IPM in the Greenhouse Series

Integrated Pest Management in Commercial Greenhouses: An Overview of Principles and Practices

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Integrated pest management (IPM) is a holistic approach to managing diseases, insects, and mites in the greenhouse, using the best tools, tactics, and strategies to control pests with the least disruption to the environment. IPM can decrease pesticide exposure of workers and the environment, and can decrease pest control costs while still maintaining high-quality, pest-free plants. Appropriate use and timing of pesticides and the use of non-pesticide methods is essential, particularly given increasing regulations on pesticide use, decreasing numbers of registered pesticides, and increasing resistance of pests to pesticides.

The most important aspect of IPM is **prevention** of epidemics, as many pest management decisions cannot be made in hindsight. As a consequence, most of this fact sheet is devoted to the prevention of pest problems, such as maintenance of a healthy crop, exclusion of pest access to the facility, close monitoring of plant health, prompt remedial action when pests are detected, and careful documentation of monitoring, pests found, treatments employed, and treatment efficacy.

"Integrated" is an essential word in IPM. It means combining a variety of pest management techniques and strategies that can either reduce pest populations or lessen their economic impact while maintaining plant quality. An IPM program is built on several basic components, many of which are already needed to grow a healthy crop. While components may be modified to customize IPM programs for different operations, most components below should be included for a successful IPM program.

Sanitation

A basic component of IPM is sanitation. Infestations are easier to prevent than to cure. Start with a clean greenhouse. Walkways should be free of soil, organic matter, weeds, and algae. Benches should be disinfected and pots, flats, and trays must be new or disinfected. Water sources should be pathogen-free and hose ends kept off the floor. Note any drainage problems and take corrective action. Growing media should be clean, preferably pasteurized, and kept covered. No plant material should be held in the media mixing area. Do not accumulate contaminated pots or media near the growing area, and systematically remove unhealthy plants and plant parts from the greenhouse. A weed-free zone should be maintained outside the greenhouse.

Cultural Practices

A healthy crop is less susceptible to most diseases. As a general rule, pathogens do not thrive under good cultural conditions but take advantage of cultural errors and stressful conditions encountered by a crop. Maintaining the proper environment for the crop being grown is the first step to eliminating problems.

Fertilization

Soluble salt levels and the pH of growing media should be tested periodically. Fertilization schedules for each crop should be implemented. Nitrogen should be applied only as needed for optimal growth. Periodic heavy applications will set up nitrogen surpluses that cause excessive growth, which enhance the population growth of aphids, pathogens, and other pests. Excess nitrogen will also leach from pots and contaminate the environment. Slow-release fertilizers are ideal to use when possible.

Irrigation

Watering is another cultural practice that can be manipulated to slow the increase of pest populations. Plants should be watered only as needed, reduced on cloudy days, and avoided late in the day. Wetting the foliage should be avoided because moist leaves provide ideal conditions for pathogens. Plants should be watered thoroughly and then allowed a dry-down period. The length of the dry-down period will vary with the species. Proper spacing of plants to allow air circulation and drying will also decrease the incidence of moisture-loving pathogens.

Media

Always grow crops in pasteurized media. Disease-suppressive mixes are available. These mixes either naturally suppress soil borne pests or contain beneficial organisms (biological control agents). Beneficial fungi are now available commercially and can be added to the media by the grower. Beneficial fungi compete with disease-causing fungi by competing for food, by parasitism, or by producing antibiotics, which kill the disease-causing fungi. Using disease-suppressive mixes and biological control fungi can reduce the number of fungicide applications for root diseases on a crop.

Plant Quarantine

Isolate incoming plants, and monitor for pest emergence or disease development. Reject pest-infested or diseased shipments. Within the greenhouse, personnel should make a habit of caring for infested and/or quarantine areas last, to avoid carrying small insects or pathogen spores on their clothing into the rest of the greenhouse.

Scouting and Monitoring

Monitoring is one of the most important principles of IPM. Pest management systems cannot be implemented if a grower does not know which pests exist and whether populations are significant. Therefore, a scouting and monitoring plan must be devised for each greenhouse. **Correct pest identification is essential**, and employees must be trained to monitor pests correctly. Refer to OSU Circular E-1011, "Arthropod Pest Management in Greenhouses and Interiorscapes" for assistance in insect and related pest identification.

Scouting and monitoring should be performed weekly or, preferably, twice weekly during the entire production season. Scouting procedures should be performed as routinely as any other greenhouse operation. Maps should be made of the greenhouse and scouting should follow the same method in the same manner every time. Scouting must be intensive; the more plants monitored the better. Scouting should always start at a major doorway, which is usually an entry point of pests. Special attention should be paid to plants around any openings in the greenhouse, especially those on outside rows of benches.

Scouts should walk every aisle and move from bench to bench in a snake-like manner. At least 10 minutes should be spent inspecting 20 or more plants for every 1,000 square feet of production area. Three or more randomly chosen plants on every bench should be inspected. Inspection starts at the bottom of the plant by checking the soil for insect, mite, or disease pests and proceeds upwards, looking at older leaves, younger leaves, and new growth. Pots should be tipped sideways for inspection of the underside of the leaves. Hanging pots and baskets should also be inspected.

A daily inspection of indicator plants and yellow sticky cards is recommended. The first plant showing symptoms on a bench becomes an indicator plant. This plant is marked with a stake or in some manner that allows the scout to check the same plant daily. Pests on this plant are monitored for population increases. A plant more susceptible to a certain pest(s) may be placed among the crop being produced to act as an indicator plant. Flagging indicator plants also can improve the time efficiency of daily monitoring.

Yellow sticky traps should be placed throughout the greenhouse. Many insects are attracted to the color yellow (thrips are also attracted to the color blue, and blue sticky traps are available), and insects caught on these traps will serve as an index of activity. The traps should be placed in a grid-like fashion, at least one card per 1,000 square feet of production area. Increasing the number of cards per square foot of production area may be beneficial. Place the cards just above the plant canopy or up to 16 inches above the crop. The cards should be placed in the same position each time to allow a true picture of insect activity to emerge. Traps should be changed and insect counts recorded at least weekly, or more often depending upon the level of pest population.

If insect populations are high, time counting insects may be saved by counting the insects within a one-inch wide vertical column on the trap. Aphids and thrips tend to be caught on the bottom half of the traps. Leaf miners are caught more often along the top, and leaf miner wasps and whiteflies tend to be spread uniformly over the trap. Aphids tend to be caught in the middle of vertical columns. Since insects are not distributed evenly, horizontally across the trap, columns counted should be vertical and towards the middle of the trap. See OSU Extension Fact Sheet HLA-6711, "Scouting and Monitoring for Pests in the Commercial Greenhouse," for more information on indicator plants, how to identify insects caught in sticky traps, etc.

Record Keeping

Proper records are critical to effective management. Record incoming plant material inspections, yellow sticky card information, and crop treatments. All production inputs must be noted concisely and accurately. Managers trying to make a diagnosis of a problem without records are at a disadvantage and may overlook potential causes of the problem. Maps of the greenhouses showing where benches, sticky cards, and indicator plants are located should be maintained. Pest infestations can be noted on these maps so that movement of the infestation can be monitored. As the season progresses, developing pest trends will facilitate direction for pest management decisions. Given time and experience, growers will determine their threshold for any given pest on various crops. Refer to OSU Extension Fact Sheet HLA-6711 for more record-keeping tips.

Control Options

The goal of IPM is long-term suppression of pest populations below the point at which they cause economic damage. Successful management of pests requires the use of multiple tactics, starting with healthy plants and a clean greenhouse, covered in the previous sections. Reliance on a single method, such as a chemical pesticide, is doomed to failure, if for no other reason than the development of pesticide resistance. The remaining information that follows will outline several of the best pest control options.

Physical Barriers

One strategy particularly suited to greenhouse IPM programs is the use of physical barriers to exclude insect pests. Screening vents and doorways can greatly limit the movement of insect pests into the greenhouse. Several factors must be considered when using physical barriers in the greenhouse. These include choosing the proper screen size mesh, assuring adequate airflow, and preventing reintroduction of insects on plant material.

Mesh size depends upon the insect targeted. Mesh with holes less than 200 micrometers is required for complete exclusion of western flower thrips; however, screening with holes as large as 640 micrometers is sufficient for excluding leaf miners.

The smaller the holes in the mesh, the more reduction there will be in airflow. This reduction can be counteracted by increasing the surface area through which air flows. Screening can be stretched from gutter to gutter to increase surface area.

Table 1. Common Greenhouse Pests and Biological Control Agents*

Pest	Agent(s)	Example Brand Names	Characteristics
Aphids	*Aphelinus abdominalus* *Aphelinus ervi*		Parasitic wasps; females parasitize and feed upon aphids for several weeks
	Aphidoletes aphidomyza		Aphid gall midge, resembles a fungus gnat; young feed exclusively on aphids
	Ladybird Beetles (Ladybugs)		Young and adults feed on aphids
	Crysoperla carnia *Crysoperla rufilabris*		Green lacewings; larvae are voracious predators; *C. carnea* recommended for dry areas, *C. refilabris* for humid areas
	Beauveria bassiana	BotaniGard® and Naturalis-O®	Pathogenic fungi
Fungus Gnats and Shore Flies	*Atheta coriaria*		Voracious rove beetle predator
	Bacillus thuringiensis	Gnatrol®	Bacterium, controls larvae in soil
	Beauveria bassiana	BotaniGard® and Naturalis-O®	Pathogenic fungi
	Steinernema feltiae		Parasitic nematode
	Hypoaspis miles		Predatory mite
Mealybugs	*Cryptolaemus montrouzieri*		Small ladybird beetle (Mealybug Destroyer), both adults and larvae attack mealybugs and scales
Spider Mites	*Phytoseiulus persimilis*		Predator mite
	Stethorus punctillum		Small ladybird beetle that feeds specifically on mites
	Ladybird Beetles (Ladybugs)		Young and adults feed on spider mites
Thrips	*Amblyseius cucumeris*		Predatory mite
	Amblyseius degenerans		Works better in flowers than *A. cucumenis*; effective in low humidity
	Ladybird Beetles (Ladybugs)		Young and adults feed on thrips
	Orius insidiosus		Pirate bugs; nymphs and adults feed on thrips
	Beauveria bassiana	BotaniGard® and Naturalis-O®	Pathogenic fungi
Whiteflies	*Encarsia formosa*		Parasitic wasp, eggs develop in body of young whiteflies
	Delphastus pusillus		Ladybird beetle
	Ladybird Beetles (Ladybugs)		Useful to “knock down” an infestation
	Eretmocerus californicus		Parasitic wasp
	Crysoperla carnia *Crysoperla rufilabris*		Green lacewings; larvae are voracious predators; *C. carnea* recommended for dry areas, *C. refilabris* for humid areas
	Beauveria bassiana	BotaniGard® and Naturalis-O®	Pathogenic fungi
Fungal Diseases in Soil	*Gliocladium virens*	SoilGuard®	Incorporation into growing media controls disease-causing soil fungi
	Trichoderma viridae	RootShield®, PlantShield® (for foliar use)	Incorporation into growing media controls disease-causing soil fungi
	Streptomyces fungus	Mycostop®	Suppresses soil Botrytis
Fungal Diseases on Leaves	*Pseudomonas fluorescens*		Controls fungal diseases on certain plants
	Trichoderma harziarum		Suppresses powdery mildew and botrytis
	Streptomyces fungus	Mycostop®	Suppresses soil Botrytis

*Commercially available examples of biocontrols are provided rather than a comprehensive list. For more information, including greenhouse supply companies that carry IPM products, see OSU Extension Fact Sheet HLA-6713.

An exterior frame may be built and covered with screening to increase surface area. Limited access to screened areas is beneficial since insects and spores may come in on clothing or be swept in with the wind. Building a screened foyer to create a double-door entry will partially solve the problem of wind-carried insects.

Biological Control

Biological control is the use of one type of living agent to suppress another. While beneficial insects most often come to mind, beneficial organisms also include mites, bacteria, fungi, and nematodes (see Table 1). The use of biological control can reduce or eliminate the necessity of pesticides. However, several factors concerning biological control need to be understood:

1. No single pest control is 100 percent effective—biological or chemical.
2. Biological pest control often involves more work and risk at first than chemical control, and may require changes in production methods.
3. Biological control agents are sometimes more susceptible to pesticides than the target pests.
4. Many biological control agents work slowly to suppress the pest populations. Therefore, introduction of these agents must occur before pest populations reach high numbers.
5. Multiple releases occasionally are required for ongoing control.
6. Finally, it must be understood that without all IPM measures in place (sanitation, proper cultural practices, resistant cultivars, etc.) biological control agents may not be successful.

Growers must take the time to learn specifics about the biological agent they intend to use and create the proper environment for its use. Limitations of biological agents must be understood. Most predators and parasites perform best at moderate temperatures and humidities. Releases should be made in the morning or evening. Once biological control fungi are incorporated into growing mixes, the mixes must not be allowed to dry out or overheat. When pesticides are required, those with the shortest residual life and highest specificity should be used.

Chemical Control

IPM programs are not designed to eliminate pesticides. The result of this program will instead lessen the amount of pesticides sprayed, reduce the number of applications, and/or enable the substitution of a less toxic, “softer” pesticide. How-ever, pesticides are still an essential component of a successful pest management program.

The mainstay of greenhouse pest management has been older broad-spectrum pesticides that, while effective, are often toxic to more than greenhouse pests. Increasing concerns about toxicity to workers and to the environment have led to changes in pesticide registrations, including the voluntary cancellation of some of these compounds. Simultaneously, there have been an increasing number of new, safer chemicals registered for use in greenhouse settings.

Despite the availability of these new tools on the market, it is important to remember that long-term pest suppression re-quires reliance on multiple, non-chemical tactics. Pesticides should be used when pest populations get out of hand, starting with the least toxic product that will still control the pest. Apply the product only in the area where the pest is a problem. The proper dosage of the right material applied at the correct time results in good control. Spraying for broad spectrum control at the wrong life stage will only increase resistance and do little to control the targeted pest. See CR-6718 “Management of Insects and Mites in Greenhouse Floral Crops.”

Insecticides labeled for use in the greenhouse include the broad-spectrum nerve poisons, such as organophosphates (Acephate®), chlorinated hydrocarbons (Dicofol®), carbamates (Mesurol®), and synthetic pyrethroids (Talstar®, Decathlon®, Mavrik®, Astro®). New products are now available that have unique modes of action and are relatively safer to use, such as spinosad (Conserve®) and imidacloprid (Marathon®). Among fungicides, there are several older compounds that remain quite effective, along with many new, safer materials. For example, there is a new class of fungicides called strobilurins (Cygnus®, Heritage®, and Compass®); these are effective preventative materials (some have curative effects as well) and have short re-entry intervals. However, they control pathogens with a single mode of action, requiring additional care toward resistance management.

The following is a brief description of some alternative products that are used more frequently by organic growers and yet should be considered as a part of any grower’s pest management strategy.

Horticultural Oils

Horticultural oils can serve as insecticides, miticides, and fungicides. These oils have low plant and mammalian toxicity, which make them desirable for use in an enclosed greenhouse. Some precautions are necessary when applying horticultural oils to prevent phytotoxicity:

1. Do not mix oil with fungicides or any product containing sulfur.
2. Do not spray oils and fungicides with the same tank unless it is thoroughly cleaned between applications.
3. Be sure the tank mix is well agitated before spraying begins.
4. Do not apply oil when humidity is excessive or during extended cloudy periods.
5. Do not apply when temperature in greenhouse might exceed 90°F

Horticultural Soaps

Soaps (M-Pede®) are effective against some greenhouse pests. Like horticultural oils, they leave little residue and have a low level of mammalian toxicity. These soaps are potassium salts of fatty acids, which disrupt the osmotic potential (salt balance) of pest cells, causing them to burst. The soaps are effective against pupae and nymphs and against certain plant pathogens, such as powdery mildews. Soaps are most effective when first applied, that is, before the liquid dries on the leaf.

Insect Growth Regulators

Insect growth regulators (IGR) are synthetic mimics of insect hormones, and act to disrupt the life cycle of insects, causing death or sterility. Examples are diflubenzuron (Adept®) and tebufenozide (Confirm®) on caterpillars; kinoprene (Enstar II®) and pyriproxyfen (Distance®) on fungus gnats, whiteflies, and scales; and cyromazine (Citation®) on leafminer larvae. These products are only effective against insects that are still developing, and will not affect adult insects.

Botanicals

Botanical pesticides are of plant origin. While some botanicals are nearly harmless to mammals, others are more toxic than synthetic insecticides. Unlike many synthetic chemicals, most botanicals decompose quickly, broken down by microbes and sunlight. Faster breakdown means less residue in the environment and also somewhat less risk to beneficial insects that might contact the pesticide.

The neem tree produces azadiractin, which interferes with the normal molting process of insects, but it is safe to plants, mammals, and the environment. Azadiractin is available under the trade names Margosan-O® and Azatin®. A different oil from the neem tree is marketed as Triact 70® and is effective against several foliage fungal pathogens.

Pyrethrum comes from a chrysanthemum species. Pyrethrins, which are chemical components of pyrethrum, are widely used. They kill insects by interrupting nerve impulses.

Bicarbonates

Bicarbonates have been applied to ornamental and vegetable crops and appear to have potential for disease control. They are used alone or in combination with oil sprays, which make them more effective. The bicarbonate/oil sprays perform best when applied as preventive sprays against diseases. Sodium bicarbonate (baking soda) is the most available bicarbonate. Research shows that a baking soda/oil mixture can help control black spot and powdery mildew of roses, powdery mildew of phlox and zinnias, and most foliar garden vegetable diseases. Potassium bicarbonate is labeled for Botrytis, powdery mildew, and anthracnose (Armicarb®, FirstStep®), though Kaligreen® is labeled only for powdery mildew. These have a short re-entry interval, and need to be applied at the first sign of disease.

Barrier-Forming Agents

Substances that form a barrier on the plant surface and prevent foliar diseases are being investigated. These barrier-forming agents were originally used as antitranspirants to delay desiccation of the plant or plant product. They include waxes, silicone, latexes, and other plastic polymers. The incidence of anthracnose, leaf blight, rust, powdery mildew, and downy mildew on maize, sorghum, and wheat has been reduced by varying degrees by these products. While little information is currently available on commercial use of these products, their potential seems high because:

- Some of them are biodegradable.
- Previous work indicates that they are stable over a range of temperatures, humidity, and radiation.
- They are commercially available for other uses.

Conclusions

IPM is a multi-dimensional approach to pest control. It requires understanding of the greenhouse as an entire unit, an ecosystem unto itself. This ecosystem must be kept in balance. Temperature, relative humidity, and both pest and biocontrol agent populations must all be monitored. Strict sanitation must be maintained. If one component becomes unbalanced, the rest of the system suffers. Careful records of these components will help the manager correct small problems before they damage the balance in the greenhouse. Maintaining this balance is the key to successful IPM programs.

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