

Integrated Pest Management

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What is Integrated Pest Management?

Integrated pest management is a stepwise approach to managing pests that combines accurate knowledge of the pest and level of potential harm with multiple tactics to prevent, reduce or eliminate the effect of pests (disease, insects, weeds, or even abiotic issues) on your crops. It is not an alternative to organic or conventional production but is a strategy that can be used by any grower, whether using organic or conventional materials.

What is a pest?

A pest is any living organism that causes economically significant damage to a crop. Pests include insects, weeds, mites, nematodes, mollusks, bacteria, fungi, viruses, and vertebrates. If an organism damages a crop, but that damage has no negative economic impact, then that organism is not considered a "pest" in an IPM program.

Damage due to pests can be direct or indirect. In direct damage, the marketable portion of the crop is negatively affected. The level of acceptable damage will vary depending on the customer base. For example, very little direct damage (from feeding, frass, egg-laying, etc.) is acceptable for grocery stores. Still, some damage might be acceptable for local farmer markets or food that will be processed.

Indirect damage is when portions of the crop that are not marketed are fed upon—roots, leaves, stems, etc. The ability of indirect damage to negatively affect yield varies significantly by crop and growth stage. Some indirect feeding is often tolerable. Vectors of plant pathogens should not be considered typical producers of indirect damage, as their feeding often influences yield.

Integrated Pest Management Step

Integrated pest management is a circular process that involves these six key components:

- Prevent Problems
- Monitor for Pest Activity
- Accurately Diagnose Problems
- Determine Action Thresholds
- Explore Treatment Options & Make Treatments
- Evaluate results

A pre-step to a successful integrated pest management program is gaining knowledge about your environment, crop, and pests. Knowing about your climate, soil, crop growing habits,

common diseases, weedy fields, and common insect pests can aid in preventing, predicting, and planning for issues in your fields. If you are farming a new field or trying out a new crop, this may take some time.

Building your knowledge of common issues during the off-season will reduce the likelihood of panic and unnecessary spray treatments during the growing season. Keeping a record of what issues arise, when, and how they are held will also help in planning and managing them.

Prevent Plant Problems:

Just like how we take steps to stay healthy to prevent sickness in ourselves, we can do the same for our crops. Healthy plants have fewer problems and can outgrow any issues that may arise. Starting with and maintaining good management practices will help keep plants healthy. Keep your soil health and reduce pest pressure by crop rotation and planting cover crops. Select crops that are suited to your climate.

Management practices include irrigation, nutrients, planting space, planting time, and planting depth. Proper planting of seeds and transplants is critical to the success of a crop. For some crops, planting times can be adjusted to avoid peck pest populations. Crops can be planted early so they will be more mature when pests emerge and less susceptible to severe feeding damage. Planting can also be delayed till after peak emergence so that pests have to move on to other food sources and will not be present when seedlings emerge. It is crucial to follow crop row spacing recommendations. In grain crops, tight rows can help to shade out weeds. However, in vegetable cropping systems, spacing can affect air circulation and disease susceptibility.

Monitor for Pest Activity

Checking or scouting fields routinely will help farmers notice issues before they cause too much damage and can be dealt with quickly. For example, small weeds are easier to remove than larger ones that have flowered and possibly gone to seed.

Regular visual inspection and observation of plants in the field or garden is the most effective monitoring method for growers. Most crops should be checked once a week during the growing season and twice a week during vulnerable stages. Remove wilted plants and examine the root system for damage due to soil-borne insects or pathogens.

When scouting, make a record of the following:

- Date, time, crop, and weather conditions
- Determine whether proper cultural care is being delivered (e.g., water, weed control)
- Number of pests observed
- Amount and type of damage
- Presence and numbers of beneficial/natural enemies. Evidence of parasitism or predation of pest organisms
- Stage of crop development

Finding insects by visual inspection can be challenging when insects are fast-moving, small, or hiding in lush foliage. In these cases, it may be necessary to use some scouting techniques that use specialized tools.

A sweep net is ideal for scouting quick-moving insects in large grain fields. While walking through a field, sweep the net from right to left and back to the right in an arc motion. Keep track of the number of sweeps and divide the number of insect capture to get an average number per sweep. Do this in several locations throughout the field to get an over picture of the pest population and distribution.

A beat sheet can be used on bush plants such as potatoes. A beating sheet is a piece of heavy-duty cloth stretched across two diagonal pieces of wood joined at the center. This method is ideal for checking for non-flying and slower-moving insects, particularly those that feign death. Held the sheet underneath foliage or flowers while beating the plant parts. Insects will be dislodged and land on the sheet where they can easily be seen and counted.



Traps can be a helpful tool for monitoring insect pests but are less effective as they tell what is on the farm rather than what is affecting the crops. Traps may also catch insects that come from outside the farm. Some commonly used traps include pheromone traps and sticky traps.

Pheromone traps attract specific insects by using a chemical lure (Figure 1). Yellow sticky card traps are useful in greenhouses or high tunnel production to capture flying adult insects and tiny pests. Light traps can be used to capture insects that fly at night. However, they often capture many beneficial insects and pests, making them less eco-friendly than pheromone traps.

Figure 1.) Pheromone traps use lures loaded with a synthetic version of mating pheromone scent for the target insect. Traps will not control the pest population but rather are use to let you know when the pest population is high. Photo Credit: Zobel, UME

Researchers have created temperature depended development thresholds for some pests and beneficial insects, which help inform farmers on the best time for control actions. Records and knowledge of pest life cycles will help growers know when to start checking fields and which pests they are likely to find.

3.) Accurately Diagnose Problems:

The ability to accurately diagnose a wide range of plant problems can be developed over time by patient observation and consulting on reliable reference materials. Timely diagnosis of plant problems can prevent yield loss and expensive control methods. Knowledge of the crop lifecycle, common pests, and diseases will help narrow down the cause of an issue. An accurate diagnosis must be made before corrective actions can

be taken. Even if no corrective measures are available, there is satisfaction in knowing what the problem is, its future development, and how it might be prevented next year.

We use the terms symptom and sign when discussing plant issues (Figure 2). A symptom is an observation of the host's response to pests or infection by the pathogen. A sign is a visible structure of the pathogen, pest, or pest by the product itself.

Symptom: Host reponse	Sign: Physical evidence of weed, pest or pathogen
<ul style="list-style-type: none"> • Leaf spots, • Marginal necrosis • Chlorosis/ yellowing • Wilt • Stunted growth • Distorted growth • Blackened roots 	<ul style="list-style-type: none"> • Presents of pest itself • Feeding damage <ul style="list-style-type: none"> • chewing or sucking • Poop/ frass • Fruiting bodies • Mold

Figure 2.) Examples of common symptom and sign seen on crops.

Plant problem causes can be abiotic (cultural and environmental), biotic (living organisms, pests), or a combination of causes, including both abiotic and biotic issues (Figure 3).

Examples of abiotic issues include chemical injury, inappropriate temperatures or soil moisture, mechanical injury, nutrient deficiency, or excess and salt damage. Examples of plant problems caused by biotic factors include damage caused by insects, nematodes, mites, mollusks, plant pathogens, and weeds. An example of a combination of causes, including both abiotic and biotic, would be drought stress and spider mite damage.

In diagnosing plant problems, a series of deductive steps can be followed to gather information and clues to aid in narrowing down the possible cause of the problem. Through this systematic diagnostic process of deduction and elimination, you can determine the most probable cause of plant damage. Steps to follow in gathering diagnostic information are listed below, each of which will be expanded in this section:

- **Define the problem** to determine that a “real” problem exists. Check plant identification and characteristics to establish what the “normal” plant would look like at this time of year. Try to describe the “abnormality” or issue that is being seen.
 - *Questions to ask:*
 - *What are a healthy plant's characteristics, appearance, and growth habits?*
 - *What is the expected growth rate?*
 - *When was the crop planted?*
 - *What are the symptoms or signs of the affected plant?*
- **Look for patterns on the affected plant and with the field.** About half of all plant issues in the field are due to human error or the environment. A broad damage pattern or a uniform injury pattern on a field or individual plant may indicate nonliving factors (e.g., mechanical, physical, or chemical factors). While

selective symptom patterns on one or only a few plant species indicate living factors, such as pathogens and insects.

- *Questions to consider:*
 - *Are there any signs of pest presence? What plant parts are affected? Leaves, stems, fruit, roots, etc.*
 - *Do they occur on one side of the plant, only on older or newer leaves, on secondary roots but not on primary roots, etc.)?*
 - *Do adjacent plants exhibit similar symptoms?*
 - *Are the symptoms restricted to one species or one cultivar of plant?*
 - *Are the symptoms restricted to one area of the field?*
 - *How are the symptoms distributed within the field? Is there a pattern to the symptoms, or do symptoms occur randomly?*
 - *What is the history of the field?*
 - *What is the soil type and pH?*
 - *What chemicals or fertilizers have been applied in the last 2 years?*
 - *Are there any areas where water pools?*
 - *What is the sun exposure?*

Note the progression of the damage pattern. A sequence of events over time causing symptoms on a plant indicates damage caused by living organisms, while the damage that occurs but does not spread within the plant or a quick, one-time event often indicates non-living damaging factors.

- *Questions to consider:*
 - *How long have the symptoms been present?*
 - *Has the issue spread?*
 - *What was the weather like this growing season?*

Determine the causes of the plant problem. Determine if the problem is due to biotic (living) factors or abiotic (non-living) factors. Then further distinguish based on symptoms and sign seen. Using the information gathered from the earlier steps and process of elimination to remove unlikely causes.

Heat Damage

- Wilt
- Leaf scorch
- Leaf curly

Cold Damage

- Leaves turn dark brown/black
- Bark cracking
- Reduced growth in spring and summer

Flooding or Water-logged Roots

- Wilt
- Chlorosis
- Stunted growth
- Discolored rotten root

Drought

- Wilting
- Leaf drop
- Chlorosis

Phytotoxicity: caused by pesticide or fertilizer burn

- Chlorosis and necrosis
- Bronzing of leaves
- Poor germination
- Stunted plant growth
- Wilt
- Leaf cupping

Nutrient Disorders

- Chlorosis
- Interveinal yellowing
- Shortened internodes
- Abnormal coloration such as red, bronze or purple,

Fungal Disease

- Presence of fruiting bodies or mold
- Chlorosis
- Stem or root rot
- Leaf spot

Bacterial Diseases

- Yellowing/browning
- Wilting
- Die back
- Leaf spots

Nematodes

- Lesions and galls on roots
- Wilting during periods of moisture stress
- Stunted plants
- Chlorotic or pale green leaves

Insects

- Presence of the insect
- Feeding damage
 - Chewing or sucking
- Poop
- Honey dew and sooty mold
- Holes in stems or tree trunk
- Slik

Figure 3.) Examples of abiotic or non-living issues are listed on the left with symptoms that are commonly observed with them. Examples of biotic or living issues are listed on the right with the sign and symptoms that are commonly observed with them.

There are resources to help diagnose plant diseases, including Universities, extension services, other professionals, and pictorial guides. Avoid jumping to conclusions and guilt by association when insects are found on a crop until the insect has been identified. Not all insects require control, as many are neutral or beneficial. A hand lens can be a helpful tool to aid with weed, insect, and disease identification.

It is easy to misdiagnose a disease, so be cautious in diagnosing and treating diseases until you have experience. Check around your area to see if there are public, such as universities, non-profits, or private labs that offer plant diagnostics. When submitting a sample, you should collect a range of symptoms, from light to heavy. Bring as much of each diseased plant as possible, including roots. Bring samples from more than one plant and note the distribution of symptoms in the field.

4.) Develop control action thresholds and guidelines:

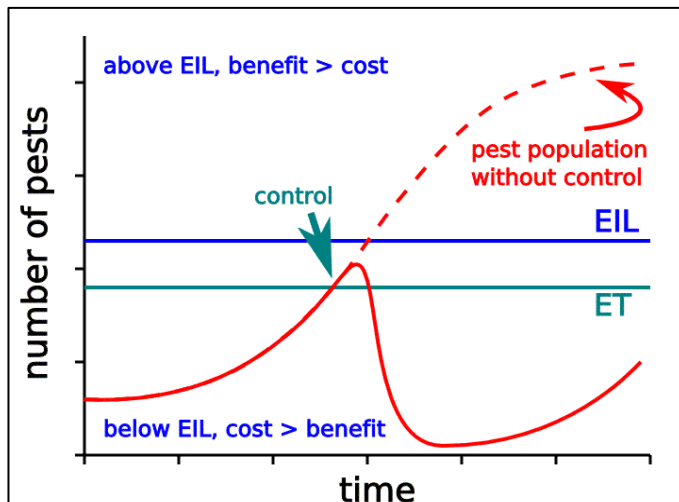


Figure 4.) The Economic Injury Level (EIL) is the pest abundance (or level of damage) at which the cost of crop yield loss to the pest begins to exceed the cost of controlling the pest. The Economic Threshold (ET) is the pest abundance (or damage level) at which the EIL is likely to be equaled or exceeded if left unmanaged. The ET is considered to be the point at which action against the pest is economically justified. Figure credit: Ed Zaborski, University of Illinois.

Several factors should be considered before deciding if action should be taken, including the value of the crop in question, the likelihood the problem could spread to other plants, and the cost of treating the problem. Not all damage or issues require control actions; for example, a single insect feeding on a plant in the middle of the growing season may not do enough damage to reduce yields. However, that same insect might need to be controlled early in the season when the plant is small.

Economic injury level (EIL) and the economic thresholds (ET), also known as the action thresholds, can help determine if a control tactic should be taken based on the number of pests, the amount of damage done, and the control cost (Figure 4). The economic injury level is the point at which a pest

population causes enough damage to justify the time and expense of a control measure, typically spraying a pesticide. It is when the financial loss caused by the pest surpasses the cost of pest control. The control action threshold is the point in time when an action must be taken to avoid additional crop damage.

Many common crops and pests will have established action thresholds or management action guidelines, which have been developed by growers or researchers who regularly monitor crops, keep records, and evaluate and summarize outcomes for comparison over time. These can often be found in production guidebooks or extension handouts.

For example, the action threshold for controlling Colorado potato beetle (*Leptinotarsa decemlineata*) on potatoes with an insecticide is when leaf defoliation is 20%-30% before the crop starts to flower, 5%-10% when it is flowering, and 15%-20% post-flowering. Another example of a threshold for Colorado potato beetles on potatoes is when you have an average of 2 adult beetles per plant, or 4 small larvae per plant, or 1.5 large larvae per plant (Figure 5.).

If you are unable to find an established action threshold and need to set your own thresholds, start by thinking about the following questions:

- Is there an economic threat? At what point will there be economic losses?
- What is the cost of taking action?
- Are there any risks to health and safety with this action? If so, how can I reduce them?

Once you have answers to these questions, compare the cost of the action with the potential economic losses. If the economic loss amount is higher, it is worth taking action. When control is needed, start with the less toxic but effective tactics.



Figure 5.) Large and small Colorado potato beetle larvae. Photo credit: Bruce Watt, University of Maine, Bugwood.org

5.) Evaluate action and continue to monitor:

After pest control tactics or management strategies have been used, continue to scout or monitor the area to see if it was successful. If not, another control measure may be necessary. Pest management plans are constantly reevaluated and changing as different pests and plant issues arise but keeping records of the issue and action taken will help in future planning. When keeping pest management records, things include the date, degree days, crop, crop life stage, control tactics or management strategies, the control method's outcome, cost, and time spent.

Integrated Pest Management Control Tactics and Management Strategies

Integrated pest management aims to use multiple tactics to suppress pests below harmful levels and effectively avoid outbreaks. Multiple tactics keep pest populations off-balance and reduce the likelihood of resistance to pesticides developing. The goal is not to eliminate all pests, as that is unrealistic and would not be cost-effective.

The following are control tactics or management strategies. Think of these tactics and strategies as tools in a toolbox that can be used to build something. Depending on the project, the tools needed will vary. The strategies used will depend on the crop, the

pest, the current growing conditions, and the farmer's goals. Each integrated pest management strategy will differ since no two farms or fields are the same. A successful integrated pest management strategy is flexible and proactive.

Prevention tactics are practices related to starting with and keeping crops healthy. Many crop problems can be anticipated and avoided. Prevention is often the least expensive, most effective, and sometimes the only control option available. Many crop issues cannot be cured, so it is essential to control them early to prevent severe damage. Prevention techniques must be thought about in advance and when planning crop production.

Some examples of these strategies would include:

- Proper fertilizer and water management for the crop will make them less susceptible to pest damage (insects, mites, and disease) and competition from weeds.
- Proper planting spacing
- Crop rotation fields may assist with weed management and disturbing pest life cycle (Figure 6).
- When growing cover crops, optimize the timing of planting to ensure robust and uniform growth. Cover crops shade the ground reducing the viability of weed populations.
- Avoid alternate hosts to reduce disease pathogen pressure.
- Select planting times to minimize the likelihood of significant pests during critical development phases of the crop.
- Avoid staggered plantings in adjacent fields to minimize the opportunity for pests to move between fields as the crop develops.
- Use disease-resistant plant varieties or grafted plants (Figure 7).
- Remove pest habitat (remove fruit, fully disk and incorporate crop residue, and manage weeds) to reduce habitat and reproductive opportunities for pests. This is especially true for pupae, which can use these microhabitats for overwintering in fields and emerging earlier than expected during the next cropping season.
- Use trap crops to attract key pests away from cash crops and into small spatial

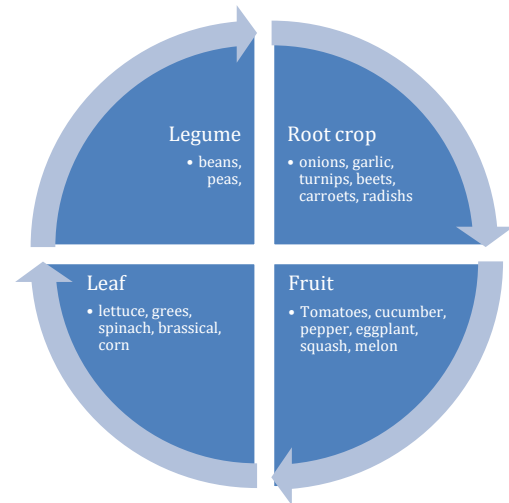


Figure 6) One way to reduce insect, disease, and weed pressure is to rotation crops. When setting up a rotation, consider the plant family, plant type, and feeding type.



Figure 7.) Grafting is a technique used in plant propagation to combine two plants so that one plant provides a desirable rootstock and the other provides desirable fruit characteristics. Photo Credit: Oklahoma State University.

concentrations, where they can be removed via cutting, vacuuming, or insecticide application.

- Plant beneficial insectary habitats such as flowering plants to provide predators and parasitoids with floral resources that would otherwise be lacking, thereby improving their ability to reduce pest pressure on the cash crop.
- Use drip tape to avoid wetting the entire soil surface. Reducing the soil surface area exposed to moisture will reduce the surface area of land able to support weed populations.

Sanitation Tactics are practices related to good farm hygiene, which minimize pest movement. Some examples of these strategies would include:

- Keep the area around fields clear of weeds.
- Cleaning tools, vehicles, and equipment. If it can move, it can carry disease, pests, and weed seeds. For equipment that is hard to clean, such as harvesting equipment, harvest clean fields first and then fields with weed issues to reduce the risk of spreading.
- Removal of disease or inflect plants from the field.

Mechanical or physical control tactics are practices related to preventing pest access to the crop or area via a physical barrier (Figure 8) or, if the pests are already present, physically removing them by some means.

Some examples of these strategies would include the use of:

Row covers

- Mulch – living, residue, or plastic
- Fences
- Traps
- Vacuuming
- Mowing
- Pruning
- Tillage

If weeds cannot be removed, consider removing the seed heads via pruning or mowing, as this can reduce the number of seeds in the future. A single season of allowing weeds to set seed may create years of weed management problems. Annual preventive clean cultivation will exhaust the existing seed bank.



Figure 8.) Example of using black plastic mulch to control weeds between pepper plants and growing a living mulch of cover between the row to reduce weed pressure. Photo Credit: Judson Reid, Cornell Vegetable Program

Biological control tactics involve using predators, parasitoids, and disease pathogens to suppress pest populations below damaging levels. This is typically done to control insect and mite pest populations since the most significant single factor in keeping plant-feeding insects from overwhelming the rest of the world is that they are food for other insects. These beneficial organisms, collectively, are named natural enemies.



Figure 9.) Top: Parasitoid wasp parasitizing cabbage aphids. Bottom: Large, swollen, tan aphids have been parasitized by braconid wasp. Photo Credit: Alton N. Sparks, Jr., University of Georgia, Bugwood.org, David Cappaert, Bugwood.org

Parasitoids are small insects whose immature stages develop either within or attached to the outside of other insects, referred to as hosts (Figure 9). Parasitoids eventually kill the host they feed on, as opposed to parasites like fleas and ticks, which typically feed upon hosts without killing them.

The use of predators and parasites as biocontrol for pests is handled in a few different ways. Farmers and gardeners may conserve and encourage naturally occurring biocontrol organisms through cultural techniques. Examples include interplanting flower plants with crops to provide additional food, overwintering habits for them, avoiding harming them by using pesticides sparingly, and selecting non-persistent and selective pesticides when pesticide use is needed.

Some predator species or parasitic nematodes can be purchased and released in the field or greenhouse to help control pest species. In most situations, employing practices that conserve natural enemies is more effective, less expensive, and time-consuming than purchasing and releasing

them. Natural enemies are unlikely to be effective when the pest population or their damage is already too widespread or if you are applying a pesticide at regular intervals. Instead, anticipate pest problems and begin making releases before pests are too abundant or economic damage is imminent.

Chemical control tactics are used in integrated pest management only when needed and combined with other management strategies for effective, long-term control. Herbicides are available to kill weeds, insecticides to kill insects, and fungicides and antibiotics to manage diseases. The toxicity of a pesticide is its capacity to cause injury to a living system. A substance's chemical makeup determines toxicity. Pesticides may have acute effects over a short period of time or chronic effects from repeated exposures at lower levels over a more extended period of time. Not all chemicals are alike from the standpoint of their range of action, toxicity, or persistence in the environment.

The selected chemical must be labeled for the management of the offending pest and for use on the specific crop upon which it is to be sprayed. All pesticide users are legally required to follow the instructions on the pesticide label, including the amount and timing of application. The main reason a chemical doesn't work is it's treating the wrong source, which is why accurately diagnosing a problem is so important.

Synthetic pesticides are compounds produced through an industrial process. Many are commercially available at retail garden or hardware stores, while others are only sold to licensed applicators.

Naturally occurring pesticides or biopesticides are derived from natural materials such as plants, bacteria, and certain minerals. Examples of botanical insecticides include pyrethrum and neem oil. Pyrethrum is derived from the chrysanthemum. It is a contact insecticide that disables the insect's nervous system. The toxicity is low for mammals, but it can irritate the skin. Neem oil is found in seeds from the neem tree. Neem oil's many components work together to act as an insect repellent, insect growth regulator, and feeding inhibitor. Neem oil and some of its purified components are used in over 100 pesticide products. Azadirachtin is the most active component for repelling and killing pests and can be extracted from neem oil.

Insect growth regulators are insecticides that mimic hormones in young insects. They interfere with insect hormone systems, making it harder for insects to grow and lay eggs. Although they are rarely fatal for adult insects, they can prevent reproduction, egg-hatch, and molting from one stage to the next.

Insecticide soaps are mostly nontoxic to other animals, but they kill soft-body insects like aphids, mites, and thrips by breaking down their exoskeleton. Horticulture oils kill small soft body insects by suffocation. Oils pose few risks to people or desirable species, including larger beneficial natural enemies of insect pests. Both soap and oils can burn or damage plants (phytotoxicity) if misapplied. Sulfur and copper are common organic fungicides growers can use to prevent and reduce the spread of plant diseases. Microbes are mass-produced entomopathogenic microorganisms, often bacteria, such as *Bacillus thuringiensis* or *Saccharopolyspora Spinosa*.

Organic standards are designed to allow natural substances in organic farming while prohibiting synthetic substances. However, there are exceptions to this rule. As requirements vary from country to country, check with your country's department of agriculture for more information about organic certification, production, and a list of allowed and prohibited substances.

In general, biopesticides have low acute toxicity and break down quickly in the environment, which reduces the risk of harm to non-target organisms but may require repeated applications to affect pests. However, naturally occurring substances still have specific modes of action, just as do synthetic pesticides. Some are toxic to



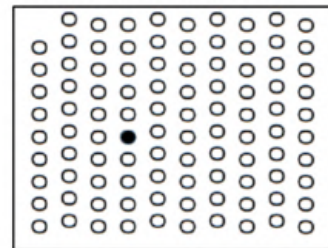
Figure 10.) Herbicide damage on lettuce injury (right); healthy (left). Photo credit: Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org

humans and other non-target organisms. The label may require personal protective equipment, even for naturally occurring products. It is essential to read the label to know if the product is safe to use at that time on that crop. For example, sulfur should not be used when temperatures are expected to exceed 80°F, as it will increase the risk of phytotoxic or plant damage (Figure 10). Caution should be taken when using pesticides, both conventional and organic, to avoid non-target effects, pesticide resistance, and secondary pest outbreaks. No matter the type of pesticides used, they should be selected and applied to minimize their possible harm to people, non-target organisms, and the environment, such as using the most selective pesticide that will do the job. When possible, use pesticides in bait stations rather than sprays or spot-spray a few weeds instead of an entire area.

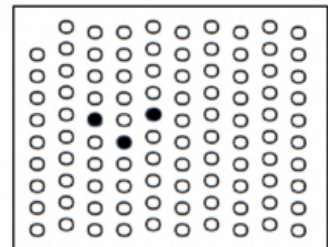
One of the best ways to prevent non-target or off-target effects is to read and follow label directions. Many of the factors leading to non-target injury are discussed on the product label. Apply pesticides using equipment that is calibrated and appropriate for the application setting. Furthermore, all chemical applications should occur under optimal weather conditions to reduce the chance of drift. Drift is the movement of pesticides, normally herbicides, away from the intended application area. Drift most often occurs when fine spray particles move through the air at the time of application (particle drift) or form a gaseous vapor due to the volatilization of the herbicide after application (vapor drift). These types of drift are most likely to occur when a pesticide is applied in high wind conditions (> 10 mph) or very high air temperature conditions. Off-site movement occurs by means other than particle or vapor drift as well. For example, high winds or rain soon after application can move soil particles that contain the herbicide to another location where non-target plants are then exposed to the herbicide.

Pesticide resistance happens when pests such as weeds, insects, mites, or pathogens develop the ability to defeat or become less sensitive to the chemical designed to kill them. The resistant pests are not killed and continue to grow and reproduce, passing this ability on to the next generation. The ability to defeat the pesticide is due to the small number of genetic differences found within a population. These genetic differences may allow the organisms to break down the pesticide, decreasing pesticide penetration, or could have altered the target site (the part of the body's metabolism that interacts with the

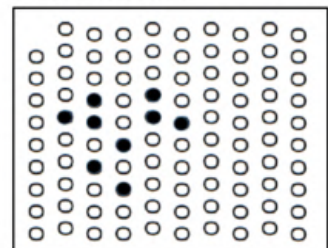
Starting Population



Generation 1



Generation 2



Generation 3

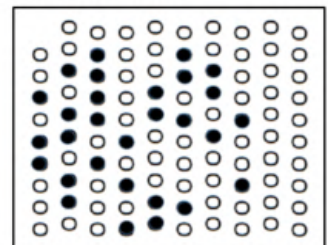


Figure 11.) Shows how pesticide resistance build up over time. Black circles are resistance pest.

pesticide) to make the pesticide less effective. The number of resistant organisms will continue to increase generation after generation until most of the population is not killed by that pesticide (Figure 11.). Worldwide, more than 600 species of pests have developed some level of pesticide resistance.

Below are some ways to prevent pesticide resistance:

- Use non-chemical approaches such as tillage and pheromone mating disruption. Rotate crops to reduce the use of the same pesticides season after season
- When practical, use spot treatments, barrier treatments, or banded treatments.
- Time chemical applications for when the pest is most susceptible such as applying when weeds are small after insects have emerged or applying preventive fungicides when weather conditions appear to be conducive to disease development.
- Alternate pesticides with different modes of action is recommended based on the theory that the likelihood of a pest population developing resistance to two or more pesticides with varying modes of action is less likely than developing resistance to only one of the pesticides. Individuals in the pest population resistant to one of the pesticides would be killed upon exposure to the (different) partner pesticide. However, there are some cases where even this strategy has resulted in resistance to both pesticide groups.
- Follow the label directions for the proper application method and rate.
- Maintaining field and farm sanitation, such as cleaning equipment between fields, controlling weeds surrounding fields, and removing disease plants from the field, will reduce pest pressure and prevent the spread of pests.
- Maintain optimum crop growth through proper fertilization, irrigation, etc. A healthy crop is more competitive with weeds and often less susceptible to disease and insect attack.
- Keep good records of pesticide usage and outcome to aid in planning for future years.

Tips for Creating an Integrated Pest Management Program

The basic structure of all integrated pest management programs involves a variety of pest and disease control products that include cultural, physical, chemical, and biological methods. All of these elements must be purposefully integrated to work in tandem to ensure they are more effective than chemical controls only were used.

Due to the customized and uniqueness of each program to each grower's crop, environmental conditions, and predicted disease and pest pressure, creating a plan can often be overwhelming.

Below are some tips for starting an integrated pest management program on your farm.

- When starting or adding to a current pest management program, it is advised to choose at most five pest and crop combinations that you would like to work on improving your management of this season. Limiting to five combinations prevents the farmer from becoming overwhelmed and leads to a more successful

pest management program. It allows the farmer to learn the pest life cycle and become more confident at using control strategies that work. Each season, new issues may arise, and you will become an expert over time.

- Here are some questions to think about when planning your pest management program.
 - What are your farm goals?
 - What crops are you planning to grow? Are any of them new to you or your farm?
 - What pests have you dealt with before? What is the weed and disease pressure in each of your fields?
 - What strategies have you used before on your farm? Did they work?
 - What other inputs, such as labor, did you have?
 - Have you grown this crop before? What were your yields? Did you make money on this crop?
- Next, start collecting background information on the crops you plan to grow and the likely pests and diseases you will encounter. Choose the pest and crop combinations you want to focus on from this information. Your choice can be based on your most valuable or newest crops or a specific pest you deal with yearly.
- Next, list some pest control tactics and strategies that could be used. Once you have your list, remove any that are not practical for your farming operation due to labor, equipment needs, cost, etc.
- It may be helpful to sort them based on when you would need to apply them or which methods require action to be done during the winter (or off-season), before planting your crop, at planting, during the growing season, at harvest, and at the end of the growing season. This allows you to select management strategies that don't need to be done simultaneously.
- Now, use this list to choose the pest management strategies you like to try on your farm. Consider writing down the steps necessary to implement your plan, the tools, and supplies needed, the people involved, resources to use, etc. Jot down dates or set calendar reminders to make sure you get trap or cover crops planted when to start transplant, know when to begin scouting for a pest, etc. When does each task need to be done or planned?
- During the growing season, remember to evaluate and record what you did and how well it worked during the growing season.

Resources:

- Barbercheck, M., & Sánchez, E. (2015). *Vegetable IPM with an Emphasis on Biocontrol*. The Pennsylvania State University.
- Caldwell, B., E. B. Rosen, E. Sideman, A. Shelton, and C. Smart. (2005). *Resource Guide for Organic Insect and Disease Management*. Cornell University. Geneva, NY. <https://northeast.sare.org/resources/resource-guide-for-organic-insect-and-disease-management/>
- Leslie, A. Chen, G., Hooks, C., (2021). *Organic Weed Management in Vegetables*. University of Maryland Extension. <https://extension.umd.edu/resource/organic-weed-management-weeds>
- Mohler, C., Teasdale, J., DiTommaso, A., (2021). *Manage Weeds On Your Farm: A Guide to Ecological Strategies*. SARE Outreach. <https://www.sare.org/resources/manage-weeds-on-your-farm/>



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