:
- Clean grain bins before putting in the new crop
- Harvest fields with delayed maturity or high lodging potential as silage or grain for anaerobic storage; or be prepared to rapidly dry grain down to 13.5% moisture content
- Aerate grain bins to prevent moisture migration caused by colder temperatures
- Harvest silage at recommended plant maturity, and pack well to eliminate air pockets

On-site test kits are available through commercial firms. Most are antibody-based and indicate contamination by a color change; other tests utilize thin layer chromatography (TLC) or minicolumns. On-site tests are quick and relatively inexpensive. They generally give accurate and reproducible results when used on dry grain samples; they are not as reliable for high moisture grain or silage. Specific mycotoxins can be quantified relative to standards that are supplied with the kits. On-site tests are often used as diagnostic tests. Commercial and government/university labs offer mycotoxin testing. Laboratory tests are expensive, comprehensive, and quantitative for many toxins, and are useful for wet and dry samples. Methods include high-pressure liquid chromatography (HPLC) and gas chromatography-mass spectrometry (GC-MS).

Sample collection and handling.
Obtain many small samples at periodic intervals from a moving stream of grain or by probing all levels and areas of a stationary grain mass to make a composite 10 lb sample that should be further mixed and subsampled to produce a 2 lb sample for shipping to a lab. Ship dry samples in breathable cloth or stout paper bags. Wet samples should be in sealed containers and be frozen or refrigerated during transit. More information is available from:

- Cumberland Valley Analytical Services, Hagerstown, MD. (http://www.foragelab.com/).
- DairyOne Forage Lab, Ithaca, NY. (http://dairyone.com/analytical-services/feed-and-forage/services-and-pricing/).
- Neogen Corporation. (www.neogen.com).
- Romer Labs, Inc.(https://www.romerlabs.com/).
- Trilogy Analytical Laboratory. (www.trilogylab.com).

29. Know types of environmental conditions that are conducive to development of mycotoxins in the field and in stored grain.

Greatest mycotoxin risk factors in corn production:

- Moist weather at silk emergence (Gibberella ear rot; deoxynivalenol and zearalenone)

- Drought, high temperatures during grain maturation (Fusarium and Gibberella stalk rots; Fusarium ear rot; fumonisins)
- Insect or other mechanical damage to ears or stalks
- Delayed maturation/delayed harvest
- Contaminated storage structures
- Failure to adequately dry grain or poor ventilation of dried grain storage
- Failure to exclude air from high moisture, anaerobic storage

CA4: Management of Arthropods and Mollusks

Biology of Arthropods and Mollusks

30. For each of the following:

a. **Be able to sight identify the pest and the damage it causes.**
b. **Classify as an important economic pest or a sub-economic/occasional pest.**
c. **Classify by feeding habit, host range, injury mechanism, symptoms and damaging stage(s).**
d. **Understand how biology influences management.**
e. **Know how environmental conditions influence population dynamics.**
f. **Know how the environment influences potential for crop damage.**
g. **Know how these pests are typically scouted/monitored**

Corn	Soybeans
Western and Northern corn rootworms	Soybean aphid
European Corn Borer	Spider mites
True Armyworm	slugs/snails
Seedcorn maggot	
Fall armyworm	**Alfalfa**
Western Bean Cutworm	Alfalfa snout beetle
Black cutworm	Alfalfa weevil
White grub	Pea aphid
Wireworm	Potato leafhopper
	Fall armyworm
Slugs/Snails	
Perennial grasses and Clover	**Small Grains (wheat, barley, oats, rye)**
True and Fall Armyworm	Cereal leaf beetle
Slugs/snails	Wireworm
White grubs	Thrips
Perennial grasses and Clover	True Armyworm

Insects, mites and spiders are members of the phylum of organisms known as Arthropods (Jointed Legs). The other members of the phylum are listed in the table.

Class: Insecta is separated from the Arachnida (mites, spiders) by the number of body parts, number of legs and the presence/lack of antenna (see table below). Examples of the different orders of Arachnida are shown below. Agriculturally important groups of Arachnida are mites (plant feeding and beneficial), spiders (beneficial), and ticks (livestock parasites), though only mites and spiders are relevant to crops.

Class of Arthropods	Common Name	Distinguishing Characteristics
Insecta	Insects	Three body regions (head, thorax, and abdomen), 6 legs and usually 2 pair wings on thorax, 1 pair of antennae.
Crustacea	Crayfish, Sowbugs, Fairy Shrimp	Have 10 to 14 legs, 2 body regions (cephalothorax and abdomen) and 2 pair of antennae.
Arachnida	Spiders, Ticks, Mites, Scorpions	Have 8 legs, no antennae, 2 body regions (cephalothorax and abdomen)
Diplopoda	Millipedes	Have long bodies composed of about 50 segments, each of which has 2 pair of legs.
Chilopoda	Centipedes	Have long bodies composed of 14 to 20 segments, each of which has 1 pair of legs.

Scorpionida – scorpions

Pseudoscorpionida – false scorpions

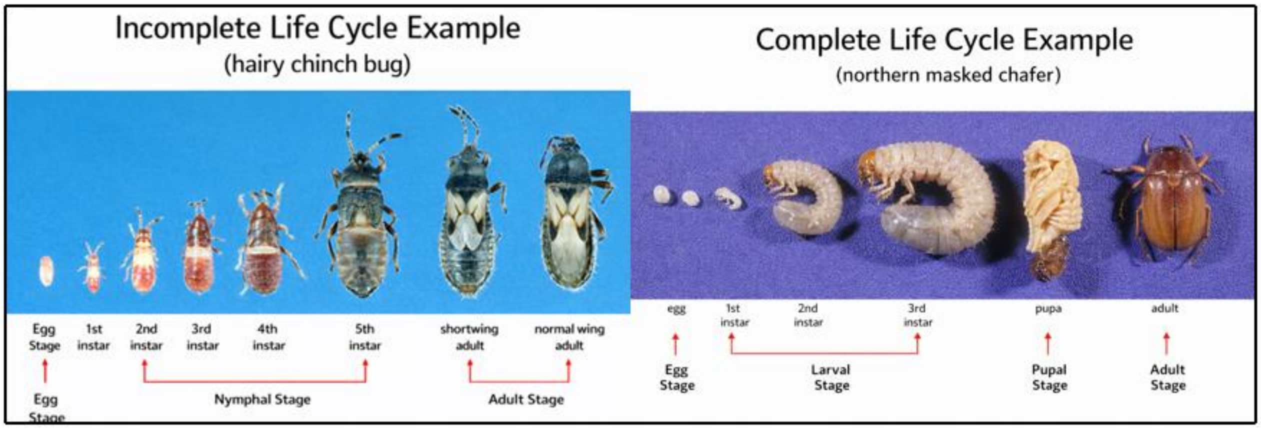
Opiliones - daddy-long-legs or harvestmen

Araneida – spiders

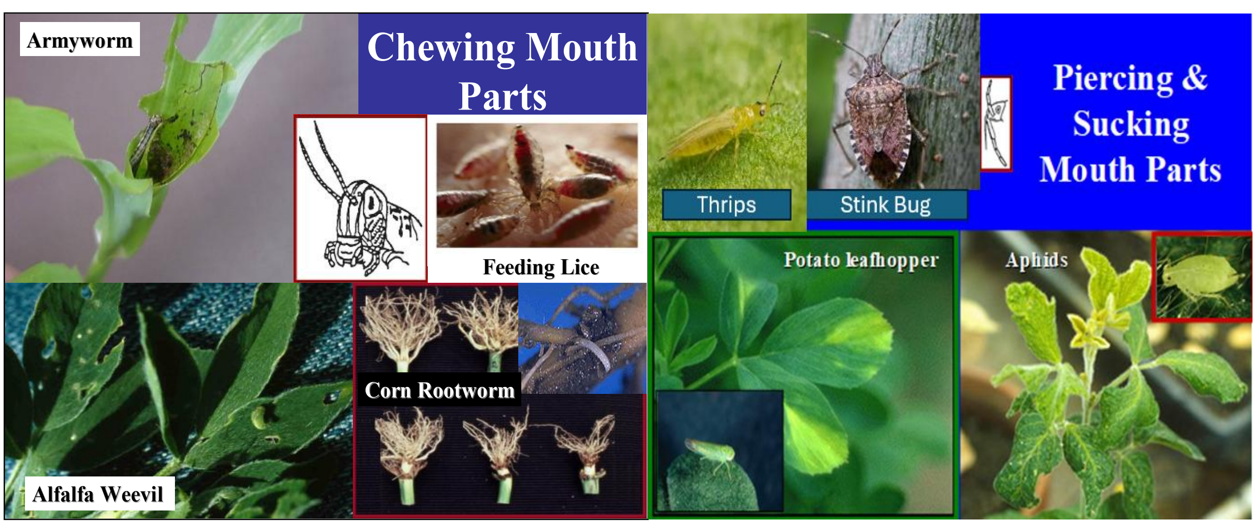
Acari - mites & ticks

Insects all have one pair of antennae, three body parts (head, thorax, abdomen), three pairs of legs, and adults usually have wings.

Insect development is divided into two life cycle groups. In the incomplete lifecycle group, the stages are egg, nymph, and adult. In this group, the nymph looks very similar to the adult but is smaller and without wings. In addition, the feeding methods are often identical to the adults. In the complete life cycle group, the stages are egg, larvae, pupa and adult. In this group, the larvae appear distinctly different than the adults.

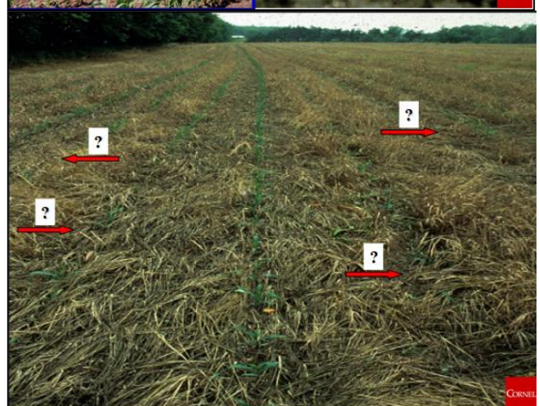


Insect feeding is divided into two distinct types and entire groups of related insects (Orders) have similar mouth parts. The two feeding types are (1) chewing mouth parts, and (2) piercing and sucking mouth parts. Chewing mouth parts remove solid tissue from the host and the tissue is ingested and utilized. A series of examples are shown below. Piercing and sucking mouth parts remove fluid from the host in modified mouth parts which operate like a hollow needle. Often saliva is injected prior to feeding to breakdown cell walls and to start the digestion process before the fluid is ingested by the insect. The saliva left behind is frequently the cause of the feeding symptoms from the insect.



Seedcorn Maggot: Secondary Pest

- Seedcorn maggot is an introduced pest of seedlings, attacking germinating seeds of corn, soybeans, and beans. Larvae feed on organic matter and germinating seeds, causing stand loss, skips, and damaged seedlings such as "snake-heads" in soybeans or holes in unrolled corn leaves. The larval stage is the damaging stage.



- Lifecycle: Adult flies emerge from overwintering puparia in late April through early June. After mating, females lay eggs in areas of decaying organic matter, dying plants, or bare soil. Larvae hatch and feed on organic matter and germinated seeds before pupating in the soil. Multiple generations occur per year, but only the early spring generation during the months of April and May causes economic damage.
- Impact of Environment on Population Dynamics: Spring temperatures directly influence larval development and crop emergence. Warm springs shorten the window of potential damage, while cool, wet springs prolong seedling emergence and increase the likelihood of infestation. Although adult populations may be high in fields with manure or recently plowed sod, research shows this does not necessarily increase crop damage.
- Impact of Environment on Crop Damage: Cool, wet soils delay emergence, increasing the exposure period during which larvae can attack seeds. Slow-emerging seedlings are more vulnerable, and missing plants caused by Seedcorn maggot can be visible even at highway speeds later in the season.
- Management: Seedcorn maggot damage is difficult to predict, so large-seeded crops are commonly protected with insecticide seed treatments. Most commercial corn and soybean seeds are treated to prevent early-season injury. However, insecticide failures can still occur in cold, wet soils, so planting into warm, favorable conditions is the most reliable cultural strategy.

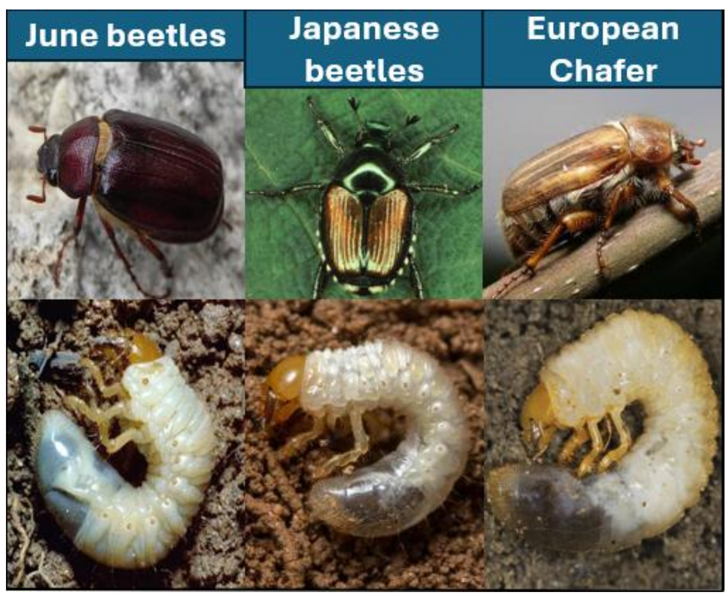
Wireworm: Secondary Pest

- Wireworms are soil-dwelling larvae that feed on plant roots, especially grasses and can damage corn following sod. They prune roots, reduce stands, and stunt plants. The larval stage is the damaging stage and persists for multiple years.

- Lifecycle: Wireworms have a multi-year lifecycle, with larvae living in the soil for 2–7 years depending on species. Adults (click beetles) emerge in early summer and lay eggs in grassy areas such as hay fields, lawns, and roadsides. Larvae feed on grass roots, move deep into the soil to overwinter, and return to the root zone in spring.
- Impact of Environment on Population Dynamics: Wireworms thrive in well-drained soils and are rarely a problem in poorly drained fields because larvae drown or suffocate when soils become waterlogged. Populations build in long-term sod or grassy rotations.

- Impact of Environment on Crop Damage: Root feeding reduces the plant's ability to take up water and nutrients, making damage more severe during drought or low soil moisture. Injury is most noticeable when corn follows sod.
- Management: Effective management requires anticipating risk before planting. Crop rotation away from sod, tillage, and the use of insecticide seed treatments reduce damage. Persistent entomopathogenic nematodes (EPNs) can suppress populations. Rescue treatments are rarely effective.

White Grub: Secondary Pest



- White grubs include many species such as June beetles, Japanese beetles, and European chafers. They feed on grass roots and can become pests of both corn and grass pastures. Larvae prune roots, reduce stands, and increase drought stress. The larval stage is the damaging stage, and injury is most common when corn follows long-term sod.
- Lifecycle: There are two major lifecycle patterns: annual and multi-year species. Annual white grubs (e.g., Japanese beetle, European chafer) have a synchronized one-year cycle. Adults emerge in June, mate, and lay eggs in July in grassy areas. Eggs hatch in late July, and small larvae begin feeding on grass roots. By fall, the larvae are 0.5–0.75 grown, at which point cooling soil temperatures trigger them to move deeper into the soil below the frost line to overwinter. In spring, these partially grown larvae return to the topsoil and resume feeding,

causing the most significant root injury. Larval development finishes in late May to early June, followed by pupation and adult emergence. Multi-year species follow the same pattern but over a longer, less synchronized period, resulting in mixed larval sizes in the soil.

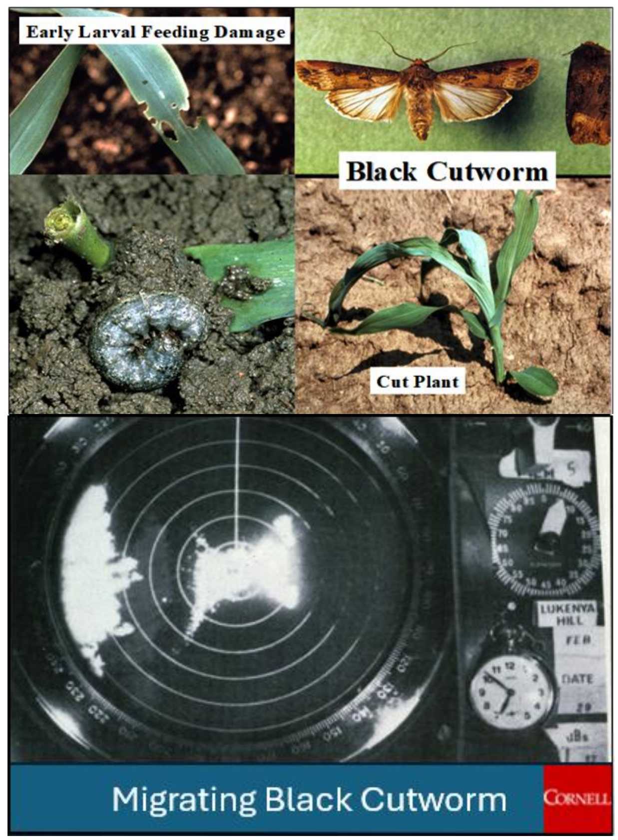
- Impact of Environment on Population Dynamics: White grubs spend most of their life in the soil, and severe problems occur in fields with good drainage. Poorly drained or down-slope fields rarely develop significant grub populations because larvae drown or suffocate when soils become waterlogged. Annual species tend to produce intense but short-lived outbreaks, while multi-year species persist at lower levels for several seasons.
- Impact of Environment on Crop Damage: Root feeding reduces the plant's ability to take up water and minerals, making damage more pronounced during drought or low soil moisture. Annual species cause severe early-season injury when all larvae are at the damaging stage simultaneously. Multi-year species cause less severe but longer-lasting injury because larvae of different ages are present over multiple seasons.
- Management: Effective management requires anticipating grub pressure before planting, especially when rotating corn after sod. Seed treatments provide reliable protection in most cases except under extremely high pressure. Rescue treatments are expensive and rarely effective because larvae are underground and difficult to reach with foliar insecticides.

Slugs: Secondary Pest

- Slugs and snails damage crops by rasping off leaf tissue with their mouthparts. Several species occur throughout the northern US, and they feed on a wide range of plants. They become economic pests in fields with enough plant residue on the soil surface to provide hiding places during daylight hours. In corn, problems are usually noted when plants are small and conditions are cool, wet, and cloudy. Injury appears as shredded or windowpane feeding on leaves. Stand loss can occur when feeding is severe. Both juvenile and adult slugs cause damage.
- Lifecycle: Slugs thrive in high-residue, moist environments where crop debris provides shelter and maintains humidity. They hide under residue during the day and feed at night or during extended cloudy periods. Their activity increases dramatically when soils remain wet and temperatures stay cool, allowing them to feed for longer periods without desiccation. Slug populations build in no-till or reduced-till systems where residue persists year-round.
- Impact of Environment on Population Dynamics: Populations increase during periods of high moisture and cloudy weather because these conditions prevent slugs from drying out. Cool springs with frequent rainfall and heavy residue create ideal conditions for population growth. Conversely, warm, dry weather sharply reduces activity and survival. Fields with chronic moisture retention or heavy surface residue are at the highest long-term risk.

- Impact of Environment on Crop Damage: Crop damage is most severe when corn is small and growing slowly due to cool, wet conditions. Slugs feed extensively during prolonged cloudy periods, and seedlings may be unable to outgrow injury. Once weather shifts to more typical warm, dry spring conditions, corn usually grows rapidly and escapes further damage. Injury is rarely significant later in the season because larger plants can tolerate feeding.
- Management: There is no economically effective rescue treatment once slug problems develop. In fields with chronic slug issues, long-term management focuses on soil and residue practices that reduce surface debris and limit daytime shelter. Improving drainage, reducing residue in problem zones, and avoiding planting into cold, saturated soils can help minimize risk. Most years, corn will grow out of slug injury once conditions turn warmer and drier.

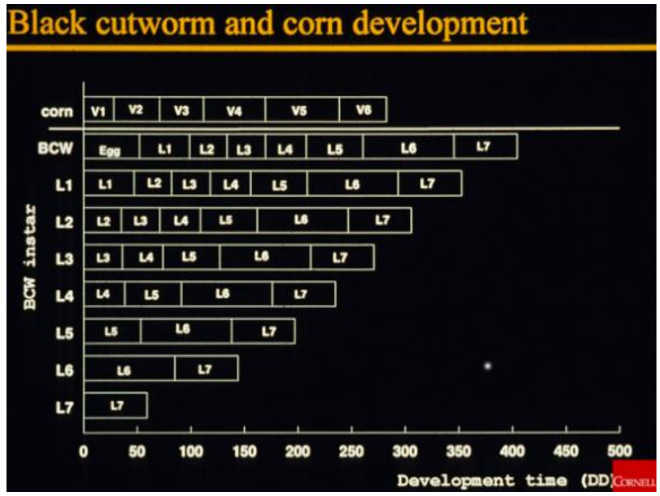
Black Cutworm: Secondary Pest



- Black cutworm is a long-range migrant that attacks young corn plants. Early larval stages feed on leaf margins, causing injury similar to armyworms (below) feeding, but once larvae reach the fourth instar, they begin cutting plants at or below the soil surface. An instar is the growth stage between molts in an insect larva; black cutworm larvae pass through seven instars, and cutting begins at instar 4. The damaging stages are the L4–L7 larvae, which can cause severe stand loss in V3–V4 corn.
- Lifecycle: Black cutworm overwinters in southern states and migrates north between mid-April and mid-May, often carried by storm fronts. Females lay eggs in grass hay fields, grassy waterways, or weedy patches in last year's corn fields. Eggs hatch in 7–10 days, and small larvae feed on dying grasses until corn emerges. During instars 1–3, larvae remain on the plant and feed on leaf margins. After molting into the fourth instar, larvae leave the plant during daylight hours and hide at the base of the plant, beginning the cutting phase. Cutting continues for about two weeks until larvae complete development and pupate in the soil.
- The chart shows the relationship between the development of black cutworm larvae and corn, both driven by temperature. It illustrates that if black cutworm eggs were laid directly on newly emerged corn, the corn would typically grow past V4 before larvae reached the cutting instars (L4–L7). This explains why cutting only occurs when larvae are already present as small instars, feeding on dying grassy weeds before corn emergence.
- Impact of Environment on Population Dynamics: Temperature strongly influences development. Warm springs accelerate both larval growth and corn development, shortening

the window of potential cutting. Cool springs slow corn growth, increasing the likelihood that larvae reach cutting stages while corn is still small and vulnerable.

- Impact of Environment on Crop Damage: Damage severity depends on the timing between larval development and corn growth stage. If larvae reach cutting size while corn is at V1–V3, stand loss can be severe. Cutting is most damaging when plants are small and growing slowly due to cool, wet conditions.



- Management: Effective management requires early detection of small larvae before cutting begins. Once cutting starts, economic losses accumulate quickly. Bt hybrids with cutworm-active traits are available. Corn can compensate for occasional missing plants, but patches of missing plants reduce yield because adjacent plants cannot fully compensate.

Cereal Leaf Beetle: Primary Pest of Small Grains

- Cereal leaf beetle is a pest of small grains such as wheat, oats, and barley. Adults overwinter in field edges and move into fields in spring. Eggs are laid on the leaves, and the larvae feed by stripping leaf tissue, causing defoliation that reduces photosynthetic area and grain yield. The larval stage is responsible for economic damage.
- Lifecycle: Adults overwinter in field edges and enter small grain fields in early spring. Females lay eggs on the leaves of small grain plants, and larvae hatch and begin feeding immediately. Larval feeding continues through spring until pupation. The lifecycle is synchronized with early growth stages of small grains, making spring the primary risk period.
- Impact of Environment on Population Dynamics: In most years, established parasitoid wasps suppress cereal leaf beetle populations and prevent outbreaks. However, localized populations can exceed biological control capacity when environmental conditions favor beetle survival or when parasitoid activity is reduced.
- Impact of Environment on Crop Damage: Damage is most severe when larval feeding coincides with early grain development. Heavy defoliation reduces photosynthesis and can significantly reduce yield, especially if feeding occurs before or during heading.
- Management: Biocontrol by parasitoid wasps is usually sufficient to keep populations below economic thresholds. Insecticide applications may be justified when localized populations exceed threshold levels, but caution is needed because insecticides effective on cereal leaf beetle also harm beneficial parasitoids.

True Armyworm: Secondary Pest

- True armyworm is a long-range migrant that feeds primarily on grasses, including pasture species and corn. Larvae remove leaf tissue, often leaving only the midrib on larger corn leaves. The larval stage causes all economic damage, with 80% of feeding occurring in the final instars.
- Lifecycle: Armyworm moths overwinter in southern states and migrate north in spring, arriving between mid-April and mid-May. Females lay eggs in grass hay fields, grassy waterways, or weedy patches. Eggs hatch in 7–10 days, and larvae feed on grasses, passing through 6–7 molts. When populations are high, larvae consume entire grass fields and then migrate in masses ("armyworms") into adjacent corn or hay fields. Larvae complete development in 7–10 days once large, then pupate in the soil. Although 3–4 generations occur in northern regions, only the first generation causes economic damage because later generations disperse widely.

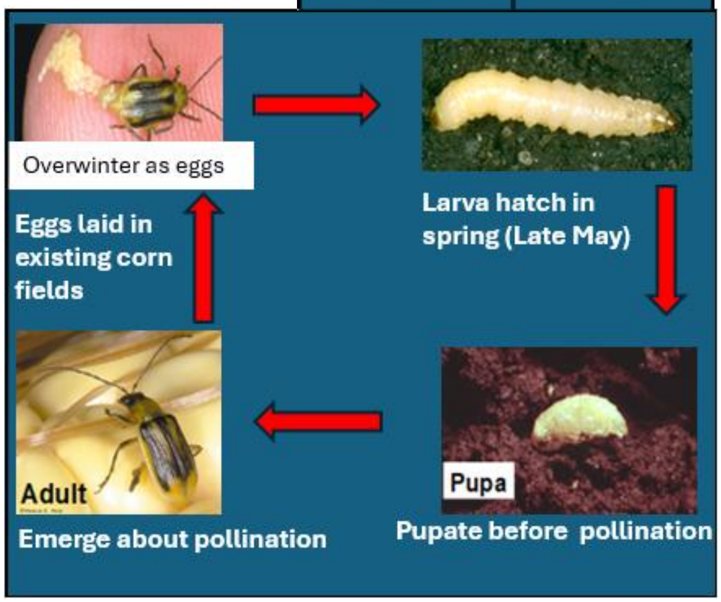
- Impact of Environment on Population Dynamics: Armyworm outbreaks depend on the size of southern source populations and the direction of storm-driven winds that carry moths north. Localized heavy egg-laying occurs when moths are deposited in concentrated areas during spring thunderstorms.
- Impact of Environment on Crop Damage: Damage is most severe when large larvae migrate into corn or hay fields after defoliating grasses. Because most feeding occurs in the final instars, infestations often go unnoticed until significant defoliation has already occurred.
- Management: Early detection is essential. Once large larvae are present and marching, feeding will continue for only about a week, and insecticide applications have limited economic benefit. Losses often include both crop damage and the cost of ineffective late-timing insecticide applications.

Fall Armyworm: Secondary Pest

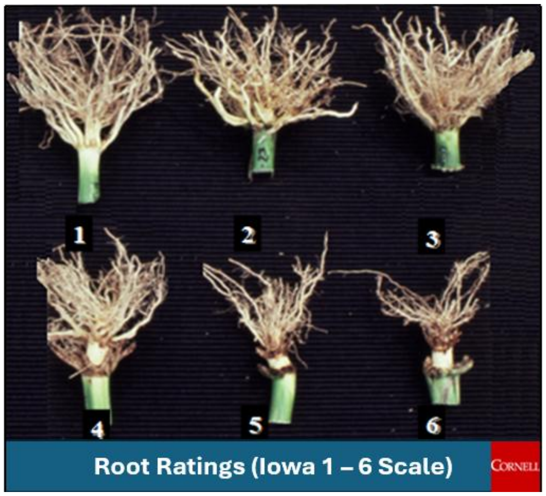
- Fall armyworms are generally not a problem in Northeast field crop production. It can be present and invade late season sweet corn, hay crops, and alfalfa. It is a long-range migrant similar to true armyworm except the moths tend to migrate northward mid-summer. It is important to know the distinction between Fall Armyworm and True Armyworm, and which is the more important economic pest.

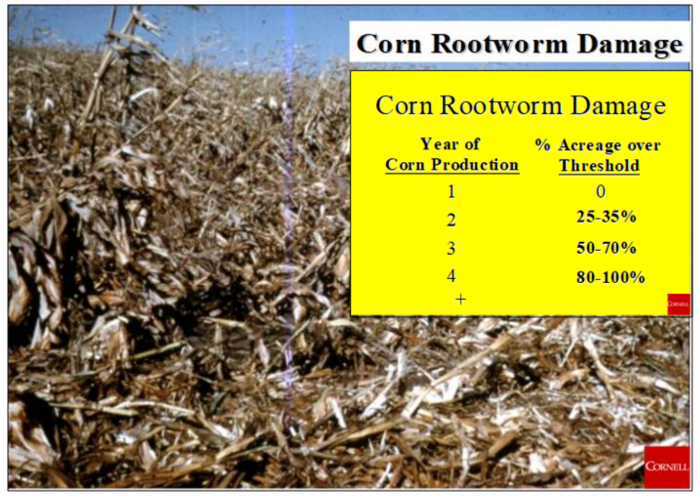
Western / Northern Corn Rootworm: Primary Pest

- Feeding Habit, Host Range, Injury Type, Damaging Stage:
- Western and Northern corn rootworms are primary pests of field and sweet corn. Larvae rely almost entirely on corn roots for survival and use chewing mouthparts to prune roots, reducing the plant's ability to take up water and nutrients. This results in weakened root systems, lodging, goose-necking, and reduced grain yield due to water stress. Adults feed on pollen and leaf tissue but cause minimal economic injury compared to larvae.
- Lifecycle: Adults lay eggs in soil cracks in existing corn fields during August and early September. Eggs overwinter in the soil until mid-May. Hatching occurs over a 4-week period from mid-May to early June, depending on soil temperature. Newly hatched larvae must find a corn root within 24–48 hours to survive and are prone to drowning in waterlogged soils. Larvae feed on corn roots until mid-July, after which mature larvae pupate in the soil. Adults emerge in synchrony with pollination and feed for the 3-week period required for mating and egg production. Most eggs are laid before September 1.



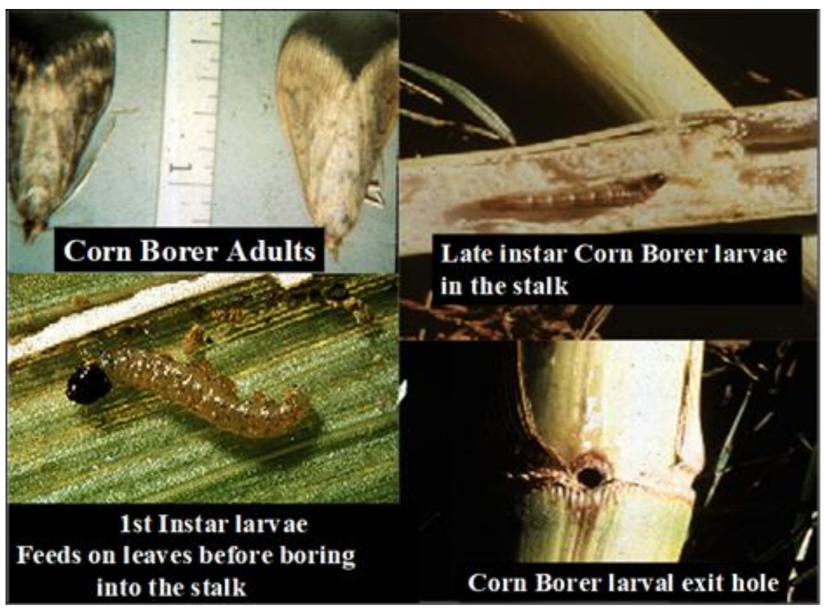
- Impact of Environment on Population Dynamics: Because the insect has only one generation per year, environmental effects focus on the survival of that single generation. Water-saturated soils during larval hatch cause high mortality, often resulting in sub-economic populations. Droughty soils during hatch can also cause mortality by limiting root access. High soil temperatures speed up larval development and lead to earlier adult emergence.
- Impact of Environment on Crop Damage: Larval feeding removes roots critical for pollination and grain fill. Dry soil conditions increase the impact of root loss by increasing water stress, reducing grain yield. In seasons with adequate soil moisture, plants can regenerate roots and recover from feeding damage.
- Management: Management focuses on reducing larval populations by removing the food source (crop rotation), using soil insecticides or seed treatments, or planting Bt hybrids expressing rootworm-active toxins. Because Corn rootworm can develop resistance to Bt traits, resistance management is essential. Entomopathogenic nematodes (EPNs) can suppress both resistant and non-resistant populations when used consistently across rotations.

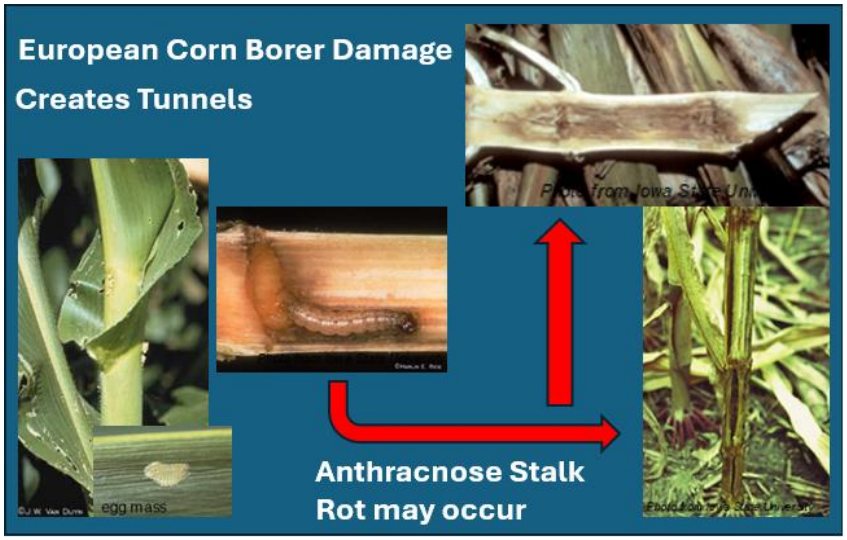




European Corn Borer (Secondary Pest)

- The European corn borer has three biotypes in the Northeast: one with a single generation per year and two with two generations. Biotypes 1 and 2 primarily attack field and sweet corn, while Biotype 3 attacks a wide array of plants including corn and wheat. All economic damage is caused by the larval stage, which has chewing mouthparts and removes plant tissue directly. Larvae feed on leaves, bore into stems, and attack reproductive structures such as the ear and ear shank. Feeding weakens stalks and ear shanks, reduces yield, and creates entry points for fungal pathogens.
- Lifecycle: Mature larvae overwinter inside corn stalks left in the field after harvest. In early spring, these larvae pupate and emerge as moths in late May to early June. After mating, females lay egg masses on the underside of corn leaves near the midrib. First-generation larvae feed briefly on leaf surfaces before migrating into the whorl and boring into the stalk, where they complete development. In single-generation biotypes, these larvae remain in the stalk until the following spring. In two-generation biotypes, first-generation larvae pupate and emerge as moths in late July. Females lay second-generation eggs around the developing ear, and larvae bore into the ear and ear shank. These second-generation larvae overwinter in the stalk and emerge the following spring.

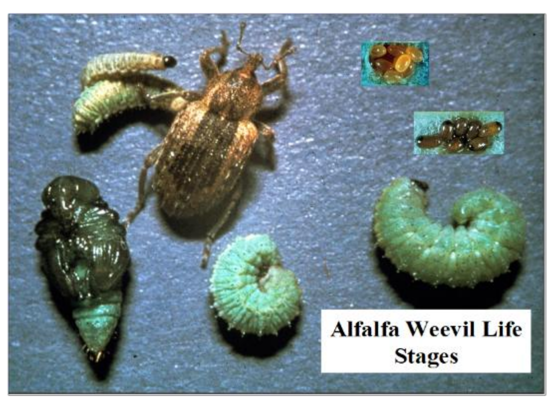




- Impact of Environment on Population Dynamics: Eggs are laid on leaf undersides, and young larvae feed on leaf surfaces before boring into the plant. Hot, dry conditions increase mortality of small larvae before they enter the stalk. Because larvae move into the whorl before boring, a timely rainstorm that fills the whorl can drown larvae. Higher temperatures accelerate development but do not add an additional generation because overwintering diapause is triggered by decreasing day length in August, not temperature.

- Impact of Environment on Crop Damage: Larval feeding weakens stalks and ear shanks, increasing the risk of stalk breakage and ear drop before harvest. Damage is worsened by strong winds in late summer and early fall. Boring into stalks severs vascular bundles, reducing water movement and photosynthesis, which lowers yield. Feeding wounds also allow stalk rot organisms to enter, further reducing standability and yield.
- Management: The only effective management strategy is the use of transgenic corn hybrids expressing Bt toxins active against corn borer. Because corn borer is localized and sporadic in the Northeast, widespread prophylactic use of Bt traits is not recommended. Instead, Bt hybrids should be used in fields with a known history or high probability of economic corn borer pressure.

Alfalfa Weevil: Primary early-season pest of Alfalfa



- Alfalfa weevil is the most important early-season pest of alfalfa in the Northeast. Both adults and larvae feed on alfalfa foliage, but nearly all economic damage is caused by the larvae. Larvae skeletonize leaves, creating a “shot-hole” or “window-pane” appearance, and heavy infestations can completely strip first-cutting regrowth. Injury is most severe in the upper canopy where larvae feed on expanding terminals. The most damaging stage is the larva.

- Lifecycle: Alfalfa weevil overwinters as adults in field edges and as eggs laid inside alfalfa stems. Adults become active in early spring and begin laying eggs when temperatures warm. Eggs hatch when sufficient degree-days accumulate, and larvae feed for several weeks before pupating in white, silken cocoons attached to stems or plant debris.
- Impact of Environment on Population Dynamics: Alfalfa weevil development is strongly temperature-driven. Warm springs accelerate egg hatch and larval feeding, while cool springs delay development and extend the feeding period. Because larvae feed on the rapidly growing first-cutting canopy, weather patterns that slow alfalfa growth include cool temperatures, cloudy conditions, or drought which allow larvae to consume a larger proportion of available foliage. Natural enemies, including parasitoid wasps, can suppress populations, but their activity is also influenced by spring temperatures.

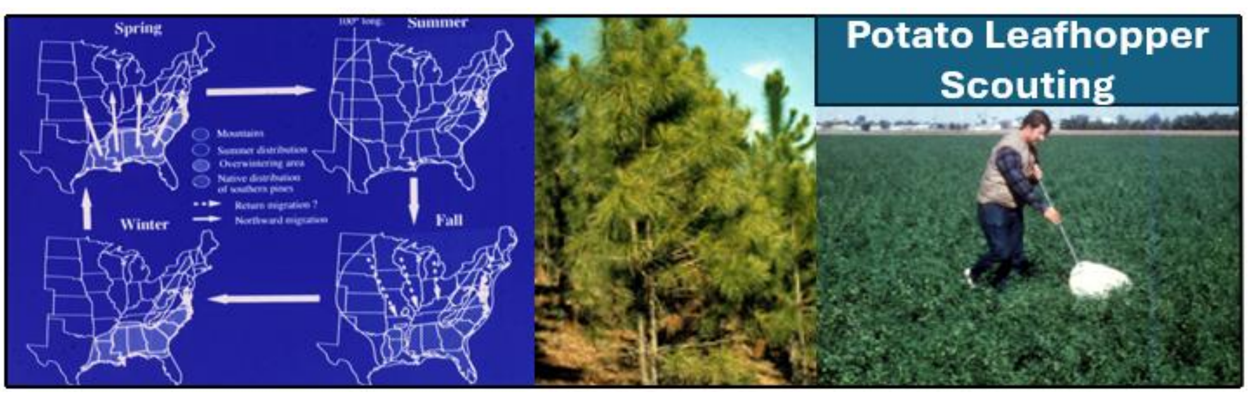
- Impact of Environment on Crop Damage: Damage is most severe when larval feeding coincides with slow crop growth. Cool, cloudy springs allow larvae to outpace plant growth, resulting in heavy defoliation of terminals and upper leaves. Severe infestations can reduce first-cutting yield and quality and delay regrowth for second cutting. When warm weather accelerates, so do both crop growth and larval development. Alfalfa can often outgrow moderate feeding.
- Management: Management relies on timely scouting and the use of degree-day models to predict larval activity. Fields should be checked for larvae and feeding injury as soon as degree-day thresholds are reached. Cutting early is an effective management tool when larvae are near peak feeding, and the crop is close to harvest maturity. Insecticides may be justified when larval counts exceed economic thresholds and harvest is not imminent. After cutting, fields should be checked for surviving larvae feeding on regrowth, as post-harvest infestations can delay recovery.

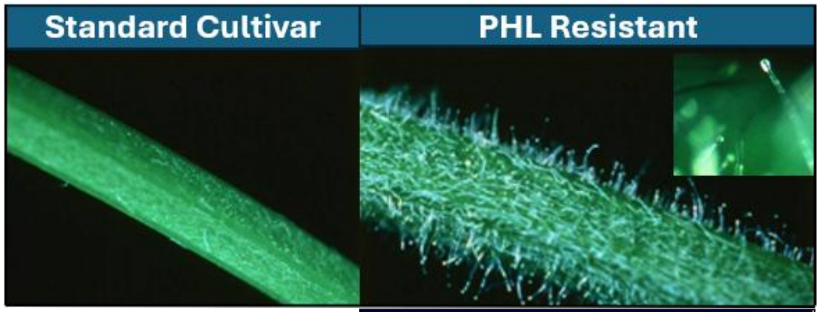
Potato Leafhopper: Primary mid-season pest of alfalfa

- Potato leafhopper (PLH) is a migratory pest that does not overwinter in the Northeast. It feeds on alfalfa, clover, dry beans, and many other broadleaf plants. Both nymphs and adults feed using piercing–sucking mouthparts that remove plant sap and inject toxic saliva. This feeding disrupts vascular flow and causes the characteristic “hopperburn”—a yellowing and cupping of leaf tips that progresses inward. Injury reduces photosynthesis, stunts plants, lowers forage quality, and can severely reduce yield. Both nymphs and adults are damaging stages, but nymphs cause most economic injury because they remain on the plant and feed continuously.
- Lifecycle: Potato leafhopper does not survive northern winters. Each year, adults migrate northward on storm fronts from the Gulf States, typically arriving in New York and the

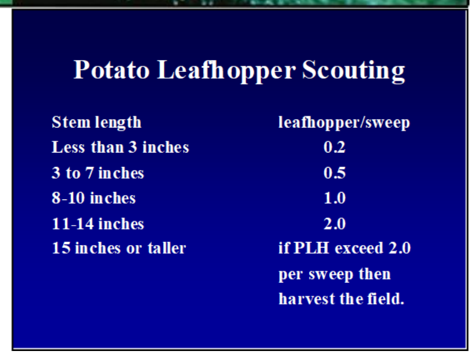
Northeast in late May to early June, shortly after first cutting. Females begin laying eggs inside alfalfa stems soon after arrival. Eggs hatch into wingless nymphs that feed on the underside of leaves and pass through five instars before becoming winged adults. Multiple overlapping generations occur throughout the summer, allowing populations to build rapidly during warm weather.

- Impact of Environment on Population Dynamics: Warm temperatures accelerate leafhopper development and increase the number of generations per season. Dry weather favors population growth because plants are already stressed and less able to compensate for sap removal. Heavy rains can temporarily reduce adult numbers by washing them from foliage, but populations typically rebound quickly. Because PLH arrives via long-distance migration, population levels vary widely from year to year depending on southern source populations and storm patterns.
- Impact of Environment on Crop Damage: Damage is most severe when leafhopper feeding coincides with slow crop growth, such as during drought or after cutting when regrowth is small and vulnerable. Hopperburn symptoms begin at leaf tips and progress inward, reducing photosynthetic area and stunting plants. Severe infestations can reduce yield, crude protein, and relative feed value. Young regrowth is especially sensitive, and even low populations can cause economic loss if not detected early.
- Management: Management relies on regular sweep-net scouting beginning immediately after first cutting and continuing through the growing season. Economic thresholds vary by plant height because smaller plants are more sensitive to feeding. When thresholds are exceeded, timely insecticide applications prevent hopperburn and protect regrowth. Cutting early is an effective non-chemical option when the crop is near harvest maturity and PLH pressure is increasing. Resistant alfalfa varieties provide long-term suppression and reduce the need for insecticides, especially in regions with chronic PLH pressure.





- PLH resistance in alfalfa is due to the presence of glandular hairs on the stem and leaves. These hairs inhibit feeding and the laying of eggs in the stems of the plant. This resistance is most effective on small leafhopper nymphs preventing them from reaching adulthood.
- Effective management of PLH in susceptible alfalfa stands requires weekly scouting with a sweep net and the use of the treatment guidelines listed below and in the current version of the Cornell Guidelines for Field Crop Production. When properly applied, insecticides are very effective in the control of PLH.

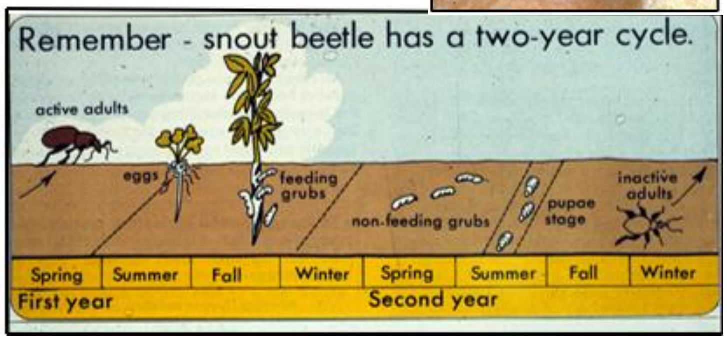


Potato Leafhopper Scouting

Stem length	leafhopper/sweep
Less than 3 inches	0.2
3 to 7 inches	0.5
8-10 inches	1.0
11-14 inches	2.0
15 inches or taller	if PLH exceed 2.0 per sweep then harvest the field.

Alfalfa Snout Beetle: Primary Soil Pest of Alfalfa

- Alfalfa snout beetle (ASB) is one of the most destructive pests of alfalfa in regions where it is established. Adults feed on foliage and create characteristic notching and girdling on leaf margins and stems, but nearly all economic damage is caused by the larvae. Larvae feed extensively on alfalfa roots, stripping the outer cortex and eventually hollowing out the entire root system. This feeding kills plants outright, causes rapid stand decline, and results in severe yield loss. The damaging stage is the larva.
- Lifecycle: ASB has a two-year lifecycle, but all development occurs during the first year. Adults emerge from deep in the soil during the first week of May, feed for several weeks, and then lay eggs. Eggs hatch into larvae that immediately begin feeding on alfalfa roots. Larvae feed throughout the summer and fall, reaching full size by late fall, and then move deep into the soil to overwinter. During the second year, the insect remains deep in the soil in a hibernation state and does not feed or develop further. Pupation and adult emergence occur the following spring, completing the two-year cycle. A unique biological feature of ASB is that all adults are female; there are no known males in the North American population. Reproduction occurs through parthenogenesis, allowing populations to build rapidly in infested regions. Adults feed on a wide array of plants, including alfalfa, clover, rhubarb, grapes, and roses, but economically the most important hosts are alfalfa and clover.

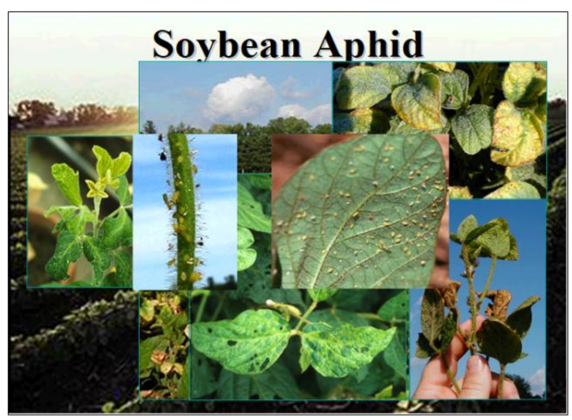


After about three weeks of feeding, adults begin laying eggs around the base of host plants. Oviposition continues for 4–6 weeks, and each female lays 150–300 eggs.

- Impact of Environment on Population Dynamics: ASB thrives in well-drained soils and long-term alfalfa stands. Because larvae spend most of their life underground, soil conditions strongly influence survival. Mild winters and deep snow cover increase overwintering success. Heavy, saturated soils can reduce larval survival, but in most established ASB regions, environmental conditions favor persistence. The two-year lifecycle allows populations to build gradually and often go unnoticed until stands collapse suddenly.
- Impact of Environment on Crop Damage: Damage is most severe in older alfalfa stands where larvae have had multiple years to build. Root feeding reduces water and nutrient uptake, causing plants to wilt, yellow, and die, especially during dry periods. Stand loss often begins in patches and expands outward as larvae spread. Because larvae destroy the entire root system, affected plants do not recover, and fields can be rendered unproductive within one or two seasons once infestations reach high levels.
- Management: The only effective long-term management strategy is the use of persistent entomopathogenic nematodes (EPNs), which attack and kill ASB larvae in the soil. EPNs are applied to alfalfa fields and persist for many years, providing season-long biological control.

Soybean Aphid: Primary Pest of Soybeans

- Feeding Habit, Host Range, Injury Type, Damaging Stage:
- Soybean aphid is a phloem-feeding insect that feeds exclusively on soybeans during the summer. Both nymphs and adults feed using piercing–sucking mouthparts that remove plant sap and inject toxins. Heavy infestations cause leaf curling, stunting, reduced pod set, and lower seed weight. Aphids also produce honeydew, which supports sooty mold growth and reduces photosynthesis. The damaging stages are nymphs and adults, with nymphs responsible for most population growth.



- Lifecycle: Soybean aphid has a complex lifecycle involving two hosts: buckthorn (the overwintering host) and soybeans (the summer host). Eggs overwinter on buckthorn and hatch in early spring. Winged females migrate to soybean fields in June and begin producing live young without mating (parthenogenesis). Populations grow rapidly, with multiple overlapping generations throughout the summer. When populations become crowded or plant quality declines, winged forms develop and disperse to new fields. In late summer, aphids return to buckthorn to mate and lay overwintering eggs. The picture you will insert will show colonies on the underside of soybean leaves, along with honeydew and sooty mold typical of heavy infestations.

- Impact of Environment on Population Dynamics: Cooler summer temperatures (70–80°F) favor rapid population growth, while hot weather slows reproduction. Dry conditions increase plant stress and make soybeans more susceptible to feeding injury. Natural enemies—lady beetles, lacewings, parasitoids, and fungal pathogens—play a major role in suppressing aphid populations. Rainfall can reduce aphid numbers by dislodging nymphs and promoting fungal infections.
- Impact of Environment on Crop Damage: Damage is most severe during early pod set through seed fill (R1–R5). High aphid populations during these stages reduce pod number, seed size, and overall yield. Stressed plants show greater yield loss, especially under drought. Honeydew accumulation and sooty mold reduce photosynthesis and further weaken plants. Late-season infestations (R6–R7) rarely cause economic damage because most yield has already been determined.
- Management: Relies on regular scouting and the use of established economic thresholds. The standard threshold is 250 aphids per plant, with populations increasing, before R5. Natural enemies should be considered when making treatment decisions, as they often suppress populations below threshold. Insecticides are effective when applied at threshold, but unnecessary early sprays can flare aphids by killing beneficial insects. Resistant soybean varieties provide long-term suppression and reduce the need for insecticides. Late-season treatments after R6 are rarely justified.

- Vulnerable soybean stages
  - Early-season infestations begin at V2 and peaking during R1–R2 (early–full flowering) can reduce yields by 3–50%, depending on aphid density.
  - Late-season infestations cause minor to undetectable losses, unless a virus is present.
- Soybean Aphid (SBA) — Biology and identification
  - Pale yellow aphid less than 1/16 inch long
  - Only aphid species that forms true colonies on soybeans
  - Has black cornicles (“tail pipes”)
  - Parthenogenic (females reproduce without males)
  - Populations can increase 10× per week under favorable conditions

- Produces 15–18 generations per season
- Overwinters on buckthorn (*Rhamnus spp.*) and kudzu (*Pueraria phaseoloides*)
- Wild hosts include Glycine spp. (wild soybean relatives)

Spider Mites: Secondary Pest of Soybeans, Alfalfa & Corn
Spider mites are not generally a problem on field crops grown in NY or the NE US. In soybeans, early insecticide applications for soybean aphid, coupled with hot dry summer conditions have been responsible for localized spider mite outbreaks. If insecticide applications are delayed until actual economically important populations of soybean aphid, spider mite infestations seldom occur regardless of the summer conditions.

31. Understand *dispersal and* monitoring strategies of emerging invasive pests

Invasive species vary in their typical dispersal behaviors, timing, and range. Monitoring efforts usually include baited traps using sex pheromones or host volatiles near host plant species but can include visual inspection of high-risk sites or known hosts and reporting positive sitings.

32. Know advantages and disadvantages of using pesticides to control arthropod crop pests.

- The use of chemical pesticides has long been viewed as the "line of first attack" when the use of pesticides should be viewed as a "strategy of last defense". The past widespread use of pesticides has created as many problems as it has solved. The development of insecticide resistance in insects, herbicide resistance in weed species and fungicide resistance in an array of plant disease pathogens was predicted by scientists, ignored by the agribusiness industry of that era, and has created a number of difficult pest management problems. These situations have led to the development of "resistance management strategies".
- Pesticides: Widespread use of insecticides since the 1940's has resulted in the development of insecticide resistance in numerous insect species. For a time, the insecticide industry could develop new insecticides as fast as insecticide resistance developed and the issue of resistance management was not a priority. With the slowing of insecticide development in the late 1980's, the issue of preserving the various insecticides by managing the exposure of the target insects to the insecticide and reducing the development of insecticide resistance became a key issue. Currently, the use of insecticides only when economic losses are expected and the rotation of different insecticide classes reduces the selection pressure on the insect population to develop insecticide resistance. An additional strategy to prevent the rapid development of insecticide resistance is deployment of refuges (see PO#30).

33. Recognize the advantages and disadvantages of target specificity of pesticides used to control arthropod crop pests.

Target specific pesticides affect only certain pests rather than a broad group of insects.

Advantages

- Protects beneficial insects/natural enemies.
- Reduces secondary pest outbreaks.
- Lowers environmental and non-target impacts.
- For resistance management/mode of action (MoA) Insecticide rotation.

Disadvantages

- Can be very life stage specific.
- Requires accurate pest identification and timing.
- Need of additional products for other pests.
- Diversity of products is limited.

34. Understand the concepts of resistance management as it pertains to pesticides and genetically modified crops with plant incorporated protectants (PIPs) incorporated into their genome.

- Resistance management: The adoption of agricultural practices which delay, reduce or prevent the development of resistance. Resistance only becomes a problem when the selection pressure on the population is intense enough that only the resistant individuals survive, interbreed and concentrate the genes for resistance in the population. An effective resistance management program utilizes a wide array of pest management practices which allows susceptible individuals to survive to interbreed with the resistant individuals to prevent the concentration of the genetic resistance in the majority of the population.
- GMO crops: Many GMO crops have an insect active toxin incorporated into the plant genome. The presence of this toxin in plant tissue has a significantly more potent genetic selection pressure on the insect to develop resistance than the use of a topically applied or systemic insecticide. The toxin in transgenic crops is always present in the plant where an externally applied insecticide concentration degrades with time, allowing some insects to reduce exposure and survive without mechanisms of genetic resistance. Currently, the EPA requires the planting of GMO-toxin free refuges in coordination with the planting of insect-active GMO crops. For example, the planting of GMO-Rootworm resistant corn varieties requires a 20% refuge plant within the field or immediately adjacent to the field with a corn variety of the same maturity rating where the plant incorporated toxin is absent in the plant. This allows rootworm larvae to survive, and emerge as adults and mate with any potential resistant individuals that have successfully survived exposure to the transgenic toxin.

35. Know examples of and understand the advantages and limitations of cultural controls for arthropod crop pests.

a. Resistant varieties
b. Planting date adjustment
c. Crop rotation
d. Tillage
e. Harvest date adjustment
f. Sanitation

Cultural control is the generalized term for the use of agricultural practices to reduce the pest pressure on the crop. These tactics include (1) resistant varieties, (2) planting date adjustment, (3) crop rotation, (4) tillage practices, (5) harvest date adjustment, and (6) sanitation.

a. Resistant varieties: Most pest resistance in field crops is incorporated into the varieties through conventional breeding techniques. Selection of the best adapted varieties to a local set of pest pressures is not only a good pest management practice but good agribusiness practice. Examples of disease resistance in corn are Northern Corn Leaf Blight and stalk rot resistance. An example of insect resistance is the array of Potato Leafhopper resistant alfalfa varieties.
b. Plant date adjustment: One classical example of adjusting planting date to avoid pest pressure is the delay of winter wheat plant date in the fall until the threat of Hessian Fly attack is minimized. In corn and soybean systems, planting date can be adjusted to minimize the risk of seed corn maggot damage.
c. Crop rotation: Crop rotation is a good agronomic practice which has benefits beyond pest management. In the scope of pest management, systems with continual single crop production build up pest pressure over time. For example, 1st year corn in NY never suffers economic damage from corn rootworm. In contrast, 3rd and 4th year continuous corn builds up an 85-100% probability of economically damaging levels of rootworm larval populations. Similar examples can be cited from the plant disease world. A planned rotation can reduce the pest problems in most crops.
d. Tillage practices: Tillage can reduce the risk of pressure from pests that live, pupate, or overwinter in the soil. An example of this is the shredding of corn stalks in corn grain production to reduce the overwintering population of European Corn Borer.
e. Harvest date adjustment: The adjustment of harvest can be an effective tool to reduce pest pressure. For example, in alfalfa production, an early harvest can prevent the economic losses from the alfalfa weevil or potato leafhopper feeding and prevent the cost of an insecticide treatment.
f. Sanitation: Many stored grain insect infestations can be directly linked to the lack of sanitation around the grain storage facility. The simple practice of completely cleaning the grain bin of leftover grain (with associated insects) before the bin is refilled with a new load of grain eliminates many of the stored grain insect problems. In addition, the use of screening on all grain bin openings prevents the insects from entering the facility after the bin is refilled.

36. Understand refuge requirements for insect-traited corn.

a. Size

b. Distance

c. Refuge in a bag

Refuge requirements exist to slow insect resistance to Bt traits by ensuring that susceptible insects survive and mate with resistant survivors. Refuge requirements include refuge size, refuge distance and whether a refuge in a bag (RIB) is allowed.

a. Size

- Refuge size depends on the Bt trait package.
    - 5% - 10% in the bag refuge is used for most pyramided Bt hybrids in the north.

   - 20% in field/adjacent refuge is used for single Bt hybrids.
 - Refuge size is calculated as a percentage of the total corn acres.

b. Distance
 - The refuge must be close to ensure mating between susceptible and resistant insects.
 - Within ½ mile of the Bt field
 - Adjacent or in field refuge is preferred
 - Refuge must be planted at the same time with similar maturity

c. Refuge in a bag
 - Typicaly 5% of the non Bt seed blend is used in the bag
 - Not allowed for single-trait Bt products; certain rootworm traits require structured refuge.

37. Recognize the three major classes of beneficial organisms and know at least two examples of each (parasitoid, predators and pathogens).

See PO#30.

38. Be able to discuss its importance in pest population regulation. Examples include:

a. Spiders
b. Parasitoid wasps
c. Parasitoid flies
d. Predaceous insects
e. Predaceous mites
f. Entomopathogenic nematodes
g. Entomopathogenic fungi

All insects within their native ranges are held in check with their own array of biological control organisms. These organisms include diseases, parasites, and predators. In addition, adverse weather conditions also have a negative impact on insect populations. Insects (and other arthropods) become economic pests when conditions change which negatively impact the biological control organisms and allow the populations of the insect pest to increase to economically damaging levels. These changes can include the introduction of the insect to a new region without the introduction of the natural enemies/diseases or a change in the cropping system which inhibits the biological control activities of the natural enemies and encourages the population buildup of the crop pest. Many of the current economically important crop pests in field crops are introduced into North America from other parts of the world. A few examples are European Corn Borer, Alfalfa Weevil, and Cereal Leaf Beetle. Alfalfa weevil and Cereal leaf beetle are generally not considered a widespread economic pest because of successful efforts to establish the biological control organisms from their native homeland which held them in check throughout their native range. Similar efforts for European Corn Borer have not been successful. In contrast, Western and Northern Corn Rootworm are native to the US and have shifted from their native plants onto cultivated corn. The change of life history and habitat has released these insects from their natural enemies, and the enhanced food source (cultivated corn) has allowed the insect to rise closer to their reproductive potential. As a result, corn rootworms are a very significant agricultural pest.

Types of biological control organisms - Biological control organisms fall into three different categories. There are insect diseases (viral, fungal, bacterial), internal parasites (parasitoids) and external predators.

- Insect diseases**:** (Insect pathology): Each insect species has an array of diseases which keep the species in check within its native habitat. When an insect species in introduced into a new environment (usually through human assisted movement), the array of diseases are not usually moved with the insect, and the insect population explodes in the new relatively disease-free environment. The reintroduction of effective disease organisms into the new area and invasive population has been very effective in controlling invasive insects which become economically important in the new outbreak area. Examples of effective biological control with the use of insect disease organisms are Alfalfa Weevil and Gypsy Moth. Insect attacking nematodes (entomopathogenic) are also considered in insect pathology. Entomopathogenic nematodes are most effective on soil insects.
- Parasitoids: (terminal endoparasites): Whole groups of insects have adapted their lifestyles as internal parasites of other insect species, including several species of flies and wasps. In both cases, eggs are either laid internally or externally on the insect host. The parasitoid egg hatches and feeds internally within the host insect until the host dies. After development is completed, the parasitic insect pupates to an adult and emerges from the host insect cadaver. The newly emerged adult then searches for other suitable hosts in which to lay eggs (oviposit). The effectiveness of parasitoids as a biological control agent is determined by the adaptation of the parasitoid species to the new environment in which they are released and the matching of the parasitoid searching behavior to the new environment to which the host insect has adapted to. Examples of effective parasitoid based biological control are Alfalfa Blotch Leafminer, Cereal Leaf Beetle and Alfalfa Weevil (in some years).
- Predators: There is a wide array of insect and mite species in numerous orders which have adapted to the role of insect predators. Insect predators search for, attack and consume other insects externally (as contrasted to internal parasitoids). Commonly recognized predators are the Lady-Bird beetle, Lacewings, Big-eyed Bug, and Damsel Bug. In addition, ground beetles, spiders and predaceous mites are also effective predators. Generally, predators are most effective when host insects are in high numbers. Examples of insects controlled by predators are aphids and plant feeding mites.

CA5: Pesticide Formulations and Labels

39. Recognize the distinction between the federal and state pesticide laws and regulations, and that state laws or regulations can be more restrictive. Be able to explain what to do if state laws or regulations are stricter than label directions.

Federal law gives the states the option of being stricter than EPA. A state may restrict products or remove products from sale and use within its borders. They may also choose to modify labels. States may also decide to interpret label statements to give them a stricter meaning, such as New York interprets the phrase “For Professional Use Only” as meaning this product is a “Restricted Use” product and cannot to be sold to uncertified people. Ultimately the applicant must follow the more stringent state regulation.

40. Be able to explain the difference between a pesticide label and labeling and identify examples of pesticide labeling.

The label is the information printed on or attached to the pesticide container. It has information about pesticide's characteristics and proper use. There are other brochures and flyers that have information about the pesticide product. These additional pieces of information are called "labeling." Labeling is all the information that you receive from the manufacturer about the product. It includes the label on the product container plus any supplemental information including the safety data sheet (SDS), brochures, leaflets, 2(ee) recommendations, and information handed out by your dealer. Labeling is just as important as the label.

41. Identify and locate the kinds of information found on a pesticide label.

- Brand, trade, or product names: Each manufacturer has a brand name for their product. Different manufacturers may use different brand names for the same pesticide active ingredient. The brand name is plainly displayed on the front panel of the label.
- Classification**:** Every pesticide will be classified by the U.S. Environmental Protection Agency as either general use or restricted use. Every pesticide product which has been classified as restricted use must carry this statement in a prominent place at the top of the front panel of the pesticide label: "RESTRICTED USE PESTICIDE". For retail sales and use only by certified applicators or persons under their direct supervision and only for those uses covered by the certified applicator's certification." This statement is followed by the reason for the restriction (i.e. ground and surface water concerns). Some products may limit use to only certified applicators. Your state pesticide regulatory agency has the authority to deem a general use product as restricted use. When a product has been restricted by a state, the restricted use statement will not appear on the label. Contact your state pesticide regulatory agency for the list of state restricted use products.
- Ingredient statement: Each pesticide label must include an ingredient statement. This lists the active ingredients that are in the product and is written so you can quickly see what the active ingredients are. Non-active ingredients (called other or inert ingredients) are not required to be listed on the product label. The percentage by weight of the active and other ingredients must be listed.
- Chemical name: The chemical name is a complex name which identifies the chemical components and structure of the pesticide's active ingredient. This name is almost always listed in the ingredient statement on the label.
- Common name: Due to pesticides having complex chemical names, many are given a shorter "common" name. Only common names officially accepted by the U.S. Environmental Protection Agency may be used in the ingredient statement on the label.
- Type of pesticide: This is usually listed on the front panel of the pesticide label. If it is not listed, there may be a short statement indicating the kind of pests the product will control. Examples: Insecticide for control of certain insects on fruits, nuts, and ornamentals; Soil fungicide; Herbicide for the control of trees, brush, and weeds; Algaecide.
    - Name and address of manufacturer: The law requires the maker or distributor of a product to put the name and address of the company on the label.
    - EPA Registration and Establishment Numbers: The EPA Registration Number identifies pesticide. It consists of at least 2 parts – a manufacturer number and a product number. An example would be EPA Reg. No. 123-456, where 123 is the manufacturer number and

456 is the product number. An EPA Establishment Number indicates the company that made the pesticide, the state where the manufacturing facility is located, and the number of the facility. An example would be EPA Est. No. 264-MO-02 where 264 is the company number, MO indicates the manufacturing facility is located in Missouri, and it is that company's second facility in that state. These numbers are needed by the pesticide applicator to comply with recordkeeping and reporting requirements, in case of accidental poisoning, claims of misuse, faulty product, or liability claims.

- Signal words and symbols: Almost every label contains a signal word that will give you a clue on the relative acute toxicity of the product to the user. Knowing the product's hazard helps you to choose the proper precautionary measures for yourself or your workers. The signal word must appear in large letters on the front panel of the pesticide label. It usually is next to the statement, "Keep Out of Reach of Children," which must appear on every pesticide label. Three signal words are used: Danger, Warning, and Caution.
    - DANGER: Any product which is highly toxic orally, dermally, through inhalation, or causes severe eye or skin burning, will have the signal word DANGER. All pesticides which are highly toxic orally, dermally, or through inhalation will also carry the word POISON printed in red along with a skull and crossbones symbol.
        - If a pesticide receives a highly toxic rating because of the possibility for corrosive damage to the skin or eyes, the signal word DANGER will be on the label without the word POISON and the skull and crossbones symbol.
    - WARNING: Any product which is moderately toxic orally, dermally, or through inhalation or causes moderate eye and skin irritation, will have a WARNING signal word.
    - CAUTION: Any product which is slightly toxic to relatively non-toxic orally, dermally, or through inhalation or causes slight eye and skin irritation, will have a CAUTION signal word.
- Precautionary statements - All pesticide labels contain additional statements with mandatory or advisory precautions to take. These precautions are to protect yourself, other people or animals), and the environment.
- Hazards to wildlife: The label may indicate that the product causes undesirable effects in the environment. In this case, the precautionary statement may tell you what to avoid doing. Some labels indicate toxicity to bees, birds, fish, and crustaceans. Labels may indicate requirements needed to protect endangered species. Limitations may include reduced rates, restrictions on types of application, or a ban on use of pesticides within a species range. The label may also tell you where additional information can be obtained.
- Protective clothing and equipment statements: Pesticide labels vary in the type of protective equipment statement they contain. You must use any listed protective clothing or equipment that appears on the label.
- Environmental hazards: Pesticides may be harmful to the environment. Some products are classified RESTRICTED USE because of environmental hazards alone. Label warnings may include groundwater advisories and protection information. Look for special warning statements on the label concerning hazards to the environment.

- Special toxicity statements: If a particular pesticide is especially hazardous to wildlife, it will be stated on the label. For example:
  - This product is highly toxic to bees.
  - This product is moderately toxic to fish.
  - This product is toxic to birds and other wildlife.

  These statements alert to the special hazards that the product may pose. They will help choosing the lowest risk product and tell you about what precautions to take.
- General environmental statements**:** These statements appear on nearly every pesticide label and are reminders of common-sense actions to follow to avoid harm to the environment. The lack of these statements does not mean adequate precautions are not needed. It is the applicator's responsibility to protect the environment. Sometimes these statements will follow a "specific toxicity statement", providing practical steps to avoid environmental harm.

  Examples of general environmental statements include:
  - Do not apply when runoff is likely to occur.
  - Do not apply when weather conditions favor drift from treated areas.
  - Do not contaminate water when cleaning equipment or disposing of waste.
  - Keep out of any body of water.
  - Do not allow drift on desirable plants or trees.
  - Do not apply when bees are likely to be in the area.
  - Do not apply where the water table is close to the surface.
- Physical or chemical hazards: This section of the label will tell you of any special fire, explosion, or chemical hazards the product may pose. For example:
  - Extremely flammable. Keep away from fire, sparks, and heated surfaces.
  - Do not mix or allow to come in contact with any oxidizing and reducing agents. Hazardous chemical reactions may occur.
- Agricultural use requirements: Pesticides with approved uses that fall under the Worker Protection Standard (WPS) will have an agricultural use requirements section. This section provides information about personal protective equipment for early worker entry, worker notification requirements, and restricted-entry intervals for workers.
- Storage and disposal: Pesticide labels contain general instructions for storage of the pesticide and disposal of leftover pesticide, empty containers, and rinsate. Note that some pesticides may have specific storage requirements that help prolong the shelf life of the product.
- Directions for use: Correct application of a pesticide product is accomplished by following the use instructions found on the label. The directions for use will tell you:
  - The crop, animal, or site the product is intended to protect.
  - The pests which the manufacturer claims the product will control.
  - In what form the product should be applied.
  - The proper equipment to be used.
  - How much to use (the rate).
  - Mixing directions, including any compatibility issues with other products, including non-pesticide chemicals.
  - Phytotoxicity and other possible injury.
  - Where the material should be applied and when it should be applied.

- Labels for pesticides used to produce food and feed will list the number of days which must pass between the last pesticide application and crop harvest or grazing livestock. These are intervals set by EPA to allow time for the pesticide to break down and prevent illegal residues on food or feed and to prevent poisoning of grazing animals.

42. What FIFRA and ESA are and how they apply to a CCA's work.

The Federal Insecticide Fungicide and Rodenticide Act (FIFRA) is the federal law that regulates the production, distribution, sale, and use of pesticides and pesticide devices in the US. This law is administered and enforced by the US EPA in cooperation with the states. FIFRA:

- With few exceptions, requires the registration of a pesticide with the EPA before it can be sold in the US.
- Establishes the requirements for pesticide registration, including review and approval of the pesticide label.
- Allows pesticides to be classified as restricted use, limiting their use to only trained and certified applicators.
- Allows for different types of registrations and exemptions, including Special Local Needs (SLN) registrations, Section 18 Emergency Exemptions, 2(ee) recommendations, and exempting minimum-risk pesticides (also called 25(b) pesticides) from registration.
- Requires the reregistration of registered pesticides every 15 years to ensure older products meet current safety and health standards as well as labeling requirements.
- Requires certification for those using restricted use pesticides and establishes two types of certified applicators – private and commercial.
- FIFRA may affect pesticide availability in the US as well as the legal uses for registered pesticides. Additionally, CCAs may need to become certified applicators if they're actively involved in applying pesticides or those they work with will make pesticide applications.

The Endangered Species Act (ESA) is a federal law that makes it illegal to kill, harm, or collect endangered species or threatened wildlife or fish, or to remove endangered or threatened plants from areas under federal jurisdiction. It also requires federal agencies to ensure actions they take are not likely to jeopardize an endangered or threatened species or destroy or adversely modify its critical habitat. As part of the pesticide registration process, the EPA is required to evaluate that a pesticide is unlikely to jeopardize the survival of any endangered or threatened species or their critical habitats. Older pesticide labels will give precautionary measures applicators must take to protect endangered or threatened species. Newer pesticide labels will have more specific requirements applicators must follow including detailed drift mitigation requirements (including buffers), runoff/erosion mitigation measures, and accessing Endangered Species Bulletins through the EPA's Bulletins Live! Two websites to determine if further mitigation measures are needed when treating a particular location. Protection for endangered/threatened species and their critical habitats may affect the pesticides that can be used.

43. Be able to explain the meaning of the phrase "Use Inconsistent with Labeling"

Every pesticide label has the following statement: "It is a violation of federal law to use this product in any manner inconsistent with its labeling." Under federal law (FIFRA), you are forbidden to use a pesticide contrary to the labeling. Essentially, the label is a "permission document" so any use not indicated on the label is prohibited. This also means that consultants or salespersons cannot legally recommend that a pesticide be used contrary to its labeling.

44. Recognize the general provisions of EPA laws and regulations such as the Clean Water Act and Worker Protection Standards and how they may impact pesticide use.

In addition to FIFRA and ESA, other federal laws and regulations impacting pesticide use include:

- The Clean Water Act is a federal law that regulates point source discharges of pollutants into US waters. Federal or state permits are required when pesticides are directly applied to water.
- The Federal Food, Drug, and Cosmetic Act (FFDCA) gives EPA the authority to set the maximum pesticide residues (called a tolerance) allowed on food or animal feed. Any pesticide used to produce food or animal feed must have an established tolerance or an exemption from the requirement of a tolerance for the food or feed to be treated. Food or feed having residues exceeding established tolerances cannot be marketed. Similarly, food or feed treated with pesticide that doesn't have an established tolerance or tolerance exemption cannot be marketed. In both cases, the food or feed can be seized by federal or even state authorities. Imported food and feed must also comply with tolerances or tolerance exemptions set by EPA. Tolerances pertain to all ingredients in pesticide (active and other). Pesticide users meet tolerance requirements by following pre-harvest intervals (sometimes called days-to-harvest) and grazing restrictions that appear on pesticide labels. Pre-harvest intervals or grazing restrictions may limit options for pest management depending on need and timing of the application.
- Worker Protection Standard (WPS) is a federal regulation intended to reduce risk of pesticide poisoning and injury to agricultural workers and pesticide handlers. Owners of farms, nurseries, forests, and greenhouses, and commercial businesses hired to apply pesticides or perform crop advising tasks on an agricultural establishment must comply with the WPS. The WPS only pertains to agricultural operations producing agricultural plants. See https://www.pesticideresources.org/wps-resources/what-are-my-responsibilities-as-a-crop-advisor/ for a detailed discussion of how the WPS affects crop advisors.

CA6: Using Pesticides in an Environmentally Sound Manner

45. Recognize how movement of a pesticide in soil or into water may be affected by:

- **a. Soil texture**
- **b. Erosion**
- **c. Topography/proximity to surface water**
- **d. Pesticide degradation**
- **e. Pesticide persistence**
- **f. Pesticide solubility**
- **g. Pesticide adsorption**
- **h. Degradation processes**
- **i. Precipitation and runoff**
- **j. Leaching**
- **k. Source of entry into the environment**
- **l. Organic matter**
- **m. Hydrolysis**

See the "[Surface, Groundwater, Runoff, and Leaching]" pages of the Pesticide Environmental Stewardship website for information on how movement of pesticides in soil and into water. See: https://pesticidestewardship.org.

46. Explain pesticide:

a. Degradation

b. Half-life

c. Washing off of foliage via rainfall

d. Photodegradation

a. Degradation is the breakdown of pesticides.
b. Half-life: The amount of time it takes for half of the original quantity of pesticide to be degraded and is a measure of pesticide persistence. The longer a pesticide's half-life, the more persistent it is.
c. Washing off of foliage via rainfall is a way for pesticides to contaminate soil and water. It also can reduce the effectiveness of pesticide applications.
d. Photodegradation: The breakdown of pesticides by sunlight.

47. Explain various spray adjuvants and how they impact product efficacy, crop health and environment.

- Drift control additives - Also called deposition aids, increase the average droplet size to make them less prone to drift. They also reduce coverage on plant surfaces, which could affect pest control effectiveness.
- Surfactants: Also called wetting agents and stickers, help pesticide spray droplets wet plant foliage and spread out evenly over a leaf. This helps the pesticide's effectiveness by increasing a pest's exposure to it. Surfactants are important when treating waxy or hairy leaves. Without proper wetting and spreading, spray droplets often run off or fail to cover leaf surfaces. Too much surfactant can cause excessive runoff and reduce pest control.
- Stickers: Increase the adhesion of solid particles to the target surface. They can decrease the amount of pesticide that washes off during irrigation or rain. Stickers also reduce evaporation of the pesticide, and some slow the degradation of pesticides by sunlight.
- Extenders: Function like stickers and retain pesticides on the target surface, slow evaporation, and inhibit degradation by sunlight.
- Plant penetrants: Enhance the penetration of some pesticides into plants. Some may do so on one species of plant, but not on another. Enhanced penetration can increase the activity of some pesticides.
- Compatibility agents: Allow pesticides that are combined with other pesticides or liquid fertilizers to mix without clumping, having uneven distribution in the spray tank, and in some cases, reduce plugging of the pump and distribution lines.
- Buffers and acidifiers: Used to adjust spray water pH to prevent pesticide degradation.
- Thickeners: Increase the viscosity or thickness of a spray mix. They're used to control drift or slow evaporation after the spray has landed on the target area. Slowing evaporation is important for systemic pesticides to allow them to penetrate the plant cuticle.
- Defoaming agents: Are used to reduce the amount of foam that can form during agitation in the spray tank. Excess foam can interfere with pesticide application.
- Foaming agents**:** Used to increase the placement of a pesticide, such as to reduce drift.

- Water conditioning agents - Used to adjust water hardness. These agents, including ammonium sulfate (AMS) or dipotassium phosphate, bond with hard water ions such as magnesium and calcium to keep pesticides from bonding to the hard water ions. Doing so allows the target plant to more readily absorb pesticide.
- Oil concentrates: Such as crop oil concentrates (COCs), modified or methylated seed oils (MSOs) or high-surfactant oil concentrates (HSOCs), are used to help pesticides penetrate leaves better, improving their effectiveness.

48. Understand soil/pesticide interactions and their influence on pesticide selection, pesticide use, and water quality protection. Be aware of pesticide runoff/leaching potential prediction tools such as Win-PST 3 and be able to recommend mitigation to improve or minimize the negative effects on the environment.

See the "Surface, Groundwater, Runoff, and Leaching" pages of the Pesticide Environmental Stewardship website for information on soil/pesticide interactions. The USDA NRCS West National Technology Support Center, Water Quality and Quantity National Technology Development Team, developed and supports the Windows Pesticide Screening Tool (WIN-PST) . WIN-PST is a pesticide environmental risk screening tool that NRCS field office conservationists, extension educators, crop consultants, pesticide dealers and producers can use to evaluate the potential for pesticides to move with water and eroded soil/organic matter and affect non-target organisms. See: https://www.nrcs.usda.gov/resources/tech-tools/windows-pesticide-screening-tool-win-pst.

49. Recognize how the following impact proper pesticide use in regard to water quality protection:

a. Soil characteristics,
b. Ground cover,
c. Proximity to water sources (surface water, groundwater, wells, etc.).

See the "Surface, Groundwater, Runoff, and Leaching" pages of the Pesticide Environmental Stewardship website for information on protecting water quality.

50. Know that pesticide labels may have mandatory runoff/erosion mitigation requirements to protect endangered and threatened species.

See https://pesticidestewardship.org/endangered-species/esa-and-herbicide-labels/ and https://pesticidestewardship.org/endangered-species/runoff-mitigation-measures/ for current information about Endangered Species Act required runoff/erosion mitigation measures and pesticide labels.

51. Know that pesticide labels may have requirements to obtain Endangered Species Protection Bulletins (Bulletins Live! Two) to identify any location-specific practices to protect endangered and threatened species.

See https://pesticidestewardship.org/endangered-species/esa-and-herbicide-labels/ and https://pesticidestewardship.org/endangered-species/bulletins-live-two/ for information about Endangered Species Protection Bulletins and Bulletins Live! Two and labels.

52. Understand how mandatory runoff/erosion mitigation needs or Endangered Species Protection Bulletin requirements may impact pesticide selection/options.

Runoff/erosion mitigation needs and/or any enhanced mitigation requirements listed in an Endangered Species Protection bulletin for a field may limit the use of certain pesticides, requiring alternative options. For example, if the runoff/erosion mitigation needs can not be met for a particular field, a different pesticide may be needed that better fits with the site. Similarly, if an Endangered Species Protection Bulletin requires mitigation measures that make using the product impractical or impossible, a different product may be needed. This requires some work ahead of time to understand the mitigations required for pesticides that might be recommended. While the pesticide applicator is ultimately responsible for complying with any runoff/erosion control mitigation measures and any mitigations required in an Endangered Species Protection Bulletin, a CCA should be aware of any mitigation needs so that appropriate products can be recommended for a given field.

CA7: Protecting Humans from Pesticide Exposure

53. Be familiar with spray drift and problems drift can cause for applicators and others.

Drift occurs when air currents cause pesticide to be deposited outside a target application site. It may occur as solid or liquid particles at the time of application or as vapors during or after application. Any pesticide that is carried out of the target area by wind or any air current may damage non-target plants, contaminate surface waters, harm wild and domestic animals, or harm people. Herbicide drift tends to be the most noticeable because of its visible effect on plants. "Invisible" effects can also be an issue. For example, pesticide drift might produce illegal residues on a neighbor's crop; even legal residues could be a problem for an organic producer. Since drift is illegal, it can lead to civil, criminal, or administrative penalties (such as fines). Both the applicator and the person (if any) who directs the applicator to use the pesticide can be held responsible for drift. Legal problems may not be the only costs associated with drift. The injured party may choose to sue for damages. Your insurance company may raise your deductible and premiums or even cancel your insurance. Finally, there is the intangible cost of strained relations with neighbors and your clients.

54. Know the factors that affect particle drift and how they affect drift:

- **a. Droplet size**
- **b. Wind speed**
- **c. Application speed**
- **d. Type of spray Equipment**
- **e. Nozzle distance from target**
- **f. Temperature, humidity, and temperature inversions**
- **g. Type of chemical being sprayed**

The object of spraying pesticides is to deposit droplets on the crop or soil surface. However, a lot can happen to a droplet between it leaves a nozzle and contacts the crop or soil.

a. Droplet size: Smaller droplets fall more slowly, evaporate more quickly, and are more easily moved by air currents. Spray droplet size is the most important factor affecting the potential for particle drift.

b. Wind speed: A stronger wind means droplets will be carried farther before they are deposited. Wind can affect any size droplet, but smaller droplets will travel farther than larger droplets.
c. Application speed– If travel speed is too high, spray can move backwards and into upward air currents, increasing the potential for drift. Operating at reasonable speeds (within any label limits) decreases the chance for drift.
d. Type of spray Equipment: Equipment or nozzles that produce fine droplets have a higher potential for drift than those producing large droplets. Mist blowers or air blast sprayers tend to produce many small droplets and release the droplets further from the target, making them highly susceptible to drift. Boom sprayers, on the other hand, tend to produce larger droplets, release the droplet closer to the target, and direct them downward rather than laterally, helping to lower drift potential. Aerial applications are at higher risk for drift than for ground equipment due to the distance droplets travel from the nozzle to the target, speed of the aircraft, and the effects of vortices around the wing tips or from the rotor. Nozzle choice can influence drift. Cone nozzles produce fine, drift-prone droplets. Air induction nozzles, on the other hand, produce large, drift-resistant droplets. Nozzle height**.** The higher a boom or nozzle is set above the target surface, the farther a droplet must travel before being deposited. This means the droplet will be in the air longer and subject to evaporation and wind longer. The greater the distance, the greater likelihood of drift.
e. Temperature increases and humidity decreases: As the air temperature gets warmer and humidity decreases, the water in the spray droplets will evaporate faster than in cooler, more humid conditions. This can make droplets smaller, increasing the risk of drift.
f. Type of chemical being sprayed: The type of chemical is not a significant factor in particle drift. However, the type of carrier used can affect drift. Oil-based carriers tend to produce smaller drift-prone droplets compared to water-based sprays. Also, oil-based sprays evaporate more slowly, allowing droplets to be available for a longer period, increasing drift potential.

55. Know factors that affect spray droplet size and minimize spray drift:

a. Spray pressure
b. Nozzle size and type
c. Spray rate (gallons per acre)
d. Drift control agents (foams, invert emulsions, spray additive stabilizers, etc.)
e. Choice of pesticide
f. Shield spray applications

Droplet size is the most important factor affecting the potential for particle drift; smaller droplets drift farther than large droplets. Spray droplets less than 150 microns in diameter are more prone to drift and droplets less than 50 microns are highly susceptible to drift (for reference, 50 microns is about the diameter of a human hair). Knowing how to manage droplet size will help reduce the potential for drift. There are several factors that come into play:

a. Spray pressure: Higher spray pressures increase the number of small droplets produced. Keeping the spray pressure as low as possible within the range for the nozzle and product you are using will reduce the potential for drift.
b. Nozzle size and type**:** Nozzles with larger openings will produce fewer fine droplets. Nozzles with wider spray angles may allow you to bring the nozzles/boom closer to the target surface, reducing the potential for drift. Some nozzles (such as a flat-fan nozzles that have a pre-orifice

turbulence chamber or air induction nozzles) are specifically designed to produce fewer fine droplets. Note that some pesticide labels may require you to use a specific nozzle type.

c. Spray Rate: Higher spray rates (that is the volume of spray mix applied over a given area) lets you use nozzles with larger openings. Nozzles with larger openings produce larger droplets that are less susceptible to drift.
d. Drift control agents (adjuvants): Drift control adjuvants such as foams, invert emulsions, or stabilizers help reduce the number of small spray droplets. However, they also reduce coverage of the plant surface. Drift reduction adjuvants should be selected based on the pesticide label to avoid compatibility issues. Pesticide labels may require the use of drift control agents under certain conditions.
e. Choice of pesticide: Choosing low-volatility pesticides will help reduce chances of vapor drift. Selecting pesticides that allow the use of larger droplet sizes will reduce the chance for drift.
f. Shielded spray applications: Ground application equipment can be fitted with shields or hoods that completely or partially cover the distance from the boom or nozzle to the ground or target. The shields or hoods reduce the chances of drift by preventing droplets from being moved off target by wind.

56. Understand how precision targeted pesticide applications may be utilized.

Read herbicide label for per season targeted application.

57. Identify mandatory drift management needs on a pesticide label.

Most pesticide labels have drift management requirements. These are often noted under a special spray drift management section on the label but may be listed in sections that discuss use restrictions for the product, including the Environmental Hazards section. Drift management requirements will vary depending on the type of pesticide, application equipment used, and where the pesticide will be applied. When tank mixes are used, the applicator must follow the most restrictive requirements for the pesticides in the mix. Spray drift management requirements may include:

- Using a specific droplet size (medium, coarse, etc.) based on the American Society of Agricultural and Biological Engineers (ASABE) standards.
- Using specific nozzle types, including size, model, and manufacturer.
- Applying under certain weather conditions and/or when temperature inversions are absent.
- Measuring wind speed at the application site.
- Equipment setup and use, such as maximum boom heights above the target, specific nozzle orientations, or turning off outward pointing nozzles at row ends or spraying outer rows.
- Spray drift buffers.

Human Toxicity

58. List pesticide modes of entry into the human system.

There are four ways in which pesticides may enter your body. Pesticides may enter the body through the skin (dermal exposure), by being inhaled (inhalation exposure), by being swallowed (oral exposure), or through the eyes (eye exposure).

- Dermal (Skin) Exposure: The skin receives the greatest amount of pesticide exposure (about 97%). Exposure can occur if pesticides are allowed to get on the skin while mixing or applying, when contacting treated surfaces, or if pesticide-contaminated clothing is not removed promptly and properly cleaned before being worn again. Once absorbed through skin, pesticides can enter the blood stream and be carried throughout the body. Oil-based forms (like emulsifiable concentrates) are absorbed more readily through the skin than water-based pesticides. Water-based formulations and dilutions are absorbed more readily than dry formulations. With any formulation or dilution, the higher the amount of active ingredients, the greater chance that the active ingredient will be absorbed. Skin varies in its capacity to act as a barrier to pesticide absorption. The eardrums, scalp and groin areas absorb pesticides more quickly than other areas on the body. Pesticides can penetrate damaged or open skin much more readily than healthy, intact skin.
- Inhalation exposure: Dust, gases, spray mists, or fumes can be drawn into your lungs as you breathe. The largest particles that are inhaled tend to stay on the surface of the throat and nasal passages. Smaller particles and gases can be inhaled directly into the lungs. Once absorbed through the surfaces of the lungs, chemicals enter the bloodstream and are distributed to the rest of the body. Inhaled pesticides can damage the linings of the nose, throat, and lungs. Those that enter the bloodstream can cause damage to organs and tissues throughout the body.
- Oral exposure: Oral exposure to pesticides can be very dangerous. However, swallowing a significant amount of pesticide is rare among pesticide applicators and almost always due to inexcusable carelessness (e.g., storing pesticide in a drink container). More commonly, oral exposure occurs when pesticide splashes or drifts into your face or when you forget to wash your hands before eating or smoking after you've handled pesticides.
- Eye exposure: The eye is extremely absorbent. Blood vessels are very close to the surface, so pesticides can be easily absorbed into the bloodstream. For their size, eyes can absorb surprisingly large amounts of chemical. They are also very sensitive to many pesticides, some of which are corrosive and can cause severe eye damage or blindness.

59. Distinguish between chronic and acute pesticide exposure effects.

- Acute exposure: Refers to one-time contact with pesticide. Acute effects occur within 24 hours after acute exposure.
- Chronic exposure: Refers to repeated exposure to a pesticide or a group of related pesticides over a long period of time. Chronic effects appear following chronic exposure.

60. Recognize general symptoms of acute pesticide poisoning.

- Mild poisoning or early symptoms of acute poisoning**:** Headache, fatigue, weakness, dizziness, restlessness, nervousness, perspiration, nausea, diarrhea, loss of appetite, loss of weight, thirst, moodiness, soreness in joints, skin irritation, eye irritation, irritation of the nose and throat.
- Moderate poisoning or early symptoms of Acute Poisoning**:** Nausea, diarrhea, excessive saliva, stomach cramps, excessive perspiration, trembling, no muscle coordination, muscle

twitches, extreme weakness, mental confusion, blurred vision, difficulty in breathing, cough, rapid pulse, flushed or yellow skin, weeping.
- Severe or acute poisoning: Fever, intense thirst, increased rate of breathing, vomiting, uncontrollable muscle twitches, pinpoint pupils, convulsions, inability to breathe, unconsciousness.

61. List possible chronic effects of pesticide poisoning.

Chronic poisoning symptoms may include: Nervousness, slowed reflexes, irritability, or a general decline in health.

62. Recognize general first aid procedures to follow if pesticide gets on skin, in eyes, in mouth or stomach, or if inhaled.

The pesticide label will have specific first aid information. It is a good idea to read and understand the first aid section before using pesticide. There may not be enough time or chance to look up the information in an emergency. Regardless of the route of exposure:
- Separate the victim from the source of the exposure, protecting yourself (and first responders) from exposure when doing so. This includes using appropriate PPE. You may be of little help to the victim if you get exposed.
- Always have a source of clean water readily available when you work with pesticides. Water is necessary in responding to most exposures. In an emergency, any source of reasonably clean water will suffice, including nearby surface water.
- Never give anything by mouth to an unconscious person.
- If a victim is convulsing, protect the person's head and watch that breathing continues.
- Learn how to give artificial resuscitation in case you ever have to help a victim whose breathing stops or becomes impaired.

For skin exposure:
- Remove all contaminated clothing immediately. If you think the clothing can be reused, wash according to directions provided. If not, properly dispose of the clothing.
- Drench the exposed skin with water.
- Wash the exposed skin with soap and water and rinse well. A shower is best. Avoid harsh scrubbing because it may cause abrasions, enhancing pesticide absorption through the skin.
- Gently dry the exposed skin and wrap it loosely in a cloth or blanket, if necessary.
- Loosely cover chemical burns with a soft, dry cloth. Do not apply ointments, powders, or other medications to the burns unless instructed to by medical personnel.

For inhalation exposure:
- Carry the victim to fresh air immediately (do not make them walk).
- Have the victim lie down and loosen all tight clothing.
- Keep the victim warm and quiet. Do not let the person become chilled or overheated.
- Keep the victim's chin up to ensure that air passages are open for breathing.

For oral exposure:
If pesticide has gotten into the mouth, but hasn't been swallowed, rinse the mouth out with plenty of water. After rinsing, the victim drink at least 1 quart of water or milk to dilute small amounts of pesticides that may have been swallowed during rinsing.

If a pesticide has been swallowed the most crucial decision to make is whether or not to induce vomiting. The decision must be made quickly and only by a medical professional because the victim's life may depend on it. Call a medical facility or the Poison Control Center immediately and relay label directions about inducing vomiting. Induce vomiting only if the pesticide label and medical professional tells you to do so and only as a first aid measure until the victim can get medical attention. Do not spend a lot of time inducing vomiting if it delays getting the victim to a hospital.

Never induce vomiting if the victim:
- Is unconscious or is having convulsions. The victim could choke to death on the vomitus.
- Has swallowed a corrosive pesticide as it will cause more burns as it comes back up. It could also be aspirated into the lungs, burning lung tissue.
- Has swallowed and emulsifiable concentrate or oil solution. These may kill the person if aspirated into the lungs during vomiting.

63. Recognize that pesticide labels are the best source of information concerning level of toxicity, handling precautions, first aid procedures, and other safety information.

Pesticide labels are the best sources of information regarding acute toxicity (signal words), all handling and use precautions and requirements, first aid procedures, and other safety related information. Labels are also a legal document, so pesticide users need to follow all safety and use directions on handling pesticides safely.

64. Know personal Protective Equipment (PPE) to be used during mixing and application of pesticides and where to find that information on a pesticide label.

- **d. Gloves**
- **e. Body covering**
- **f. Apron**
- **g. Footwear**
- **h. Protective eyewear**
- **i. Head and neck coverings**
- **j. Respirators**

Pesticide labels will list required personal protective equipment (PPE) for those mixing and/or applying pesticides under the "Precautionary Statements" section of the label. These are the minimum required PPE; users can always use more.

- Gloves: most labels require the use of waterproof or chemical-resistant gloves during handling activities. Gloves should work anytime pesticides may get on your hands, including when working on contaminated equipment or contaminated surfaces. Gloves that go up over the wrist and at least halfway to the elbow should be used. Choose gloves designed to give additional protection for a particular job, such as elbow-length gloves for mixing a loading. Glove materials include nitrile rubber, butyl rubber, neoprene rubber, natural rubber, polyethylene, polyvinylchloride (PVC), viton, and barrier laminate. Pesticide labels will list specific types that are acceptable to use. In general, do not wear cotton and leather gloves because they absorb and hold the pesticide close to your skin for long periods of time. However, cotton gloves may be specified on some fumigant labels.

- Body covering**:** regular work clothes of long pants, long-sleeved shirt, shoes, and socks are acceptable for many pesticides. Shirts and pants should be made of sturdy material, free of holes and tears, and made of tightly woven material.
- Coveralls are one: or two-piece garments that fit loosely over the regular work clothes, covering the entire body except for the hands, feet, and head. Some are water resistant and disposable. Others are reusable. Well-designed coveralls have tightly constructed, sealed seams and snug, overlapping closures that do not have gaps or unfasten readily. Some may have elastic wrists and ankles. Coveralls can be made of various materials including non-chemical-resistant fabric or chemical-resistant coated, non-woven fabric. (Tyvek® is one brand name.) Fabric coveralls are not chemical-resistant and should only be used when handling pesticides. Chemical-resistant coveralls may be required by the label and are used when a large amount of pesticide could be deposited on your clothing.
- Apron: a chemical-resistant apron that extends from the chest to at least the knees protects the front of the body from splashes and dust. Some aprons have attached sleeves and gloves. Labels may require chemical-resistant aprons for mixers and loaders.
- Boots (Footwear): sturdy shoes and socks may be sufficient to protect your feet during many handling activities. If the label specifies "chemical-resistant footwear," you can wear chemical-resistant shoes or boots or chemical-resistant shoe coverings over your work shoes or boots. Never wear open-toed shoes or sandals as they do not provide protection for the feet. Also, canvas and leather shoes and boots are not appropriate because they absorb pesticides easily and hold it against the skin, increasing skin exposure. If pesticide is likely to get on your lower legs or feet, chemical-resistant boots that extend at least halfway up to the knee are a good option. Some fumigant labels may tell you not to wear footwear that is rubber or chemical-resistant for the same reasons as mentioned for gloves.
- Protective eyewear: If a pesticide label requires protective eyewear, you must wear shielded safety glasses; a full-face respirator; goggles; or a full-face shield. Shielded safety glasses and face shields are often a good choice as they're relatively comfortable and do not cause fogging or sweating. Face shields that are cupped inward around the throat give better protection from splashes than straight face shields. Tight fitting goggles should be used when you are enveloped in spray, mist, or dust. Polycarbonate goggles that have protected air baffles will reduce the chances of fogging.
- Head and neck coverings**:** The neck and head must be protected, particularly in situations where exposure from overhead dust or sprays is possible. Chemical-resistant hats with wide brims or a chemical-resistant hood are available. Headgear must not contain absorbent material such as cotton, leather, or straw. Many chemical-resistant jackets or coveralls come with protective hoods.
- Respirators**:** respirators protect you from breathing in pesticide-contaminated air. Labels may require the use of a respirator and tell you the specific types to use. Respirators used must be approved by the National Institute for Occupational Safety and Health (NIOSH). In cases where a label doesn't require their use, consider using a respirator if the label states "do not breathe

vapors or spray mist" or "harmful or fatal if inhaled." There are two major groups of respirators:

- Air-supplying respirators provide clean, uncontaminated air (outside source). They are typically used in low-oxygen environments. Often, their bulky size puts strain on the user.
- Air-purifying respirators use physical and chemical filters to trap and remove pesticides from the air being breathed. Adequate oxygen must be present in the air that's being breathed since this type of respirator does not provide oxygen. When pesticide contaminants are present as a solid or liquid particulate, a particulate respirator or filter is specified on the label. If gases or vapors are present, a contaminant-specific chemical cartridge or cannister will be required. Respirators approved for use only against particulates cannot be used for gases. Air-purifying respirators come in both powered and non-powered types. A powered type uses a blower to move contaminated air through a purifying filter and can be used with a tight-fitting facepiece or a loose-fitting hood. Non-powered types can be either half-mask or full-face devices that have a filtration unit (cartridge or cannister) between your breathing passage and the contaminated air source.

65. Describe proper cleanup procedures for application equipment and protective gear.

a. Care of equipment
b. Cleaning sprayers
c. Cleaning granular and dust application equipment

Before removing PPE, wash the outside of gloves with detergent and water and then do the same with other PPE you're wearing. For PPE labeled as disposable, it is designed to be worn once and thrown away. This includes particulate-removing masks, filtering and/or vapor-removing cartridges and cannisters, and a few cartridge respirators. Wash reusable PPE thoroughly inside and out between uses, even if used briefly, according to manufacturer's instructions. If there are no instructions, clean after each day's use. Launder work clothes and fabric coveralls daily and separately from the household laundry to avoid contaminating other clothes. Discard any items that are drenched or saturated with pesticide concentrate. Clean protective eyewear with detergent and hot water. For respirators, remove and discard filters, cartridges, and cannisters, and wash the respirator and facepieces according to the manufacturer's instructions. Remove contaminants under running water with a soft brush.

a. Care of Equipment: Whether equipment is very simple or very complex, it must be properly cared for so that it remains reliable and properly applies with pesticides. Care includes following any manufacturer's maintenance schedules or service intervals. Cleaning equipment, including hoses, nozzles, pumps, tanks and hoppers is very important to keep equipment operational. Pumps and other liquid-containing portions of the sprayer that will be stored below freezing weather should be thoroughly drained or have antifreeze circulated through the equipment. Nozzles should be removed, cleaned, and stored.
b. Cleaning Sprayers: Clean spray equipment away from wells, surface water, or other sensitive areas. Avoid washing equipment repeatedly in the same area unless using a containment pad. Ideally, sprayers should be cleaned at the application site so that rinsate can be applied to the site within label limits. Pesticide labels, particularly herbicides, may provide specific cleaning procedures. Be sure to wear appropriate protective clothing when cleaning any piece of application equipment. A general cleaning procedure includes washing the outside of the

sprayer with water and a small amount of detergent if necessary. Fill spray tank approximately 1/3 to ½ full of water and run any agitator or flush lines for several minutes. Using a commercial tank cleaning and neutralizing compound can further decontaminate the tank. Nozzle, nozzle screens, and suction screens should be cleaned with either compressed air or a soft bristle brush and water. When rinsate cannot be applied to an appropriate area, it must be drained into a holding container. Rinsate can be used as makeup water for filling a spray tank when using the same pesticide at a later date in compliance with the label and state laws. Rinseate can also be transported to a hazardous materials disposal site.

c. Cleaning granular and dust application equipment: Granular and dust application equipment must be cleaned following use and prior to winter storage. Here are some recommended steps:

    1. Remove all pesticides from the device. To be thorough, this may require taking it apart.
    2. Clean the inside of the hopper.
    3. Use sandpaper or a wire brush to clean rusted parts. Paint the cleaned parts.
    4. Coat the inside with oil. Oil or grease the bearings.
    5. Thoroughly clean and oil the flow control slides or valves.
    6. Excess oil should be wiped off if it will contact the chemical upon the next use.

66. Recognize proper ways to dispose of pesticides and containers.

- Pesticide disposal: Follow any disposal directions on the pesticide label. Pesticides which are still factory-sealed may often be returned to the manufacturer. Check with the company to see if they will take your surplus back. Excess pesticides can also be disposed of through a collection drive sponsored by a local or state agency. Another option is to contact a commercial hazardous waste hauler for pickup at your location.
- Store your extra pesticides in a locked storage area while you are waiting to dispose of them. They must be kept in their original containers with the label intact.
- Container disposal: Follow any container disposal requirements on the pesticide label. Keep in mind that empty pesticide containers are not really "empty." They still contain small amounts of pesticide even after they have been rinsed out properly. Do not leave even triple-rinsed pesticide containers unsecured at the application or mixing/loading site. Someone who doesn't know better may be exposed to pesticide. The only options for disposing of emptied pesticide containers are to return to the dealer for reuse or refilling, recycling them at a pesticide container collection drive, taking them to a chemical collection drive, or disposing of them at an approved disposal facility.

67. Describe safe storage of pesticides.

- Follow specific storage directions in the "Storage and Disposal" section of the pesticide label. Keep in mind that some pesticides, such as some biological ones, need to be stored at certain temperatures to maintain their viability.
- Pesticide storage facilities should be in an area where flooding is unlikely. It should be downwind and downhill from sensitive areas such as houses, ponds, and play areas. There should be no chance that runoff or drainage from the site could contaminate surface or

groundwater. The location should be selected so that the soil, geological, and hydrologic characteristics will not lead to contamination of any water systems through runoff or percolation. Ideally the storage should be a separate facility, but if this is not possible, a secure area within an existing building can be used. The facility should also allow safe, efficient access but limit unauthorized users from accessing the facility.

- Pesticides should be stored in a cool, dry, airy environment. Mechanical ventilation that vents outdoors is an important feature to moderate temperature and humidity, to remove any fumes in the storage facility, and to reduce worker exposure to the fumes. A properly installed ventilation system should have a switch outside, so that the fan can be turned on before anyone enters the facility. Fuel and heating sources should be located outside the storage area to reduce the chance of fire. The storage area floor should be sloped, bermed, or equipped with a sump to is can contain at least 25% of the total liquid volume stored. There should be sufficient lighting to detect leaks and deteriorating packaging. A spill cleanup kit should also be available. Dry-chemical fire extinguishers and systems should be used to reduce runoff and contaminated water in case of a fire. Shelving should be metal or plastic as they're easier to decontaminate. Aisles need to be wide enough to allow easy access, even during an emergency, and to prevent from damaging containers or knocking them off the shelf. An emergency eyewash station, PPE, and first aid supplies should be nearby, but outside of the storage area. Emergency numbers should also be posted at each entrance. The storage area should be fenced in or at least able to be locked tightly to prevent unauthorized access. Weatherproof warning signs should be outside the facility to discourage unauthorized entry.

68. Recognize procedures to follow when a pesticide spill occurs.

The following are general procedures for responding to a spill. Remember to wear all label required protective equipment during the entire spill response. It's also suggested that you not leave the spill site until someone relieves you. (Someone should be at the site until it's cleaned up and the danger is removed.) For legal protection, keep records of the spill response activities, including conversations with regulatory authorities, emergency response personnel, and the general public. Photographs help document the cleanup process.

Proper spill response involves the "4Cs":

- Control the spill.
- Contain the spill.
- Contact authorities to report the spill.
- Clean up the spill.

Control the spill - Take immediate steps to stop a leak or spill. Rope of contaminated area to keep people away from the spill. Avoid contact with any drift of fumes. Do not use road flares if you suspect the spill is flammable. If necessary, evacuate people downwind from the spill.

Contain the spill: Keep the spill from spreading by keeping it in as small an area as possible. This may require constructing dikes or dams out of soil or absorbent pillows. Do not allow spilled material to get into water bodies, including storm sewers or drains. When practical, recover as much uncontaminated spilled material as possible and store it properly for later use. Use absorbent materials such as fine sand, clay, or pet litter to cover the entire spill. Avoid using sawdust or sweeping compounds since they present a fire hazard if the pesticide is a strong oxidizer. Contain spills of dry formulations by lightly misting the material with water or covering the spill with a plastic tarp.

Contact authorities: The risks to people and the environment vary based on what was spilled, how much, and where. In some cases, the risks are so great that you're required to report the spill to local, state, and/or federal authorities. Whom you must notify will also vary depending on the situation. If a spill contaminates surface water, immediately contact the state agency responsible for streams and fisheries and the agency for pesticide regulation. Local Emergency Planning Committee (LEPC), State Emergency Response Commission (SERC), or state agency responsible for environmental protection can provide a summary of local, state, and federal requirements. At least one person at your business should have this information. Those transporting pesticides should have this information with them.

Clean up the spill: Once a liquid spill is soaked up, put the contaminated absorbent materials, pillows, tubes, or pads into heavy-duty plastic bags for disposal. For dry spills, sweep or shovel the material into the bags. If you used a tarp, discard that as well. Be sure to comply with any pertinent hazardous waste disposal regulations and any label requirements.

If necessary, use household bleach in water (approximately 30 percent bleach), hydrated lime, or a commercial decontamination preparation to help decontaminate or neutralize the area. Work the cleaning material into the spill area using a coarse broom. Then add fresh absorbent material to soak up the contaminated cleaning solution. Sweep up this material and place it in a plastic bag or drum for disposal. You may need to repeat this procedure several times to ensure that the area has been thoroughly decontaminated.

Soils contaminated due to application errors or minor spills can sometimes be cleaned up by immediately applying activated charcoal. Charcoal may absorb or tie up enough chemicals to avoid significant plant injury and long-term contamination. If soil is saturated with pesticide, you must remove it and dispose of it according to state guidelines. You can then cover the area with at least 2 inches of lime and put fresh topsoil over the lime.

Clean contaminated vehicles and equipment using household bleach in water (approximately 30 percent bleach) or an alkaline detergent (dishwashing soap) solution. Items such as brooms, leather shoes, and cloth hats cannot be effectively decontaminated and must be discarded along with disposable garments and gloves or badly contaminated clothing. As soon as you finish the spill and equipment cleanup, wash yourself thoroughly with soap and water. Wash any skin that might have been exposed, and always wash your face, neck, hands, and forearms.

69. Be familiar with the Restricted-Entry Interval (REI) listed on the pesticide label to avoid unnecessary exposure.

Part of the Worker Protection Standard (WPS), the restricted-entry interval (REI) is the time immediately after a pesticide application where agricultural workers cannot enter a treated area. This is noted under the "Agricultural Use Requirements" section of a pesticide label. The REI only pertains to pesticides that fall under the (WPS) regulations.