IPM/POLLINATORS

BEGINNING FARMERS

A Subpoena for Suffering Plants

This mix of hands-on, participatory, field-based learning, and classroom discussion will give you the tools to summon your symptomatic plants for cross-examination of the factors affecting their current condition.

TEACHING OBJECTIVES: WHY DO THIS?

- Identify plant diseases, insects, nutritional disorders, and weeds that commonly affect vegetable crops. Experience this through field walks and classroom learning.
- Demonstrate differences insect feeding patterns and disease signs
- Predict causes for the problem and learn about some potential solutions.

BEST LOCATION

A farm or greenhouse with different types of plants being grown for harvest. Also, a small classroom setup to examine plants and insects.

BEST TIME OF YEAR

September through April for a stronger classroom component, or May through August for a stronger field walk component.

LEARNING OBJECTIVES: WHAT CAN PARTICIPANTS LEARN?

- Differences between major groups of problems affecting plants by learning their symptoms and signs
- Scouting techniques to determine seriousness of problem and and when to treat
- Techniques and tools for management
- Poor conditions or management that may lead to problems such as:
  - lack of or poor crop rotations
  - presence of alternative weed hosts to diseases or insects
  - poor seed and transplant quality
  - poor soil and/or water quality
  - not know if a pesticide works well to control the problem
  - not know typical weather patterns
  - problem caused by herbicide resistance
  - not know pests' biology

IPM/Pollinators

A Subpoena for Suffering Plants

IMPORTANCE FOR BEGINNING FARMERS

This information will provide an introduction to production limiting conditions in vegetable crops. Beginning farmers may not know how to identify a problem or the full array of tools available to them or how their decisions can affect the whole farm. Also, many growers may have unanswered questions regarding management options.

UNIQUE ASPECTS OF THE CURRICULUM

This training serves as:

1. an introduction to the overall concepts of integrated crop management and their practical use in production agriculture
2. a discussion forum where growers can ask questions relevant to their through interests, ideas, and specific needs
3. an opportunity for growers to obtain resources that can help inform their management decisions

Facilitator Planning & Preparation

There are four ideas for activities in this module, and they can be run simultaneously or individually. There are also outlines for structuring an outdoor on-farm component that take some more time to prepare and conduct. How much time needed for prep depends on the knowledge of the facilitator and access to resources.

Activity	Est. Instructional Time
Primary Activity 1: Insect Investigator	2 Hrs
Primary Activity 2: Nutrition Deposition	2 Hrs
Primary Activity 3: Pathogen Patrol	2 Hrs
Primary Activity 4: Weed Proceedings	2 Hrs
Additional Activity: On-farm activities	8 Hrs

Technical Content

Facilitator Background Information:

Nobody, not even the experts, have a complete understanding of the biological systems at play on a farm. Everyone shares a piece of the puzzle from their experiences. Someone might be wrong, you might not know what something is, and that's OK. Nobody learns from being right all the time. These opportunities to meet and focus on crop management topics for beginners are not a competition. The take home messages are intentionally small and concise so as not to overburden or confuse and create room for experiences to provide answers.

This is not about what you know as an facilitator. This is about what the group has experienced and understands enough to share, and where one can go for more information. Even if participants have no experience growing plants, their interests and intent can be mined and molded.

The overarching objective of this module is to encourage participants to understand and recognize symptoms, signs, circumstances, and patterns leading to plants that are suffering. Sometimes these conversations can lead to opinions about what one can do about it, and that is OK, but that should not be the focus. Identifying the problem and the factors contributing to the plant's problem(s) is the common ground we can all share.

Facilitators for this module will need to prepare for several eventualities:

- The facilitator or the participants may have different levels of knowledge on the subject of crop management of pests and fertility.
- Participants may or may not know each other or the instructor.
- The timing of the workshop may or may not coincide with conditions or facilities that support an outdoor field walk activity.

A Subpoena for Suffering Plants

Before the event:

1. The first objective of the facilitator of these activities is to understand the core takeaway messages for whichever activity they focus on through pre-reading the Facilitator Background sections of the activity and paging through the accompanying resources to see how they are organized and what they offer.
2. The second objective is to decide on the which parts of the module and setting of the event will be used. Then learn about the attributes of the different “Easy Learning Activities” to ensure you establish a learning environment that is supportive of all types of learners. For example, in a fully indoor workshop, one might prepare for sharing some pictures of known issues accompanied by the stories to explain the situation of what is in the photo. In an in-season workshop, consider whether there are opportunities to see first-hand, crop pests and symptoms on site, or whether you or participants should collect items ahead of time from their own farms and gardens to bring together and discuss. In a quiet crowd, or with a dominating personality in the room, consider more individual or paired activities instead of large group activities.
3. The third objective before the event is to decide on how deep into each activity you and your participants would like to go. If you already have contact and rapport with the participants you can build this course around their needs by asking them what they want. Consider assigning students to read only certain sections of the resources ahead of class, instead of the whole resource.

At the event:

1. The first objective is to establish a safe atmosphere to facilitate knowledge sharing from within the pool of participants. There are several icebreaker activities from which to choose. (See handout in Intro to Curriculum, LINK)
2. The second objective at the event is to establish the structure and flow of the experience, guided by the participants’ input. You may be able to do this ahead of time, or you could build this into an icebreaker activity.
3. The third objective is to keep things moving and on time. Set timers, or ask for a timekeeper to help. Identify linkages between the discussions and activities. Make connections with the conversations from the audience to the topics in the curriculum to promote a flow of information. But be kind.

KWL Process

Know, Want to Know, Learn

Suggested prompting questions to find out what participants want to learn:

- Which crops do you grow?
- How many acres and markets do you work with?
- What is your primary role on the farm?
- What production factors do you hope to change and which do you now want to change?
- What kinds of sprayers or spreader have you used before or use on your farm?

Suggested prompting questions for farmers to share from their experience:

- Have plants ever died on your farm? What do you think caused it?
- What sort of visual cues do you look for that indicate plant stress?
- What is your favorite tool or technique for managing your most common problems?
- Where or who have you gone to get more information about a problem?

Primary Activities

Overview of the main activities in this module

All of these activities can be combined in a single field walk or series of field walks, with a single group or multiple groups, with one or more classroom sessions. If only one activity is desired, a longer preparation and deeper dive into that specific topic may be an option.

Activity 1

Insect Investigator

In this "who done it" activity, students will learn to differentiate symptoms, signs, and basic appearances of caterpillars, beetles, stink bugs, aphids, leafhoppers, thrips, mites, and flies. Students will also learn how to collect and store insects for photography and sending to a qualified entomologist or to use a phone app.

Activity 2

Nutrition Deposition

In this "eyewitness account" activity, students will learn how nutrients are used by plants, how plants show symptoms when lacking, what they look like, why toxicities and deficiencies occur, and when are they more likely to occur. Students will also learn how to collect, package, and mail representative soil and plant tissue samples to a diagnostics lab for ID.

Activity 3

Pathogen Patrol

In this "walk the beat" activity, students will develop an eye for the patterns of plant problems from diseases, insects or nutrients. They will practice the best ways to collect, package, and mail representative samples to a diagnostics lab.

Activity 4

Weed Proceedings

In this activity, students will "take weeds to court" to understand primary reasons for integrated weed management in vegetable production at different scales. Students will also learn how to identify common species in a field setting using guides or phone apps.

Activity 1: Insect Investigator

In this "who done it" activity, students will learn to differentiate symptoms, signs, and basic appearances of caterpillars, beetles, stink bugs, aphids, leafhoppers, thrips, mites, and flies. Students will also learn how to collect and store insects for photography and sending to a qualified entomologist or phone app.

METHOD

In the classroom, first to go over basic patterns and symptoms of insect-, mite- and slug- related issues. Then, optionally, a field walk to find evidence of insect activity and specimens to observe.

KEY TERMS

Symptoms: Expressions from the plant, such as purpling, spots, bleaching, yellowing between the veins, discolored veins, wilting, twisting, puckering, lumps, bumps, holes, scrapes, etc.

Signs: Physical pieces or impressions left by an afflicting organism, such as frass (poop), shed skins, spores, bacterial ooze, foot prints, trail cam footage, etc.

Economic Threshold: The point at which taking an aggressive reaction to manage the pest makes the most economic sense.

Weather Model: Programs that read weather data and perform calculations that determine the risk of problems from organisms that cause problems in plants.

MATERIALS NEEDED

- Easy Learning Activities *
- Scouting and Identifying Vegetables for Insect Pests *
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions *
- Sample Pictures of Known Issues and Their Stories*
- Pictures from participants with or without answers
- Packaging materials to mail samples
- Student Handout printed for each student
- Evaluation printed for each student
- Optional: Computer with internet access.
- Optional: Smart TV or projector to show pictures on slideset.
- Outdoor option:
  - Cooler (ice can help slow bugs down to better observe)
  - Gallon ziplock bags
  - One bug net (How to use a bug net) https://youtu.be/gQb1BLdcfUM?si=WQp4U0HZoTsGlI6G

* This indicates a resource with a link found in list of resources and QR codes

Activity 1: Insect Investigator

FACILITATOR BACKGROUND

Insects physically damage plants with their mouths. Insects that make holes have chewing mouth parts, and these include beetles and grubs, caterpillars and sawfly larvae, grasshoppers and crickets, fly maggots, ants, earwigs, pillbugs, and slugs. Draw in your mind or on a piece of paper a pair of scissors or pliers that cut or pinch. This is how their mouth parts work. Depending on where they make the hole, the plants can also exhibit wilting symptoms. For example, squash vine borer is a caterpillar that bores into squash stems at the base of the plant and causes the plant to wilt.

Insects that have piercing and sucking mouthparts can appear to leave no trace but with continued feeding and more individuals feeding together they can create yellowing, twisting, cupping, curling, wilting, and russeting (speckled spotting) of plant parts. Draw in your mind or a piece of paper a hypodermic needle that pokes and sucks like their mouthparts. Insects with piercing and sucking mouthparts include aphids, leafhoppers, stink bugs, whiteflies, thrips, and mites.

Larvae or caterpillars are not developed insects so mostly eat and deposit frass (insect poop). While adult insects mostly lay eggs. These eggs come in many shapes, colors, and sizes, and are laid singly or in groups. These can often be a way to ID the pest and sometimes even be what is treated to managed the insect. Insects also go through a series of life stages in which they change their appearance. At each of these transitions, they shed their skin, which can be left behind and used as evidence of their presence. They also poop, which can be spread all over as little pellets if they are mobile, or piled up in one spot if they are slower moving or making a hole in a plant. Aphid feeding can also generate a black mold on crops from the sugary ‘honeydew’ that they leave behind, and slugs leave behind a shiny iridescent trail that catches the light.

Activity 1: Insect Investigator

FACILITATOR BACKGROUND (cont.)

With most insects, you can wait to treat them when they are present. This is a reactive approach. Some insects can also be planned for following temperature-based weather models that predict their life stages (growth), or forecasting tools that show the likelihood of an insect migration from another part of the world. Sometimes it is easier to prevent infestation with netting or row covers, planting at a different time of year, or avoid a certain crop or variety all together. Growing different crops in different places from year to year is another way to reduce infestations of some bugs.

Whether you have symptoms, signs, or the insect itself, there are ways to identify it. Resources include the information included in this module, the MSU Plant & Pest Diagnostic Lab, bugguide.net, and various phone apps.

The takeaway messages are:

1. Some bugs make holes or scrapes because they have chewing or rasping mouthparts, while others have piercing or sucking mouthparts that can leave spots or contort plant tissues.
2. Some insects can be folllowed by weather models and trapping with lures (attracting and catching the insect) for preventive management, while others can be directly observed on plants for to treat them when present.
3. There are places to send captured insects or pictures for identification.

Activity 1: Insect Investigator

PROCEDURE

1. Send the resources from this module to participants ahead of the event, and read them yourself. For an outdoor component, you will need to source a bug net, gallon ziplock bags, and a cooler with ice.

2. Pick an Easy Learning Activity as an icebreaker.

3. Pick another Easy Learning Activity to discuss the patterns of an insect infestation. Using facilitator notes and prepared pictures, practice vocabulary to describe the types of symptoms and signs made by the insect. Is the hole all the way through the leaf? Did they leave anything behind, like poop, or eggs, or a cocoon? How big are the holes, or how much plant tissue is left?

4. Practice filling out an MSU Plant & Pest Diagnostics lab form and practice packaging collected insects properly for shipment.

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Activity 1: Insect Investigator

PROCEDURE (cont.)

5. Discuss how phone apps can be used to identify insects. Does anyone have any recommendations or experiences with them; good or bad? It's ok if people already have apps and want to show them off, but do not try to get everyone to download or use apps for an in-depth tutorial as there are several options, phone types and levels of comfort with using them, and it is difficult to keep everyone together without devolving into highly individual IT problem solving.

6. Mention how weather models can be used to predict insects coming to the plants and moving in from other places but do not try to demonstrate how to work with these models because it is not a very entry-level experience and is more likely to confuse or at least detract from the energy of the room as you click around faster than anyone can follow.

7. Pick another Easy Learning Activity to engage in a conversation about how much of an insect problem is tolerable for themselves or for their target markets. Is one aphid on one plant enough to justify a management action (control)? Is it good to manage insects without ever looking for them?

Activity 1: Insect Investigator

VARIATIONS

Outdoor option:

1. Start in the classroom with an icebreaker, discussion of the concepts using an easy learning activity or two.
2. Go outside to observe insects in crops. A bug net can be shared. Empty the bug net into a ziplock bag to see the contents. Use the cooler with ice to chill the insects in the bag so they don't move around so much.
3. Take a sample of insects that look the same from this collection, practice taking up close pictures, put them in ziplock bags, and package for mailing to a diagnostics lab.
4. Upon returning to a classroom or back to vehicles, discuss whether or not some of the observed symptoms or signs were from something other than an insect.

PRINTABLES & HANDOUTS

- Sample Pictures of Known Issues and Their Stories
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions
- Student Handouts
- Evaluations

CONNECTIONS

Some diseases, like viruses, are dependent on insects, like aphids and thrips, to infect plants. Some weeds are hosts to insect pests, like Colorado potato beetle on horsenettle, or leafminers on amaranths. Some nutrient stress symptoms can look like feeding damage from a piercing and sucking insect.

Activity 2: Nutrition Deposition

In this "eyewitness account" activity, students will learn how nutrients are used by plants, where plants show symptoms, what they look like, why toxicities and deficiencies occur, and when to expect them. Students will also learn how to collect, package, and mail representative soil and tissue samples to a diagnostics lab.

METHOD

Classroom first to go over basic patterns and symptoms of nutrient-related issues. Then, optionally, a field walk to find evidence of nutrient stress to observe.

Symptoms: Expressions from the plant, such as purpling, spots, bleaching, yellowing between the veins, discolored veins, wilting, twisting, puckering, lumps, bumps, holes, scapes, etc.

Signs: Physical pieces or impressions left by an afflicting organism, such as frass, shed skins, spores, bacterial streaming, foot prints, trail cam footage, etc.

pH: A measurement of the amount of hydrogen in soil or water, indicating how acidic or basic it is.

Cation Exchange Capacity: A measurement of soil texture indicating how well nutrients and water will stay available to plant roots.

MATERIALS NEEDED

- Easy Learning Activities
- Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida and Beyond
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions
- Sample Pictures of Known Issues and Their Stories
- Pictures from participants with or without answers
- Packaging materials
- Student Handout printed for each student
- Evaluation printed for each student
- Optional: Computer with internet access
- Optional: Smart TV or projector to show pictures
- Outdoor option:
  - Cooler or box
  - Gallon ziplock bags
  - Shovel
  - Bucket

Activity 2: Nutrition Deposition

FACILITATOR BACKGROUND

Nutrient-related issues in crops are frequently put on display through their leaves. The symptoms include yellow colors between the leaf veins, crispy brown edges to leaves, spots, bleaching, and purpling.

It is important to recognize any patterns between the older leaves and the newer leaves. Some nutrients are mobile inside the plant, and so when there isn't enough to go around the plant will move the nutrients from the oldest growth to the newest growth and the deficiency will show up on the oldest growth. When a non-mobile nutrient is short, the plant keeps it where it is and the new growth shows the deficiency symptom. The complete opposite occurs when a nutrient is so high that it is toxic to the plant. Toxic levels of mobile nutrients show symptoms in the new growth, and toxic levels of non-mobile nutrients show symptoms in the old growth.

These symptoms are not always related to the levels detected in the soil. The pH and the cation exchange capacity (CEC) play a large role in the availability of nutrients to plants and a soil test will tell you what condition your soil is in for the best availability of nutrients. A low pH will cause deficiencies and toxicities of certain nutrients, and a high pH will affect the availability of others. The CEC is an indication of how large your soil particles are, and affects both how you fertilize and irrigate.

Another factor in nutrient availability is the balance between certain nutrients. High levels of some nutrients inhibit the uptake of others. An antagonized element may be present in adequate levels, but there is so much of another element present the plant doesn't have access to it.

Activity 2: Nutrition Deposition

FACILITATOR BACKGROUND (cont.)

For example, adequate potassium increases the plant demand of iron and manganese, but if it is too high it will hinder utilization of magnesium, boron, nitrogen, phosphorus and calcium. If calcium is in excess it can simply out-compete other elements such as potassium and magnesium for uptake sites on the roots, or it can change soil chemistry by elevating pH to the point iron and boron become unavailable.

Soil and tissue testing labs are essential to understanding the nutrient dynamics at the root level. These same labs will often include tissue sampling in their portfolios, which can give you information on whether the soil nutrients are in balance or available enough for plants to actually bring them into their tissues.

In situations where soil pH, CEC, or individual nutrient levels are unbalanced in the root zone, liquid fertilizers can be sprayed onto the leaves as a supplement to a soil-based fertility program, and driven by data from tissue-tests.

The takeaway messages are:

1. Nutrient mobility contributes to where symptoms can be found.
2. pH and cation exchange capacity are key factors for soil fertility.
3. The amount of one nutrient can affect the availability or demand for another.
4. There are places to send tissues and soils for nutrient analysis.

Activity 2: Nutrition Deposition

PROCEDURE

1. Send the resources from this module to participants ahead of the event, and read them yourself. For the outdoor option you will need to source gallon ziplock bags, shovel, bucket, and a cooler or box.
2. Pick an Easy Learning Activity as an icebreaker.
3. Pick another Easy Learning Activity to discuss the patterns of an insect infestation. Using instructor notes and prepared pictures, practice vocabulary for the nuances in the types of symptoms and signs of a nutrient issue. What part of the plant is showing symptoms? Do we know anything about the soil or fertilizer applied? Is it actually a pathogen or insect?
4. Discuss the forms in which fertilizer can be found. What might the costs/benefits be to granular versus liquid, or manures versus composts? Can anyone share experiences applying fertilizers to the leaves of plants?
5. Practice filling out a Soil Testing and Tissue Testing lab form and practice packaging properly for shipment.
6. Pick another Easy Learning Activity to engage in a conversation about how much of a nutrient problem is tolerable for themselves or for their target markets. Are we close to the end of harvest? How much fertilizer is too much? How can irrigation or rain affect nutrition?

Activity 2: Nutrition Deposition

VARIATIONS

Outdoor option:

1. Start in the classroom with an icebreaker, and discussion of the concepts using an easy learning activity or two.
2. Go outside to observe crops and soils. If it is dry, follow the soil sampling instructions, and package for mailing to a nutrient testing lab. Wet soils should be dried on a tray or in an oven before mailing.
3. Take leaf samples from plants according to the sampling instructions, place in a ziplock bag, or directly in a box for mailing to a diagnostics lab.
4. Upon return to a classroom setting or back to vehicles, discuss whether or not some of the observed symptoms or signs were from something other than a nutrient.

PRINTABLES & HANDOUTS

- Sample Pictures of Known Issues and Their Stories
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions
- Student Handouts
- Evaluations

CONNECTIONS

Some nutrient stress symptoms can look like feeding damage from a piercing and sucking insect, and damaged tissue from nutrient stress can become an easy entry point for diseases. Some diseases are worse depending on the pH of the soil. For example, potato scab is worse in alkaline soils.

Activity 3: Pathogen Patrol

In this "walk the beat" activity, students will develop an eye for the patterns of pathogenic symptoms and signs, and will learn the best ways to collect, package, and mail representative samples to a diagnostics lab.

METHOD

Classroom first to go over basic patterns and symptoms of disease-related issues. Then, optionally, a field walk to find evidence of pathogens to observe.

Symptoms: Expressions from the plant, such as purpling, spots, bleaching, yellowing between the veins, discolored veins, wilting, twisting, puckering, lumps, bumps, holes, scapes, etc.

Signs: Physical pieces or impressions left by an afflicting organism, such as frass, shed skins, spores, bacterial streaming, foot prints, trail cam footage, etc.

Economic Threshold: The point at which taking an aggressive reaction against a pest makes the most economic sense.

Weather Model: Programs that read weather data and perform calculations that determine the risk of problems from organisms that cause problems in plants.

MATERIALS NEEDED

- Easy Learning Activities
- Identifying Vegetable Diseases
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions
- Sample Pictures of Known Issues and Their Stories
- Pictures from participants with or without answers
- Packaging materials
- Student Handout printed for each student
- Evaluation printed for each student
- Optional: Computer with internet access
- Optional: Smart TV or projector to show pictures.
- Outdoor option:
  - Cooler or box
  - Gallon ziplock bags
  - Shovel
  - Bucket

Activity 3: Pathogen Patrol

FACILITATOR BACKGROUND

Diseases in crops can be found on various plant parts. Symptoms include external spots and rots on leaves, roots or fruit; vascular discoloration; wilts, dieback, lumps and bumps on leaves, roots or fruit; and twisting or puckering of leaves and stems.

The main categories of pathogens are bacteria, fungi, oomycetes, and viruses. Each one has distinct patterns of dispersal and infection. In general, bacteria spread with splashing water and some infected plants can carry some bacteria in and on their seed. Fungi spread their spores with wind but require high moisture conditions to “bloom”. Some oomycetes have the ability to spread with spores on the wind, while others have a swimming spore stage that requires saturated, flooded, or over-irrigated soils to move. Viruses are most typically spread by insect feeding, but can also be moved by workers through physical transfer of plant sap from one plant to another, and some can reside in or on seeds. Unlike the rest of the pathogen types, viruses tend to be more prevalent in dry conditions when insect feeding from aphids and thrips is increased.

Plant disease can sometimes be distinguished from environmental or nutrient issues by their randomness of infection. There are typically hotspots and invasion fronts for pathogens that make them less uniform in the field, whereas nutrient issues stemming from mis-application of fertilizer or soil dynamics are more clearly aligned with a human action, field topography, or soil type. Gardeners with just a few plants will see disease infections at higher percentages. For example, 1 porch tomato plant that gets a virus has a 100% infection rate. But, in a field setting, infection levels are easier to observe as a patchy distribution with gradients of light, medium, or extreme symptoms.

Activity 3: Pathogen Patrol

FACILITATOR BACKGROUND (cont.)

Scouting fields for diseases is best done in the morning because active infections will often look darkened, or as if water is inside the leaf thoroughly soaking it from the inside out. This can help distinguish a leaf symptom as being a pathogen instead of a nutrient issue.

Some pathogens are important to manage as young transplants, like damping-off disease when plants are overwatered. Others are mostly an issue on larger plants in the field, like powdery mildew in pumpkins after the plants are burdened with fruit set. Still others may only become apparent on large plants that are grown in hoophouses where humidity levels are high all the time if proper venting procedures are not followed, like leaf mold in tomatoes.

Unlike with insects, you should not wait to respond to diseases once they present. Diseases require a preventive approach with a multitude of tactics. Some diseases can be planned for with temperature- and moisture-based weather models that predict their infectivity threats. But for most diseases it is easier to prevent infestation with proper moisture management, air flow, and variety selection. Growing different crops in different places from year to year is another way to reduce infestations of some diseases. Good weed control will ensure better airflow and the potential for cross-over viruses spread by insects. Pulling out or destroying your crop quickly once you are done with it will prevent it from serving as a disease reservoir, and sanitation of greenhouse tools and surfaces can help prevent bacterial diseases that can lay dormant.

Activity 3: Pathogen Patrol

FACILITATOR BACKGROUND (cont.)

If fungicides are used, be sure to follow label information. Some rules of thumb for fungicides are to apply them before rain periods with enough time to dry, or immediately after a rain. Fungicides will not prevent or treat viruses, and currently no hardware store or garden center chemicals are effective on oomycetes. Bactericides include metals like copper and sulfur, which can burn leaves when applied on sunny afternoons over 80 F. Biological fungicides that rely on microbial competition, parasitism of plant pathogens, or inducing plant defenses may be effective on bacteria, fungi and oomycetes, and are best applied weekly or more frequently.

Resources for proper identification include the information included in this module, the MSU Plant & Pest Diagnostic Lab, and the American Phytopathological Society's Compendia series publications. Each compendia focuses on a crop or crop group, and details all of the known pathogens, as well as some insect and fertility issues with detailed pictures and descriptions. The compendia are written for a diagnostician audience, and can lead to mis-diagnosis using pictures alone. Further, some pathogens described in the compendia are exceedingly rare, or only known from other parts of the world.

The takeaway messages are:

1. Visual identification is problematic, and there are places to send tissues for identification.
2. Bacteria, fungi, oomycetes, and viruses spread in different ways, aided by different factors
3. Prevent infection and protect plants from the conditions supporting disease spread.

Activity 3: Pathogen Patrol

PROCEDURE

1. Send the resources from this module to participants ahead of the event, and read them yourself. Source gallon ziplock bags, shovel, bucket, and a cooler or box.
2. Pick an Easy Learning Activity as an icebreaker.
3. Pick another Easy Learning Activity to discuss the patterns of pathogen infestation. Using instructor notes and prepared pictures, practice vocabulary for the nuances in the types of symptoms of diseases. Are their symptoms on both sides of the leaf? Is there discoloration inside the stem? Is it a nutrient or insect issue instead?
4. Practice filling out an MSU Plant & Pest Diagnostics lab form and practice packaging properly for shipment.
5. Mention how weather models can be used to predict insect emergence and migrations but do not try to demonstrate how to work with these models because it is not a very entry-level experience and is more likely to confuse or at least detract from the energy of the room as you click around faster than anyone can follow.
6. Pick another Easy Learning Activity to engage in a conversation about how much of a disease problem is tolerable for themselves or for their target markets. Is one wilting plant enough to justify a management action? Is it good to spray fungicides on a disease without knowing the disease?

Activity 3: Pathogen Patrol

VARIATIONS

Outdoor option:

1. Start in the classroom with an icebreaker, discussion of the concepts using an easy learning activity or two.
2. Go outside to observe crops. Collect symptomatic plant parts from several areas, including belowground parts. Put them in a ziplock bag, or directly in a box for mailing to a diagnostics lab.
3. Upon return to a classroom setting or back to vehicles, discuss whether or not some of the observed symptoms or signs were from something other than a pathogen.

PRINTABLES & HANDOUTS

- Sample Pictures of Known Issues and Their Stories
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions
- Student Handouts
- Evaluations

CONNECTIONS

Some pathogen symptoms can look like feeding damage from an insect, and nutrient stresses. Bacterial infections can dry out leaf tissue and cause them to break through in ragged holes that can look a bit like insect feeding. The fruit disease called blossom end rot is actually a secondary infection of weakened tissue caused by a lack of calcium. The calcium issue is not usually due to a lack of calcium in the soil, but rather by the frequency and length of irrigation. Diseases with a broad host-range, like *Phytophthora* or *Sclerotinia*, can infect common weeds as well, and can build populations that later jump to crops.

Activity 4: Weed Proceedings

In this activity, students will "take weeds to court" to understand core tenets of integrated weed management in vegetable production at multiple scales. Students will also learn how to identify common species in a field setting with guides or phone apps.

METHOD AND KEY TERMS

Classroom first to go over basic information on weed biology and dynamics. Then, optionally, a field walk to find plants to observe.

Cotyledon: The first leaves that emerge from the soil. Most broadleaf plants have two, while grasses and sedges have just one.

Annual: Plants that germinate from seed, grow, flower, set seed and die within a year.

Biennial: Plants that germinate from seed and grow in one year, then flower, set seed and die in their second year. Most die back to the ground in winter before regrowing.

Perennial: Plants that germinate from seed and grow continuously through the years, flowering and setting seed as conditions allow. Some die back to the ground every winter and live on from their root system.

MATERIALS NEEDED

- Easy Learning Activities
- Weed Seedling Identification Guide for Montana and the Northern Great Plains
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions
- Sample Pictures of Known Issues and Their Stories
- Pictures from participants with or without answers
- Packaging materials
- Student Handout printed for each student
- Evaluation printed for each student
- Optional: Computer with internet access
- Optional: Smart TV or projector to show pictures
- Outdoor option:
  - Cooler or box
  - Gallon ziplock bags
  - Shovel
  - Bucket

Activity 4: Weed Proceedings

FACILITATOR BACKGROUND

Weeds are integrally connected to every other crop management issue. They absorb nutrients and sunlight intended for crops, block drying winds, host insect pests and pathogens, and intercept spray droplets used for management. Unlike tools for disease, insect, or nutrient management, managing weeds also has a high probability of hurting crops.

Weeds can be broadleaved or grass-like and generally fall into a few life cycle categories. Annuals start from seed every year and complete their flowering cycle before dying. Among annuals, some weeds germinate in the spring, and others in summer and fall. Biennials spend one year growing vegetatively before flowering in the second year and dying. Perennials grow from the same root every year and usually flower every year if they can survive long enough. Perennials can be woody above ground trees and shrubs, or herbaceous plants that dieback to the root level every year.

Each category of weed has their own optimal management times and techniques. Annuals can be managed before emergence with herbicides to prevent germination, and during or after emergence with uprooting, burying, cutting, or flaming. Tarping and solarizing are techniques to flush weeds into a inhospitable environment so they die. Biennials and perennials can be managed like annuals in their first year, but herbicides before emergence to stop seed germination would not work beyond their first year of growth.

When weeds are allowed to flower, they will set seed that can disperse and persist in what is known as the “soil seed bank”. Some seeds can travel long distances on wind or with animals, and some can last several decades in dormancy. Every soil disturbance from plowing, tilling, hoeing, irrigating, or pulling weeds causes a flush of weed seeds from within the top 2 inches of soil.

Activity 4: Weed Proceedings

FACILITATOR BACKGROUND (cont.)

One technique to use before planting is the “stale seedbed technique”, which involves two to four soil disturbances that churn the top two inches of soil and invigorate seed germination. Another soil disturbance or flaming is used to kill these emerged weeds and another germination period is encouraged to drain the top two inches of soil from as many weed seeds as possible. Flaming tools use fire directed at newly emerged weeds to dehydrate them without further disturbing the soil. Some growers will seed radishes, beets, and carrots at the same time, and due to their differing germination times they serve as bioindicators for each other for proper flaming. When the radishes emerge there will likely be weeds in the beets but the beets will not have emerged yet and can be safely flamed. When the beets emerge the carrots will be safe to flame.

After seeding or transplanting crops the goal becomes keeping the height of your crops ahead of weeds, and preventing weeds from flowering. Increasing crop plant density is one way to edge out weeds and quickly close the canopy in the rows. Using mulches can also shade the ground enough to allow crops to grow without competition. Continuous cultivation between and in rows of plants throughout the season prevents escaped weeds from growing too tall and keeps them from setting seed and putting more deposits in the seed bank. If weeds escape management until late in the season you are more limited to hand-pulling them, using a chemical wick that wipes the tall weeds with a herbicide and doesn’t drip on the crop, or electrical weeding with a specialized tool that sends an electrical current through vegetation that is taller than the crop. In all cases tools and workers must be carefully adjusted and trained to protect the crop from meeting the same fate as the weeds.

Activity 4: Weed Proceedings

FACILITATOR BACKGROUND (cont.)

Chemicals are another tool with windows of opportunity that can fit among the options already mentioned. Options include grass and broadleaf herbicides herbicides that can prevent seeds from germinating, or systemically killing them from their leaves to their roots. Several herbicides work on both grasses and broadleaves, and can have some activity on plants before they emerge and also after they emerge. Other herbicides are more specific with how they can be used. In general, none of them work very well on weeds that get taller than 3 inches. Preemergence herbicides can stunt or discolor the crop when soils are cooler or wetter. Some postemergence herbicides can be sprayed over the top of some crops, but others must be directed at row middles or shielded from touching crops. Over time of continuous herbicide use, weeds can become resistant to the chemical. This is a community problem in some cases where seeds are wind- or animal-dispersed. Suspected resistant weeds can be sent to MSU for a herbicide screening.

The takeaway messages are:

1. Weeds are a passive aggressive opponent with different life cycle strategies used to compete with crops.
2. Identification of the weed and understanding its distribution on the farm can help make strategies to lower the population. There are places to send samples or pictures for identification.
3. Weed management techniques include both preventive and reactive measures.

Activity 4: Weed Proceedings

PROCEDURE

1. Send the resources from this module to participants ahead of the event, and read them yourself. Source gallon ziplock bags, shovel, bucket, and a cooler or box.
2. Pick an Easy Learning Activity as an icebreaker.
3. Pick another Easy Learning Activity to discuss weed biology. Using instructor notes and prepared pictures, practice vocabulary for the nuances in weed life cycles. Are they a perennial, biennial, or annual? Are they in the same botanical family as the crop? What are the best times and techniques for management?
4. Practice filling out an MSU Plant & Pest Diagnostics lab form and practice packaging properly for shipment.
5. Discuss how phone apps can be used to identify plants. Does anyone have any recommendations or experiences with them; good or bad? It's ok if people already have apps and want to show them off, but do not try to get everyone to download or use apps for an in-depth tutorial as there are several options, phone types and levels of comfort with using them, and it is difficult to keep everyone together without devolving into highly individual IT problem solving.
6. Pick another Easy Learning Activity to engage in a conversation about how much of a weed problem is tolerable. Are the weeds making harvests more difficult or preventing dew from evaporating? Are the weeds related to your crop and hosting a pest insect, or are they a flowering plant in a drive row hosting beneficial insects that are attacking pest insects?

Activity 4: Weed Proceedings

VARIATIONS

Outdoor option:

1. Start in the classroom with an icebreaker, discussion of the concepts using an easy learning activity or two.
2. Go outside to observe crops. Collect weeds among the crop from several areas. In some cases it may be informative to dig them out in the case of perennial spreading species like milkweeds, nutsedge, quackgrass, or Canada thistle. Practice taking up close pictures. Put them in a ziplock bag, or directly in a box for mailing to a diagnostics lab.
3. Upon return to a classroom setting or back to vehicles, discuss whether or not the weeds were concerning, and factors that could contribute to their prevalence at the site. Tolerance for weeds is wide-ranging.

PRINTABLES & HANDOUTS

- Sample Pictures of Known Issues and Their Stories
- Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions
- Student Handouts
- Evaluations

CONNECTIONS

One technique for understanding environmental stressors on crops is to look at the weeds surrounding crops too. If they are also exhibiting similar symptoms of stress as your crop plants, it is likely that the issue is larger than a single disease or insect outbreak. Issues like hail, high winds, or herbicide drift can damage plants without discrimination.

Additional Resources
For Facilitators

Resource 1

Easy Learning Activities (2 pages)

This table of activities can be used to identify learning opportunities for all sizes and manners of audiences.

Resource 2

Plant, Soil, and Pest Diagnostic Lab Submission Forms and Packaging Instructions (28 pages)

These are essential diagnostic services for farmers and gardeners to utilize for a positive identification of nutrients, insect pests, pathogens, weeds, and other forms of crop injury.

Resource 3

Sample Pictures of Known Plant Problems and Their Stories (48 pages)

This slideset includes high resolution and large format pictures of suffering vegetable plants and weeds. When printed two-sided the back of each picture will include a short description of the issue. These can be used to generate discussion in classroom settings.

Resource 4

American Phytopathological Society Compendia

The gold standard resources for crop stress investigation are available for purchase or with a subscription online. These are global resources, and include far more details than most growers would ever need to know, including disease, insect, herbicide, and nutrient symptoms.

Additional Resources
For Students & Facilitators

Resource 5

Scouting and Identifying Vegetables for Insect Pests (42 pages)

This combined University of Wisconsin and Purdue resource showcases approximate times to expect certain pests in vegetables, and what to look for when scouting.

Resource 6

Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida (50 pages)

This University of Florida resource disucusses what nutrients do for plants, symptoms of nutrient-related issues, the procedures for sending samples, and interpreting the results.

Resource 7

Identifying Vegetable Diseases (68 pages)

This Penn State resource is a picture-heavy reference for the most common symptoms of vegetable pathogens that can be found in the Midwest and Great Lakes region.

Resource 8

Weed Seedling Identification Guide for Montana and the Northern Great Plains (87 pages)

This Montana State University resource is organized in a strategically helpful way, assuming you do not already know the name of the weed and only have leaves to guide you to the answer.