Best Management Practices for Bedding and Container Color Plant Production in California

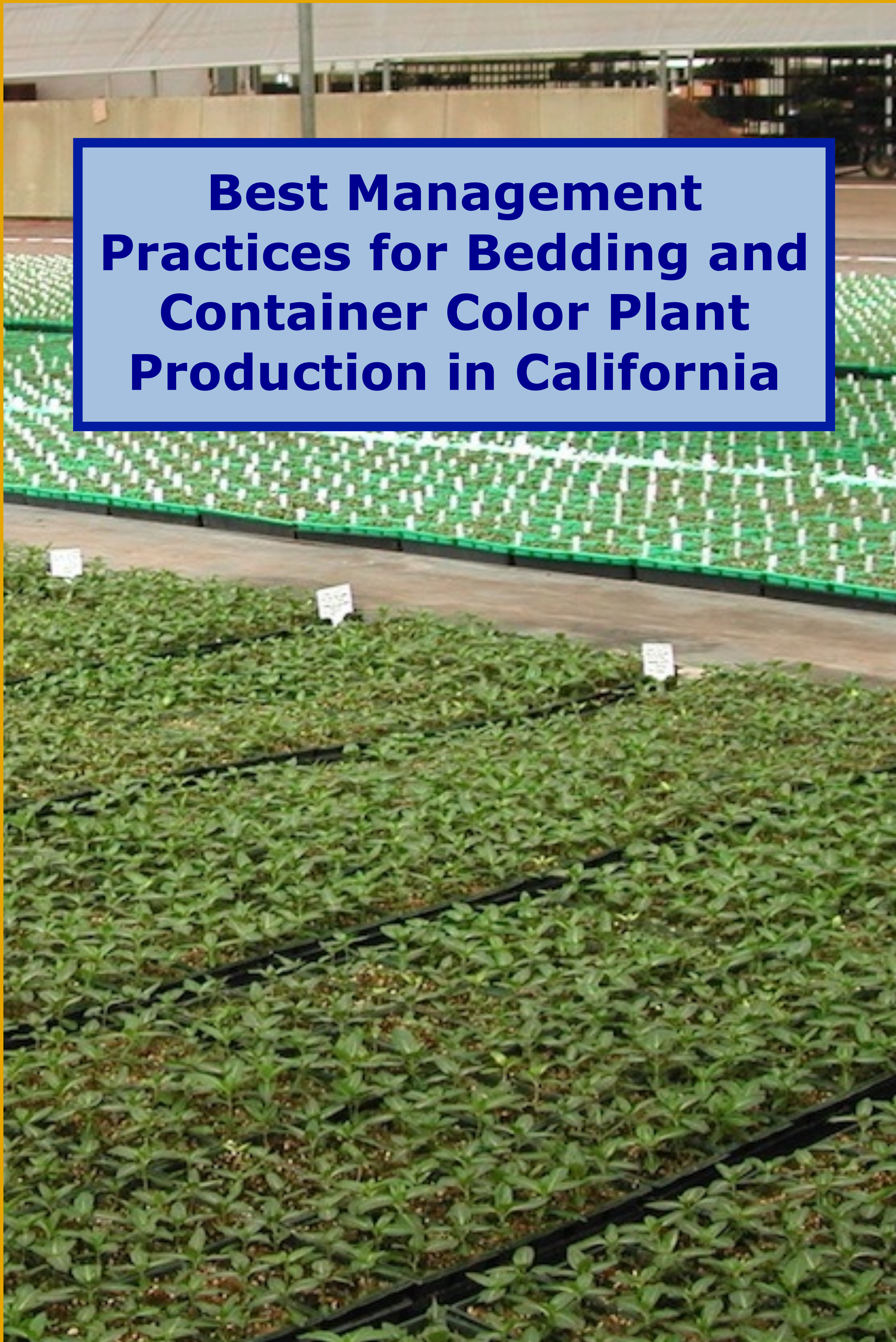

Table of Contents

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Christine Casey, editor
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Introduction

This guide is the result of a bedding and container color plant integrated pest management (IPM) demonstration conducted in California greenhouses between 2011 and 2013. Our goal is to provide a resource for bedding and container color producers who wish to develop their own best management practices approach to IPM. It is intended to serve as a general reference, so rather than provide extensive information on pest biology we refer the reader to other resources where this information can be found in greater detail. Whenever possible, specific pests or problems are linked to more detailed University of California IPM program resources.

While all chapters pertain to best management practices and IPM, they are written so they may be used independently of each other. This manual assumes a basic familiarity with ornamental plant production and pest management. A glossary is included for terms that may be unfamiliar to the reader.

Current Integrated Pest Management Practices in California
Bedding and Container Color Plant Production

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Bedding and potted color plants are produced for use in the outdoor landscape (bedding plants) and for interior decoration (potted color). This commodity group encompasses about one hundred plant species and several hundred varieties. Not every grower produces the same plant mix, although there are some plant species common to every grower. Some of the same species of plants may be produced for either bedding plants and potted color, while others are grown solely for indoor or outdoor use. The common arthropod, disease, and weed pests occur on all plant species grown. In California, production of these plants is rapid; an eight to ten week crop cycle is typical. Most growers make their profits from rapid turnover of large numbers of plants, which results in low tolerance for pest injury and limited options for biological control.

Insect/Mite Control:

There are several key arthropod pests that affect bedding and potted color plants. They are described below in order of severity.

Western flower thrips (*Frankliniella occidentalis*)

The western flower thrips is a small (1/16 inch), highly mobile, polyphagous insect. Thrips can blow into greenhouses through vents and doorways, be imported on clothing or infested plants and cuttings, or be maintained year-round on weeds. Thrips damage usually appears as scarred, stunted, or distorted foliage or flowers, or as white areas on leaves or petals. Black fecal material may be visible on damaged tissue. Thrips often feed inside developing buds so that injury is not seen until the flower opens, at which point the plant may be too damaged for sale. Thrips are vectors of the tospoviruses - impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV).

Thrips can be expected on every bedding plant crop at numbers high enough to cause plant loss, although thrips pressure is lower in spring and fall. They will be found on every plant unless control measures are taken. If INSV or TSWV is present the entire crop may be lost.

Monitoring programs for thrips include the use of sticky cards (either yellow or blue) and direct plant inspection. Sticky cards can be used to track population changes to initiate controls in advance of plant injury. An action threshold of 10 thrips/card/week was validated in greenhouse cut roses by the Rose Pest Management Alliance.

Pesticide rotation is essential, as thrips have developed resistance in the past. Recommended active ingredients include spinosad, novaluron, avermectin, neem, and some of the neonicotinoid insecticides. Many growers also still use carbamate (mesurol), organophosphate (acephate), and pyrethroid (fenpropathrin) insecticides despite the availability of effective reduced risk pesticides. Most applications are made with a

hydraulic sprayer, although some growers use specialized application equipment that creates a pesticide fog of much smaller droplet sizes (fogger: 30-60µ vs. hydraulic: 100-400µ).
Greenhouse weeds are hosts of both thrips and tospovirus and can have a significant impact on thrips and virus levels if not controlled. Growers also often leave old, unsold flowering plants in the greenhouse and removing these also helps to control thrips. Replacing soil greenhouse floors with concrete can substantially reduce thrips levels because thrips pupate in the soil, but for most growers this is cost-prohibitive.

There is evidence that use of a potassium silicate fertilizer can make plants more resistant to thrips feeding, but this has yet to be tested widely in commercial production. We propose to incorporate this into our integrated pest management program.

Biological control includes the biopesticide BotaniGard (*Beauveria bassiana*), which is most effective during fall and spring when thrips reproduction is slower and there is little migration into the greenhouse. The soil-dwelling predatory mite, *Hypoaspis miles*, is easily released and can provide long-term control when applied to greenhouse soil floors. This product is incompatible with many fungicides. Effectiveness of the predatory mite *Neoseiulus cucumeris* used in combination with spinosad has been demonstrated in Massachusetts bedding plant production, but it is not widely used in California. The predatory mite Amblyseius swirskii,an effective predator of thrips and whiteflies is gaining wider use in the state. The predatory bug *Orius insidiosus* is also available for thrips biological control, but winter diapause can limit its use and this natural enemy is rarely released into California greenhouses.

Twospotted spider mites (*Tetranychus urticae*)

The twospotted spider mite is a small (1/16 inch) highly mobile, polyphagous arthropod pest. These mites can blow in from outside a greenhouse or move from older infested material to clean plants. They are also easily spread by workers. They will feed on most bedding and potted color plants. Mites create white stippled areas on foliage as they feed and also leave unsightly webbing on plants.

Mites can be expected on every bedding plant crop at numbers high enough to warrant control, and presence of mites in the crop can only be determined by plant inspection. A presence-absence sampling plan based on an action threshold of five mobile mites per leaf was validated by the Rose Pest Management Alliance, and a presence-absence sampling plan has also been validated in the bedding plant impatiens (*Impatiens wallerani*). Because there are a number of effective miticides available, most growers simply start a control program once any mite activity is observed. Applications every ten to fourteen days using a hydraulic sprayer are typical. Rotation of pesticides is essential, as mites have developed resistance in the past. Recommended pesticides include abamectin, bifenazate, acequinocyl, fenpyroximate, spiromesifen, chlorfenapyr, horticultural oil, neem products, and the mite growth inhibitors hexythiazox and clofentazine.

A study in Kansas demonstrated that the predatory mite, *Phytoseiulus persimilis*, was as effective as the pesticide bifenazate at controlling spider mites in impatiens.

Whiteflies -- silverleaf whitefly, greenhouse whitefly (*Bemisia argentifolii*, *Trialeurodes vaporariorum*)

Two species of whitefly may infest vegetative annuals: the silverleaf whitefly and the greenhouse whitefly. Both are small (1/8 inch), highly mobile, polyphagous insects. Whiteflies can blow into greenhouses through vents and doorways, be imported on clothing or infested plants and cuttings, or be maintained year-round on weeds. The presence of whiteflies can be objectionable, and heavy infestations can affect plant vigor. Sooty mold can grow on the honeydew they excrete.

Whiteflies can be expected on every bedding plant crop at numbers high enough to cause plant loss. Monitoring programs rely on yellow sticky cards to monitor adults and visual plant inspection for the immatures. These stages are readily identified on plants but the adults are more difficult to distinguish on sticky cards. Some growers will begin whitefly management as soon as insects are seen on sticky cards or plants, while others will wait until they see five to ten adults per card per week. Recommended pesticides include the neonicotinoids, the selective feeding blockers pymetrozine and flonicamid, the insect growth regulator pyriproxifen, horticultural oil, and insecticidal soap. Depending on the formulation used these are applied as a granule to the pot, a soil drench, or to the foliage with a hydraulic sprayer.

Development of biological control methods for greenhouse whitefly and silverleaf whitefly has been the subject of a great deal of research; the result has been the commercialization of several predators, parasitoids, and pathogens. This work was concentrated in poinsettias, and other than the biopesticide *Beauveria bassiana* , whitefly natural enemies are not commonly used in bedding plants. However (as noted above under WFT), the predatory mite *A. swirskii* has the potential to control whiteflies in bedding plants.

Green peach aphid and melon/cotton aphid (*Myzus persicae*, *Aphis gossypii*)

Two common species of aphids in greenhouses are the green peach aphid and the melon/cotton aphid. Both are light green , while green peach aphid may also appear as red or pink color forms. Other aphids occasionally found in greenhouses include the chrysanthemum aphid, the cabbage aphid, the foxglove aphid, and the tulip bulb aphid. Aphids can blow into greenhouses through vents and doorways, be imported on clothing or infested plants and cuttings, or be maintained year-round on weeds. Aphids give birth to live young, so rapid population increase is possible. Infested plants have individuals or colonies, cast skins of molted aphids, honeydew, and sooty mold on plant leaves, and distorted or stunted new growth. Aphids also vector cucumber mosaic virus (CMV), alfalfa mosaic virus (AMV), and potato virus Y (PVY), all of which affect bedding plants.

Aphids can be expected on every bedding plant crop at numbers high enough to cause plant loss, although it would be unusual for the entire crop to be lost. They will be found on every plant unless control measures are taken. If CMV, AMV, or PVY is present additional plant loss will occur.

Monitoring for aphids relies on direct plant inspection, as the winged form is generally only seen on sticky cards once populations are high enough for plant damage to have occurred.

Pesticides are used for aphid control because their populations can increase so quickly. Recommended pesticides include the selective feeding blockers pymetrozine and flonicamid, neonicotinoids, abamectin, neem, insecticidal soap, and horticultural oil. Many growers also use pyrethroids (cyfluthrin, fenpropathrin, and pyrethrum). Depending on the formulation used these are applied as a granule to the pot, or to the foliage with a hydraulic sprayer.

Weeds in and around the greenhouse can be an important source of aphids and the viruses they vector.

Several biological control agents are commercially available but are often not used because of the perception that they work too slowly. One exception is the banker plant system. Rye plants (*Secale cereale*) are grown in pots on the greenhouse bench to provide habitat for a grass-specific aphid (corn leaf aphid; *Rhopalosiphum maidis*) that will not infest the bedding plant crop. These corn leaf aphids are infested with the aphid parasitoid *Aphidius colemani*, and since these plants remain in the greenhouse continuously, they provide a continual source of aphid parasitism on the bedding plant crop.

Dark-winged fungus gnats (*Bradysia* spp.)

Fungus gnats are pests in the larval stage, when they feed on young roots and cause delayed plant development, wilted foliage, leaf yellowing, and leaf drop. Both larvae and adults can also carry spores of root system pathogens and are thought to contribute to disease epidemics.

Fungus gnats can be expected to occur on every bedding plant crop, with higher numbers under cool, damp conditions. Control measures are typically needed one to three times per eight-week crop cycle. They can cause significant crop loss in propagation.

Fungus gnats are easily detected in bedding plants. Yellow sticky cards are attractive to the adults, which have a distinctive shape that is quickly recognized on the card. Larval activity in the soil can be monitored by inserting 1 in. sq. potato slices far enough into the soil surface to cover the cut edges; larvae are white with a dark head capsule are and will be observed feeding on these after two days. This technique will detect only a small number of the fungus gnat larvae actually present so is not useful for quantifying pest density. However, this technique can be used post-treatment to evaluate control action. Additionally, there are no published action thresholds for this insect, so most growers will initiate control when any fungus gnats are observed.

Chemical controls are targeted at the larvae and are applied to the soil as a drench. Recommended pesticides include chlorfenapyr, imidacloprid, and the insect growth regulators diflubenzuron, pyriproxifen, and cyromazine. These are applied as a drench to the soil. Avoiding excess water in the greenhouse will also help control fungus gnats. To knock down large adult populations, many growers will use an aerosol application of synergized pyrethrin.

Biological control is another good option but it is not widely used. The soil-dwelling predatory mite, *Hypoaspis miles*, is easily released and can provide long-term control when applied to greenhouse soil floors. The nematode *Steinernema feltiae* is also effective. The biopesticide Gnatrol (*Bacillus thuringiensis israelensis*) will give control with multiple applications.

Shore flies (*Scatella stagnalis)*

Adult shore flies spread root system pathogens within greenhouses, and large populations of shore flies leave quantities of unsightly dark fecal material on flowers, foliage, and plant labels. Shore flies can be expected to occur on every bedding plant crop, with higher numbers under cool, damp conditions. Control measures may or may not be needed.

Shore flies are easily detected in bedding plants. Yellow sticky cards are attractive to the adults, which have a distinctive wing pattern that is quickly recognized on the card. There are no published action thresholds for this insect; most growers will initiate control when large numbers of adult flies or flyspecks are seen on plants. Generally fungus gnats, which are controlled by the same pesticides that control shore flies, are seen first and thus shore flies are controlled by default.

Chemical controls are targeted at the larvae and are applied to the soil as a drench. Recommended pesticides are the insect growth regulators diflubenzuron, pyriproxifen, and cyromazine. Shore fly larvae feed on algae, and preventing algal growth in the greenhouse is an effective control option.

The rove beetle, *Atheta coriata*, is available for shore fly biological control but its use is not common.

Tarsonemid mites -- cyclamen mite, broad mite (*Stenotarsonemus pallidus*, *Polyphagotarsonemus latus*)

These yellowish-white mites are visible only under a microscope. They move into and around the greenhouse on plant material and greenhouse workers. These mites feed in the growing tips of the plants, causing stunting and distortion of new growth that is often mistaken for a plant disease. Both mites affect a number of bedding plant crops, although they do not occur regularly. Because their injury may be confused with plant disease they are often misdiagnosed and not properly treated, which can cause significant crop loss.

A regular monitoring program is difficult because a microscope is needed to see these mites, and they do not produce webbing. Once a grower has experienced a significant infestation they may institute a regular monitoring program that would include initiation of control as soon as symptoms are seen.

Chemical controls include abamectin, chlorfenapyr, and spiromesifen, all applied with a hydraulic sprayer. Some growers make prophylactic releases of the predatory mite, *Neoseiulus cucumeris,* on species or cultivars that have experienced regular damage.

Mealybugs -- longtailed mealybug, citrus mealybug, obscure mealybug (*Pseudococcus longispinus*, *Planococcus citri*, *Pseudococcus affinis*)

Mealybugs are soft-bodied insects, 1/8 to 1/4 inch long. Their bodies are covered with a white waxy secretion; egg masses are covered with a fluffy white material. A long tail is usually visible on the longtailed mealybug. All immature stages and adult females are mobile, although slow moving; only adult males have wings and fly to mate. The citrus and longtailed mealybugs are the most common species on bedding and potted color plants.

Mealybugs infest all above-ground parts of a plant, and the obscure mealybug will move up and down between roots and foliage. The white, cottony egg masses and bodies of the mealybugs are objectionable, and infested new growth is sometimes distorted. Mealybugs also leave deposits of honeydew, followed by the growth of sooty mold. Heavy infestations cause yellowing and leaf drop. They are a sporadic pest in bedding plants, but are more likely to occur if the grower is also producing a cut flower crop that is a mealybug host. If control is needed, applications are usually made weekly because this insect is difficult to kill with currently available pesticides.

Monitoring consists of visual plant inspection, and growers will treat when the first mealybug is observed. Recommended pesticides include the neonicotinoids and insect growth regulators (kinoprene and pyriproxifen). The pyrethroid bifenthrin is also often used. These are applied with a hydraulic sprayer.

Natural enemies have been sold commercially in the past, but are currently not consistently available.

Caterpillars (many species)

Many species of caterpillars may occur as occasional pests in bedding and potted color plant production. These include loopers, armyworms, cutworms, leaftiers, and leafrollers. Loopers are generally the most common. These insects enter on infested plant material or as adult butterflies or moths (adults of some species are attracted to the lights in the greenhouse). The larvae are small (1/8-inch) when they first hatch, so plants need to be inspected carefully for their presence. Color will be green, brown, black, or reddish-brown depending on species. Pheromone traps are available for the adults of some species but they are rarely used.

Damage may render plants unsalable if not detected early. Types of injury include leaf eating; feeding on growing points or buds, causing excessive branching; webbing, tying, or rolling together of leaves; and plants cut off at the base. Recommended pesticides are spinosad, chlorfenapyr, or novaluron. These are applied with a hydraulic sprayer.

The biopesticide *Bacillus thuringiensis kurstaki* is most effective when small larvae are actively feeding, so it is best used when there is a monitoring program in place.

Plant Pathogens and Disease Control:

There are several plant pathogens that affect bedding and potted color plants. Because of the high risk for crop loss and the lack of any system for early detection, these are all controlled largely with prophylactic fungicide or bactericide applications. Control of root and foliar pathogens represents the largest use of pesticides in this crop. Common diseases are listed in order of severity.

Root and stem rots (*Pythium* spp., *Rhizoctonia solani*; *Botrytis cinerea; Thielaviopsis basicola*)

Root and stem rot pathogens are the most serious disease problem in bedding and potted color plant production. In propagation these pathogens cause root decay and seedling loss; in older plants they cause both root and stem disease. Infected plants are not salable and epidemics can cause 50% or more crop loss.

These pathogens enter the greenhouse on infected seedlings, or via recycled soil or water that has not been properly sterilized. Even current sterilization treatments are not completely effective at eliminating these pathogens. They are likely to occur in every bedding plant crop and growers routinely apply prophylactic fungicide applications in expectation of this.

Infected plants will appear stunted and wilted despite adequate water. The roots will have dark, rotted areas and the outer layer of tissue will slough off easily. Affected stems will have dark cankers; the mycelium of *R. solani* will appear as webbing in the plant canopy if that pathogen is present.

Currently used fungicides include triflumizole, fludioxonil, thiophanate-methyl, iprodione, and the strobulurins. The last three are classified as high risk for resistance development by the Fungicide Resistance Action Committee. Applications are made every seven to fourteen days as a soil drench.

Proper water management and greenhouse sanitation practices, such as keeping hose nozzles off the floor, can reduce the need for fungicide applications against these diseases but do not eliminate the need for fungicides. Likewise, maintaining correct pH and soluble salts levels in the growing media help reduce, but do not eliminate, fungicide use. Fungus gnats and shore flies can spread spores between plants and should be controlled also.

Two promising alternatives for control of these pathogens are chlorine dioxide used as an irrigation disinfectant and enhanced microbial products that introduce fungi antagonistic to the plant pathogens into the soil. Neither of these has been widely tested in commercial production. We propose to incorporate evaluations of these products into our integrated pest management program.

RootShield is a commercially available fungicide that contains a fungal antagonist to *Pythium* spp.and *Rhizoctonia.solani*. It can be incorporated into the soil prior to planting or applied as a drench after planting, but is most effective when used prophylactically.

Botrytis leaf and flower blight (*Botrytis cinerea*)

Botrytis leaf and flower blight caused by the pathogen *Botrytis cinerea* is another serious plant disease in bedding and potted color plants. The disease appears as dieback and stem cankers accompanied by a grey mold. Botrytis is unusual in that even healthy plant tissue can be infected. Some growers will pull off damaged leaves to make damaged plants salable, but this may do more harm in the long run, as research in Michigan has also shown periods of high *B. cinerea* spore release associated with worker activity in the greenhouse.

B. cinerea spores are ubiquitous in the greenhouse environment, so some degree of disease is expected in every crop. The disease will be most severe under damp, overcast conditions, when significant crop loss can occur.

Fungicides used include chlorothalonil, copper hydroxide, mancozeb, triflumizole, fludioxonil, fenhexamid, iprodione, and the strobulurins. The last two are classified as high risk for resistance development by the Fungicide Resistance Action Committee. Applications are made every seven to fourteen days using a hydraulic sprayer.

Sporulation occurs in response to specific environmental conditions (i.e. the right combination of leaf wetness, relative humidity, and temperature). Good practices that can reduce the need for fungicides include switching to drip irrigation; using a tensiometer to time overhead water applications rather than irrigating on a schedule; watering early enough in the days so leaves are dry at night; heating and ventilating the greenhouse to reduce relative humidity.

The biofungicide *Bacillus subtilis* is also used for Botrytis control.

Bacterial leaf spots (e.g., bacterial leaf spot of geranium; bacterial leaf spot of zinnia; bacterial leaf spot of begonia (*Xanthomonas campestris* pv. *pelargonii; X.c.* pv. *zinniae; X.c.* pv. *begoniae*)

These diseases appear as small (1/16 to 1/8 inch) brown circular lesions that are often surrounded by yellow tissue. Under the appropriate environmental conditions (higher temperatures and overhead irrigation) they can spread quickly to cause extensive crop loss. As with other plant diseases, infected plants cannot be cured and must be discarded.

Bactericides used include copper hydroxide, mancozeb, and the biofungicide *Bacillus subtilis.* Applications are made every seven to fourteen days using a hydraulic sprayer.

Seed-grown plants are less susceptible than those that are vegetatively propagated. Disease spores are spread by splashing water, so switching to drip irrigation or using a tensiometer to time overhead water applications rather than irrigating on a schedule are both useful management options.

Fungal leaf spots (many species)

Symptoms will vary with the affected plant species, but these generally appear as small (1/8 inch) circular lesions that are tan with a brown border. Some of the fungal leaf spots are seed borne. These diseases can be expected to occur regularly in bedding plants but do not cause significant crop loss.

A number of fungicides are used; many are specific for particular fungi. Recommended fungicides include chlorothalonil, copper hydroxide, mancozeb, fludioxonil, myclobutanil, triadimefon, triflumizole, iprodione, and the strobulurins. The last two are classified as high risk for resistance development by the Fungicide Resistance Action Committee. Thiophanate-methyl is labeled but should be avoided due to resistance. The biofungicide *Bacillus subtilis* is also recommended. Applications are made every seven to fourteen days using a hydraulic sprayer.

Since they tend to occur early in the crop cycle, monitoring can help prevent a serious outbreak. Prolonged wetness can exacerbate these diseases, so switching to drip irrigation or using a tensiometer to time overhead water applications rather than irrigating on a schedule are both useful management options.

Powdery mildew (many species)

Powdery mildew can cause significant plant damage, but because the pathogen is host-specific it is unlikely to cause widespread crop loss. Spores move through greenhouse air currents. This disease appears as a white, powdery coating on affected leaves; a handlens is useful to confirm the presence of mycelia to distinguish this from pesticide residue. Mildew interferes with photosynthesis and affected tissue turns grey and necrotic.

Fungicides used include chlorothalonil, neem oil, peperalin, muclobutanil, thiophanate-methyl, and the strobulurins. The last two are classified as high risk for resistance development by the Fungicide Resistance Action Committee. The biofungicide *Bacillus subtilis* is also recommended. Applications are made every seven to fourteen days using a hydraulic sprayer.

Wide temperature fluctuations seem to trigger spore release, so maintaining consistent greenhouse temperature is helpful.

Downy mildew (*Peronospora* spp., *Pseudoperonospora* spp.)

This disease is most likely under cool, humid conditions and is especially problematic in greenhouses near the ocean. Beige to purple spores occur on the undersides of badly distorted leaves; in some plant species leaves and growing tips become chlorotic. The downy mildews tend to be host-specific, so while individual infected plants must be discarded there is little likelihood of widespread crop loss.

Because sporulation occurs on leaf undersides, excellent coverage is important when applying fungicides. Labeled products include copper compounds, dimethomorph, fenamidone, fosetyl-Al, phosphorus acid, thiophanate-methyl, and the strobulurins. The last two are classified as high risk for resistance development by the Fungicide Resistance Action Committee. The biofungicide *Bacillus subtilis* is also recommended. Applications are made every seven to fourteen days using a hydraulic sprayer.

Thrips-vectored viruses (Tomato spotted wilt virus [TSWV] and impatiens necrotic spot virus [INSV])

TSWV and INSV do not occur regularly in bedding and potted color plant production, but when present that can cause substantial crop loss. Plants do not recover from virus infection and cannot be sold. Virus symptoms vary between plant species and include generalized necrosis and chlorosis that is confused with abiotic or fungal disease, which complicates diagnosis.

Infected plants may be brought into the greenhouse or infective thrips vectors may enter the greenhouse from surrounding vegetable fields. It is common practice in bedding plant production to move plants to different areas of the greenhouse as they mature; this practice also moves viruliferous thrips throughout the facility. These viruses are managed by controlling their hosts (weeds and western flower thrips). An ELISA-based diagnostic test kit is available for grower use for both viruses

Aphid-vectored viruses (Cucumber mosaic virus [CMV], alfalfa mosaic virus [AMV], potato virus Y [PVY])

CMV, AMV, and PVY do not occur regularly in bedding and potted color plant production, but when present that can cause moderate crop loss. Plants do not recover from virus infection and cannot be sold. Virus symptoms vary between plant species and include generalized necrosis and chlorosis that is confused with abiotic or fungal disease, which complicates diagnosis.

Unlike thrips, aphids do not persistently transmit viruses, so sources of CMV, AMV, and PVY outbreaks are most likely within the affected greenhouse. Virus management focuses on control of the weed hosts. An ELISA-based diagnostic test kit is available for grower use for CMV.

Nematode Control:

Foliar nematodes (*Aphelenchoides* spp.)

Foliar nematodes are an occasional pest in bedding and color plant production. Nematode infestation causes necrotic leaf spots that are often mistaken for a fungal pathogen or twospotted spider mite injury. Often, growers seek assistance and obtain a correct identification only after repeated unsuccessful fungicide or miticide applications Affected leaves defoliate, leaving a plant that is reduced in value or unsalable. Because many growers do not recognize foliar nematode injury, infested plants may be sold at the retail level, spreading the nematode problem to home gardens.

Nematodes spread in the greenhouse via splashing from overhead irrigation. Drip irrigation, combined with monitoring and removal of infested plants, can eliminate a nematode problem. Spiromesifen is labeled for foliar nematode control but has not been consistently effective.

Weed Control:

Many weed species occur in greenhouses used for bedding and potted color plant production. Some common weeds include chickweed, purslane, and malva, but species composition in an individual greenhouse is determined largely by the species that are present outside the greenhouse. Bedding and potted color plants are grown in an artificial soilless media that is not a source of weeds, but airborne seeds will occasionally germinate in crop plants. If media is re-used and not properly sterilized it can be a source of weed seeds. Most greenhouse weeds occur on the floor, where they are a concern as a source of insects (especially thrips, aphids, and whiteflies) and of plant viruses vectored by those insects. Weeds growing directly in containers will compete with the crop plant for water and nutrients.

Grower tolerance for weeds in the greenhouse varies, but most growers perform some type of weed control. There are postemergent herbicides labeled for greenhouses, but they are not commonly used due to the risk of crop plant injury. Hand weeding is common, as is the use of weed barrier fabric on the greenhouse floor. While retrofitting with concrete floors is often not feasible, new greenhouses may be built this way.

Best Management Practices for Disease Prevention

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The best practices for disease prevention center on creating an environment that favors the plant and not the disease, which is the core of any good integrated pest management program.

Practice good sanitation

This is the first line of defense in the battle against disease in the greenhouse or nursery. Many diseases can be avoided all together if a thorough and consistent sanitation program is in place. It is important that everyone in your business understands the ways diseases spread and the ways they can stop them. Stopping disease before it becomes established is critical. Some of the steps that can be taken to keep the greenhouse or nursery "clean" are described in this article.

Clean all tools, equipment and work surfaces before working with plants. Wash these tools or surfaces first with water and follow-up with a disinfestant. We have tested a number including chlorine products (like bleach and chlorine dioxide), peroxides (like X3 and ZeroTol) and quaternary ammoniums (like GreenShield, KleenGrow and Physan). They all work in some instances but the quaternary products are overall very effective and relatively safe on plants if they are accidentally sprayed. Many disinfestants can prevent pathogens and algae from growing and can even eradicate spores on surfaces but they do not usually have any residual effect to speak of and new spores may not be killed once the product dries. KleenGrow is an exception to this rule and is also labeled for direct use on plants as a bactericide/fungicide making it a good choice in sanitation.

Start with new of clean pots, flats and other containers

Use only new or thoroughly cleaned pots, flats and other containers. Wash and disinfest using the products listed above. We performed some simple tests in cooperation with a nursery operation to determine the actual need for cleaning if a quaternary ammonium soak was used on recycled plug flats. The best control was a thorough washing followed by a 5 minute soak in a quaternary ammonium at labeled rates. Even higher rates used much longer were not as effective when the flats were not washed first. Other research has shown that steaming flats can also be very effective if the plastic will withstand it. This has been especially effective in reducing contamination of flats with the black root rot pathogen, Thielaviopsis basicola.

New potting medium

Try not to reuse any potting media and do not add native soil to any potting medium without steaming or treating with a product like methyl bromide. Think about how potting medium gets into a compost or dump pile. The plants fail to grow and are not salable (signaling the possibility of a disease).

Use only disease-free seeds, cuttings and liners
Finding pathogen-free materials can be a challenge since even the best propagators face disease situations occasionally. Be careful and check all plants when they arrive. If you have your own stock plants, maintain them in a healthy un-stressed state. Take cuttings from the tops of the plants to facilitate rapid rooting and avoid possible contamination. Clean cutting instruments between stock plants. Never use any plants with symptoms on any part of the plants since taking cuttings from a plant that has symptoms anywhere is not safe.

Avoid dipping cuttings
This is an excellent way to spread many bacterial and fungal pathogens including Xanthomonas, Erwinia, Fusarium and Cylindrocladium. Even when effective fungicides or bactericides are used, the spores will spread throughout the entire batch of dipped cuttings. If you suspect a pathogen, a post-sticking sprench will be the most effective way to apply a fungicide. In other cases, spraying the stock plants the day before cuttings are made can be a very effective way to reduce losses from pathogens like Cylindrocladium.

Grow on benches when possible
Do not place containers directly on the ground. Be sure to treat the surface (gravel, concrete or ground pack) with a disinfestant like bleach, chlorine dioxide, hydrogen peroxide or quaternary ammonium. In some cases, pots are placed on concrete blocks, flats or over-turned pots to avoid contamination from water run-off between pots or other areas.

Rogue dead plants
Weekly or even daily removal of dead or dying plants is a very important way to reduce disease spread. Keep the dump pile downhill from any growing or display area and do not maintain it as a source of pathogens. Runoff from the dump pile can spread pathogens into your production area. Worse yet is to position the potting media down hill from a dump pile. Contaminating media before they are even used can happen.

Water treatment for recycled water
This water has the same concerns as reused potting media. Fertilizer, pathogens and pesticides may wreak havoc in your propagation and throughout production of the crop. The most common pathogens that are spread this way are the water-molds, Pythium and Phytophthora. However, Erwinia has been found in southern ponds and I have seen even leaf spot pathogens like Helminthosporium reintroduced into the foliage of palm trees when recycled water is used to overhead irrigate them.

Keep leaves dry
Do not water crops from overhead if at all possible. Splashing rain water or over-head irrigation spreads spores for bacteria and many fungi such as Alternaria, Cercospora, Colletotrichum, Cylindrocladium, Glomerella, Helminthosporium, Myrothecium, Pseudomonas and Xanthomonas. There are only a few foliar diseases that spread and infect without the help of free water on the leaves including rust, powdery mildew and

downy mildew. These diseases require a moderate relative humidity but spread via wind or fans and infect leaves with a mere film of moisture. To keep leaves dry:

1. Do not use overhead irrigation or expose to rainfall if possible.
2. Water early in the day or when leaves will dry quickly.
3. Never water late in the day since plants will stay wet all night.
4. Space plants to allow air movement and reduce RH around plants.
5. Use HAF (horizontal air flow) fans to improve leaf drying.

Best Management Practices For Insect And Mite Prevention

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Best management practices for insect and mite management focus on prevention, which applies to plants grown in greenhouses and outside. Exclusion methods such as screening can be useful for greenhouses, but are expensive to install and maintain and require strict control of all people, equipment, and plant movement in and out of the greenhouse to be effective.

Sanitation

As with diseases, sanitation can go a long way towards preventing insect and mite problems. Pots, tools and other equipment should be cleaned immediately after use and stored away from production areas. Workers should always move from clean to infested areas and wash their hands when moving between crops.

Isolation

If possible, hold incoming plant material in an isolated area until it can be inspected for insects and mites, especially if the plants are from a supplier that has sent infested material in the past.

Weed management

Weed in and around growing areas can provide additional hosts for greenhouse insect pests. Whiteflies, aphids, and thrips are especially likely to use weeds as alternate plant hosts. Weeds can also host many of the plant viruses that these insects vector. Use of herbicides in the greenhouse can be problematic, so hand removal of existing weeds may be the best option. Avoid damp areas that may favor weed development, and remember that weed seeds may blow or wash into media and media components left uncovered outside.

Rogue heavily infested plants

Heavily infested plants may not ever recover sufficiently for sale, or may require multiple pesticide applications. Under high population pressure, insects and mites readily disperse to look for new food sources. This makes these plants the most likely serve as a source of infestations in the greenhouse. In most cases, the loss of the plant material balances the savings from preventing new infestations.

Insect and mite movement

Closely spaced plants can facilitate the interplant movement of non-flying pests like twospotted spider mite or the non-flying, mobile immature lifestages of pests such as thrips or aphids. When production demands necessitate close spacing, pay particular attention to these plants for these problems. Workers can also effectively spread pests between plants on their tools, hands, and clothing. Always move from clean to infested areas and wash tools and hands as well. Yellow clothing is attractive to thrips, whiteflies, and aphids and should be avoided.

Water management
We tend to associate water mismanagement with disease problems, but excessively damp areas can also favor the development of fungus gnat, shore fly, and moth fly populations.

Media management
Media with higher organic matter content or excessively damp media both tend to be more favorable for fungus gnat development, so this should be kept in mind as monitoring and management programs are developed. The covers on unopened bags of media can tear or degrade, providing access to insects that have a soil-dwelling life stage. The same holds for media components left uncovered in mixing areas. Cull piles located next to media areas (or re-use of infested media) can also provide routes of infestation.

Impact of Common Bedding And Container Color Plant Production Practices on Pest Management

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Container size

The size of the container in which a plant is grown has a substantial influence on the health of the plant. Choice of container size is generally dictated by the market, meaning that the grower must cope with the limitations imposed by the container. In general, plants in smaller containers tend to have more stress on the root system. There is less media to retain moisture and nutrients; reduced media volume also means less of a buffer from the temperature extreme at the edge of the container. This increased stress can exacerbate disease problems caused by root system pathogens such as Phytophthora and Pythium. Media is smaller containers can also dry out faster, further stressing root systems. Depending on the production time, smaller containers may be more likely to become root bound. These containers will not retain moisture or nutrients as effectively and are more likely to do poorly at the retail level and in the garden.

At the other extreme, plants must sometimes be sold in large containers when the root ball has not yet filled the container. It is easy for the media to remain too damp, encouraging the growth of root system pathogens and providing an ideal environment for fungus gnats and shore flies. There is some evidence from nursery production that plants in larger containers may be more attractive to insects. This may be due to larger leaf area and not the container itself, but this is something to keep in mind when developing a scouting program.

Best management practices to overcome effect of container size:

- Match irrigation to plant species and container size; use irrigation controllers to do this
- Match media to plant species and container size; larger containers might have more porous media while smaller containers will have a media that retains more moisture (i.e. has more organic material)
- Consider use of media amendments that are fungicidal or serve to promote plant health (e.g. *Bacillus subtilis*, *Trichoderma harzianum*, Ag1000™)
- Monitor root system growth and percentage of container filled with roots and plan irrigation accordingly
- Monitor EC via pour-through method and adjust fertilizer accordingly

Production stage

Production of bedding and container color plants is rapid, with an 8 to 10 week production cycle being typical. On the extreme, propagators may have plants for as little as five weeks, while some container plants may take up to 15 weeks. In general, smaller plants are more susceptible to insect, mite, and disease injury. Younger plants are growing rapidly and need large amounts of water, nutrients (which are taken up by roots) and sugars (which are produced in the leaves via photosynthesis) so even a small amount of root or leaf damage has a relatively large impact on plant physiology and capacity for growth. At the same time, young plant tissue may be less durable and more subject to phytotoxicity from pesticides.

Pest levels and damage that can be tolerated in finish will depend in part on the intended use of the plant. Different retail settings and landscapers will vary in their tolerance levels and it is useful to understand these in advance. Some pests and diseases tend to cause fewer problems once the plant is removed from the favorable greenhouse environment and may be tolerated at low levels at the end of production. Aphids feed primarily on succulant new growth that hardens off once the plant is in retail or the landscape. Botrytis is highly favored by the warm, humid greenhouse environment and likewise may die off in the harsher retail or landscape setting.

Best management practices that consider production stage:

- Monitor young and pesticide-sensitive plants most closely so that treatments can be applied when pest levels are low
- Consider discarding heavily infested or infected plants that may be difficult to treat to prevent spread of a problem
- Prophylactic use of natural enemies (e.g *Hypoaspis miles*, *Steinernema feltiae*) or biofungicides (e.g RootShield) that target soil-borne insects or pathogens may provide early control of minor problems

Production location

Whether plants are grown in the greenhouse or outdoors can have a substantial influence on pest management, both in terms of the type of pests and the available management options. Highly mechanized greenhouses afford a great deal of environmental control that permits substantial adjustment of temperature, humidity, and light. In many cases, however, when these conditions are optimized for plant growth they are also ideal for pathogen, insect, and mite development. In some cases, just a small amount of manipulation can tip the balance against the pest. One good example is heating and ventilating in the evening for Botrytis control. Habitat manipulation may also be used to influence success of natural enemies. The insect pathogen *Beauveria bassiana*, for example, needs a relative humidity of at least 45% for mycelial growth, while the spider mite predator *Phytoseiulus persimilis* requires a relative humidity of 70% for egg development. Because these processes occur on leaf undersides where the microclimate may already create a higher relative humidity than in the entire greenhouse, relatively minor changes to the greenhouse environment as a whole may be sufficient.

On the other hand, plants grown outdoors tend to be hardier. Exposure to the elements creates a thicker leaf cuticle and stronger stems, which can reduce the ability of insect mouthparts and pathogen growth structures to penetrate plant tissue. These plants can also be subject to weather damage from wind and rain, and may be more exposed than greenhouse plants to pests like thrips that travel on air currents.

Best management practices that consider production location:

- While the greenhouse provides the most control over the growing environment, the greenhouse environment also tends to be most favorable environment for insect and disease development
- Plants grown outside tend to have thicker leaf cuticle and stems, which may provide some protection against certain insects and diseases
- Plants grown outside are more susceptible to damage from wind and rain that may create wounds through which pathogens can infect the plant
- Not all pesticides are labeled for use in both greenhouse and outdoor settings, and natural enemies may have different efficacy in greenhouse and outdoor settings

Plant location and spacing

Greenhouse structures are capital-intensive, and it makes economic sense for growers to produce plants on multiple levels (hanging, bench, and floor) to fully utilize this valuable space. This practice presents pest management challenges, however. Plants on the ground may be exposed to runoff from plants above them and from plants in adjacent ground areas. Pathogens can travel in water moving between plants, and insects that normally drop to the ground to pupate (e.g. thrips, leaf miners) can move to plants below them. Likewise, plants on the ground may be more vulnerable in infestation by weed seeds since weeds may grow on the greenhouse floor, and airborne seeds may settle on floor-based plants first depending on what plants or cover are over them. If there is not a substantial barrier (such as gravel or intact ground cloth), there is also the possibility that soil-dwelling insects might move into containers from the ground.

On the other hand, plants on the ground are easily accessed for monitoring and it is more likely that subtle changes indicative of a pest or disease will be noticed when large blocks of flats are easily viewed. These plants may also be easier to irrigate effectively if hand watering is used, which can prevent problems caused by excess or insufficient water.

Plants on the ground may grow more slowly than plants on a bench as cool air tends to settle on the ground. This could be exacerbated if a bench and plants above are shading the ground.

Growers often use close plant spacing to capitalize on expensive greenhouse infrastructure. This may lead to conditions that favor disease development, but can provide valuable plant bridges that improve natural enemy movement if biological control is being used. If diseases are an issue and plants must be more widely spaced, flagging tape can be run between pots to provide bridges for natural enemy movement.

Best management practices that consider plant location and spacing:

- Recognize that plants on the ground may have more insect, disease, and weed problems

- Recognize that plants on the ground may grow slower than plants that are raised
- Plants on the ground may be easier to irrigate if hand watering is used
- Plants on the ground may be easier to monitor
- Close plant spacing may facilitate pest spread, but can also enhance natural enemy movement. Natural enemy bridges can provide dispersal corridors if wider spacing is used.

Irrigation system and water source

Water is the most critical production input. While its direct impact on plant survival is obvious, growers may not always consider how irrigation can influence insects, diseases, and weeds. Many growers use hand watering because it requires the least capital investment, but this method can be inconsistent and lead to excessively wet or dry plants. However the person who does hand watering is generally familiar with the crop and can notice small problems or changes before they become significant. Other common irrigation problems include missing or clogged drip system emitters, floor or ground areas with poor drainage that allows water to collect, and leaking faucets or hoses that also create damp areas.

Irrigation water may come from a city system, wells, retention ponds or tanks, or some combination of these. A city system that is blending water from many wells or providing a combination of well and surface water may be the most variable in terms of pH, salts, and nitrates.

Best management practices for irrigation:

- Hand watering can be inconsistent and lead to some plants being too dry or too wet. Consistently wet soil may favor pathogens or fungus gnats, shore flies, and moth flies. Damp areas on floors can also favor these pests and growth of some weed species. Focus scouting on areas of the greenhouse where this has been a problem, and takes steps to correct poor drainage.
- Hand watering is less efficient than drip irrigation, but emitters can become clogged or dislodged. Either of these can go unnoticed until the plant(s) die.
- Overhead irrigation requires the least labor and infrastructure, but may be the most wasteful. Splashing and runoff from overhead irrigation can move pathogens between plants.
- Well water and city water may have pH, salt or nutrient contents that are not ideal for plant growth
- Water from retention ponds or tanks may contain levels of salts or pathogens that are not ideal for plant growth
- Recycled water may vary in availability, cost, and quality

Developing an Effective Insect, Mite, and Disease Monitoring Program for Bedding and Container Color Plants

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Why monitor?

A monitoring program allows you to make informed management decisions because control is based on the actual pest and disease pressure in the growing area. Monitoring is also essential for detecting new pests and for assessing the effectiveness of previous control measures.

Who will monitor?

Scouts might be growers, other greenhouse employees, or private consultants. Most growers find hiring a consultant to be worth the cost. This person is experienced in problem identification and brings an unbiased outlook to the greenhouse, and cannot be diverted to other activities. On the other hand, an employee scout has more flexibility to change the scouting schedule to accommodate pesticide applications or shipping schedules. This means that incoming plants could be inspected immediately as they arrive at the greenhouse, helping to prevent unwanted pest entry. This person would also be at the greenhouse everyday, so problems detected as the crops are handled could be quickly diagnosed.

Once a scout is selected, the grower and scout should agree on the amount of time to be spent scouting, when scouting will take place, and (for independent scouts) what the scout will charge. Some scouts charge by the hour, while others receive a flat fee per visit. Establish an isolated area where plants will be left and examined by the grower after rogueing, or receive permission from the grower to discard them directly. Other details, such as responsibility for sending plants to diagnostic labs (and who will pay for this) as well as purchase of sticky cards, also need to be discussed. The scout and grower should consider the type of information to be left at the end of each session. How much detail does the grower want, and are management recommendations desired? Finally, it is important to establish good communication with the person in charge of pest management decisions and other employees who regularly work with the plants; they will often notice the development of new problems during the time between scouting sessions.

Develop a monitoring strategy

1. Gather background information

The next step before the scouting season begins is to gather background information about historical problem areas, the greenhouse layout, irrigation, pesticide application equipment, and media and fertilizer. All of these factors can interact to affect the development and management of pest problems.

2. Historical problem areas and crops

Find out which crops tend to have pest problems so you can pay particular attention to those plants while scouting. In addition, many greenhouses have spots that have environmental problems, such as poor drainage, limited air movement, or cold spots that can lead to pest problems. These areas should also be noted when gathering background information.

3. Set a scouting route and schedule

Establish a sampling route that will allow you to visit all areas of the greenhouse and inspect different plants each week. The pests that commonly attack bedding plants do not distribute themselves evenly throughout the crop. For example, whiteflies tend to have a clumped distribution; contagious diseases are usually spread by water or air movement, which are rarely uniform. In a typical greenhouse layout, the most efficient route is a zig-zag pattern down the aisle between two benches. Stop at about 10 locations in an area of 1000 ft^2, examining a plant or flat on each side of the aisle as well as any baskets overhead. Start this pattern at a slightly different location each week. The number and density of plants will affect the scouting pattern, as will the location and size of benches in the greenhouse.

4. Understand the layout of the growing area

At the first visit, inspect each growing area for situations that may lead to pest problems, such as watering nozzles left on the floor, areas of standing water, weeds, algae, and plants left from a previous crop. Look for whiteflies and thrips on the weeds, and for shore flies on the algae. Check for weeds outside the greenhouse that will need to be controlled in the spring. A 15-foot border around the greenhouse should be kept free of weeds.

Determine patterns of plant movement during a normal production cycle. For example, do plants move from propagation to a holding house, from which they are distributed throughout all greenhouses? If so, inspect plants carefully before they leave the holding area. Do all greenhouses share a common head house through which all plants pass as they are moved from one range to another? This means that a problem in one house could quickly be distributed to all greenhouses.

5. Create an IPM notebook

The IPM notebook serves as a resource center at each greenhouse. It will contain information used weekly, such as blank scouting forms, greenhouse maps, and all scouting records. This book, which is always kept in the same place, should also contain pesticide recommendations, spray records, MSDS sheets, pesticide labels, and fact sheets or trade journal articles pertaining to pest problems. Other relevant information, such as fertilizer inputs, should also be included here. Establish this notebook before scouting begins, as you are preparing scouting forms and greenhouse maps. Continue to add new information to keep everyone on the IPM team up-to-date. It may be easier to maintain this electronically on a file-sharing site or on a computer or tablet that everyone is able to access.

6. Develop a key pest and disease list

Base your scouting strategy on the grower's schedule for the crop and the pests you expect to encounter. To determine the date that the crop should be pest-free, project backwards from the expected sale date. The pest-free date is affected by the capacity of the insect, disease, or mite to injure a plant at a certain stage, as well as how difficult it is to detect the problem and the likelihood of the problem to spread.

To illustrate, fungus gnat larvae can seriously injure root systems that are less than three weeks old. Older roots, however, can tolerate a higher population of larvae. As a second example, even a small number of aphids—because of their great capacity for reproduction—is a concern on young plants, whereas on mature plants, one or two aphids could be washed off before sale. Thus scouting for these two insects would be a priority during the first few weeks of the crop.

Whiteflies mature from eggs to adults in about one month, so these insects should be under control at least one month before sale. A few geraniums with Botrytis blight can be managed by removing the infected leaves and improving air circulation, yet if a few geraniums have rust lesions, a fungicide is needed. Rust lesions are also more difficult to see than Botrytis blight, so individual plants will need to be examined for rust, whereas Botrytis will usually be visible as you move through the crop.

Sometimes apparent injury is not necessarily related to current pest levels. For example, injury from thrips feeding early in the crop cycle may not be noticeable until several weeks later, when flowers and leaves have expanded.

How to monitor

1. Scouting sanitation protocol

Follow the sanitation protocol outlined below to reduce the possibility of spreading insects or diseases and to minimize contact with pesticide residues. Before leaving one business or house to scout another, wipe off your clothing and wash your hands. Treat plants gently as you inspect them. Another part of being a responsible scout is continuing education. Attend trade and educational shows, read trade journals, and stay in contact with other scouts. New pest problems will always develop, as will new ways to manage them. To remain effective, you need to be aware of these changes. Finally, remember that at times the grower's priorities will be different from yours. Patience and good communication will be essential at these times. Don't expect to see all management recommendations implemented every week, but be prepared to prioritize problems and alert the grower to those that are urgent.

Procedure	**Justification**
Avoid wearing yellow, blue, or light-colored clothing	Light colors attract many insects, which could then be carried on your clothing to another area
Wear disposable gloves	Disposing of gloves helps prevent pathogens from being transferred among plants. Wash or change gloves after contact with contaminated material. Gloves will also help protect against contact with pesticide residues on plants.
Check the pest control record before entering an area	Reduces your risk of pesticide exposure and points you to possible problem areas
Monitor least-infested first, heavily infested areas last. Base this judgment on conversations with the grower and your previous visit.	Minimizes the possibility of inadvertently carrying insects or pathogens from one area to another or from older to younger plants
Examine stock plants first, then cuttings	Reduces the chance of infesting stock plants
Don't carry infected plants to a clean area or another greenhouse	Minimizes the spread of insects and diseases. When rogueing plants or removing dead leaves, place the material in a plastic bag, then remove it from the greenhouse.

2. Monitoring equipment and use

Equipment	Use
Hand lens of at least 10x power Optivisor® (a hands-free magnifier)	Examine suspected arthropod or disease problems under magnification. Optivisor® allows you to keep both hands free as you inspect plants.
Blank scouting and report forms with clipboard and pen	Record scouting observations on forms and report findings to grower. Pen attached to clipboard is useful.
Colored survey flags and flagging tape	Mark indicator plants or problem areas
Sticky cards, stakes, and clothespins	Monitor adult insect flight activity
Potato disks	Monitor immature fungus gnat activity
Hand counter (tally meter)	Fast, accurate way to count large numbers of insects
Plastic gloves	Protect scout from pesticide residues and prevent disease transmission during root system inspection
Garbage bags	Isolate plants that are rogued or sent out for diagnosis
Small plastic and paper bags	Attach plastic bag to belt while scouting to discard leaves and sticky cards. Use paper bags for transporting soil or tissue samples.
Plastic wrap	Wrap sticky cards for later ID or counting
Vials of alcohol, small artist's brush, and tweezers	Collect and preserve insects and mites for identification
QTA Tospo™ detection kit	Test performed by the scout to determine if a plant is infected with INSV or TSWV
Bleach solution (10%) or other disinfectant and rag. Prepare fresh solution weekly and store out of direct light.	Wash plastic gloves between root inspections to prevent disease transmission. Wipe gloves after applying bleach.

Scout the greenhouse once a week by inspecting plants and assessing root system health. Leave information in the IPM Notebook at the end of each session. A consistent schedule is necessary to accurately observe pest activity and trends. Scouting should take place on the same day of each week, and at the same time each week. This way the grower knows when you are coming and can prepare questions or schedule pesticide applications accordingly. It is possible that before a scouting visit, an area of the greenhouse will have been treated with pesticide or plant growth regulator. Always check pesticide application records in the IPM Notebook for the reentry intervals specified by the Worker Protection Standards before entering a greenhouse.

Be sure the grower keeps up-to-date records about the materials sprayed, the date, and the location. Knowledge about these applications will help scouts to evaluate the current pest situation and to protect their personal safety. The time it takes to scout bedding plants depends on the experience and skill of the scout, the level of pest infestation, the size of the greenhouse(s), and the number and kind of plant species. A new scout may require an average of 20-25 minutes to inspect every 1,000 sq. ft. Once the scout is comfortable with pest identification, experienced at making pest counts, and familiar with the greenhouse layout, the time needed for scouting generally drops to an average of 10–15 minutes per 1,000 sq. ft.

As a rule of thumb, allot four hours per week for a greenhouse of approximately 1.5 acres. An additional one to two hours per range each week is optimal but may not be feasible. Allow time to discuss your work with the grower before and after scouting. Growers can guide your scouting by telling you what they've seen or news of problems in other greenhouse operations.

3. Start with an overview of the growing area

Each time you enter an area to begin scouting, scan the entire crop for plants that are off-color, of uneven height, or abnormal in some other way. Make a note of the bench location and be sure to examine that area in detail as you work along your scouting route. Look under the benches for weeds, and check those weeds for insects. Note on the data sheet any presence of insects on weeds. A small weed population can be pulled by hand as you scout.

Do the same outside the greenhouse or field, noting the presence of weeds and ornamental plantings and any insects on them. Usually these weeds are too numerous for hand removal. They should be killed with an herbicide and replaced with a gravel border over weed barrier fabric.

4. Using insect monitoring tools

Use colored sticky cards to monitor changes in adult insect populations and to detect pest populations in new shipments of plant material that has just arrived at the greenhouse.

The color of the trap is attractive to a particular insect, which is caught on the adhesive surface. Sticky traps do not, however, significantly reduce insect populations. Yellow cards are used to detect winged aphids, fungus gnats, shore flies, whiteflies, leafminer flies, and thrips. They will not pick up mites or wingless aphids. They also attract many natural enemies of insects, so try not to release beneficials near yellow sticky cards. Blue sticky cards also attract thrips, although it is more difficult to see the thrips against the blue background. Yellow cards are more practical for the wide range of pests that generally occur in bedding and container color plants.

Examine sticky cards weekly as part of the scouting routine. Identify and count insects, then record this information with the other scouting data. Weekly changes in insect counts indicate general levels and trends of insect activity in a greenhouse. Because there are no guidelines for relating the number of insects on a trap to the population on the crop, you should use plant inspections as the primary source of information for pest management decisions. Place traps in hanging baskets, at bench level, or on the floor (if the greenhouse has soil floors). Place one card per 1,000 sq. ft. Number each card. Correlate the number to a specific location; that location will have a card (or replacement card) for the life of the crop. Use both sides of the card each week. If only a few insects are caught in a week, the card may be reused. Circle the insects with a waterproof marker so they are not counted again. Place cards at the level of the crop canopy, moving them each week as the plants grow.

Sometimes a different approach is used if a specific insect is of primary concern. For example, cards placed horizontally above the soil may be more effective for fungus gnat and shore fly monitoring. For thrips, cards should be placed in areas of air movement because thrips move around the greenhouse primarily on air currents. Attach cards near vents or other openings, on the eastern and western ends of the greenhouse, and near floors and ceilings until you are able to determine the most "popular" spots; continue to place cards in only the spots that collect thrips. In hanging baskets, suspend cards from the support used to hang the baskets. At bench level, clip a card to a stake with double clothespins and place the stake in a pot. At the basket or bench level, set cards vertically. Choose whether cards will be oriented with the short or long side parallel to the ground, and maintain this orientation for the life of the crop. Keep the bottom third of the card below the crop canopy. At the floor level, cards should be placed horizontally, since the purpose of these cards is to catch insects as they emerge from the soil. Another technique that may be used is to coat the inside of a clear plastic shoe box or sweater box with sticky material so the insects are caught as they emerge from the soil. These traps can help to determine the need for soil treatment.

Unusual insects may occasionally be found on these cards. Several species of parasitic wasps may be seen in greenhouses where few pesticide applications are made. Insects not normally seen in the greenhouse may enter from outside through open vents or doors. If an unknown species is trapped more than twice, it should be identified. Always be alert to the arrival of a new pest. Sticky cards covered with insects can be wrapped in plastic to be saved for identification.

Occasionally other types of insect monitoring devices are used in greenhouse scouting. Potato disks may be placed on the soil surface to monitor for fungus gnat larvae. Cut a potato into 1-to 2-inch cubes and press the raw surface lightly into the soil. If larvae are present, they may be seen feeding on the potato when it is lifted from the soil after 24 hours. Duct tape or packing tape may be wrapped sticky side out on bench legs to determine if slugs feeding on benches are moving up from the greenhouse floor; look for their slime trails on the tape. Pheromone traps are occasionally used in greenhouses to detect European corn borer.

Descriptions of insects on sticky cards

Aphid. (varied species) Family Aphididae. These are small (1/8 inch) insects that vary in color from black to green. Only the winged forms will be caught on sticky traps. They tend to shrivel after a few days on the trap, but if fresh will appear stout with cornicles visible near the tip of the abdomen. The wings are often spread out on the trap and a large dark vein will be visible near the front of the forewing. Nymphs may be seen near the body of the adult.

Fungus gnat. (*Bradysia* spp.) Family Sciaridae. These are small (1/16 inch) slender flies that resemble small mosquitoes. Distinguish them by their long legs and antennae. They appear to be hunchbacked and have one pair of clear wings with a Y-shaped vein in the center.

Leafminer. (*Liriomyza* spp.) Family Agromyzidae. These are small (1/16 inch) stout-bodied flies that are mostly black with areas of bright yellow. There is typically a bright yellow patch on the thorax. Being flies (order Diptera), they have only one pair of wings.

Moth fly; drain fly. (varied species) Family Psychodidae. These are small (1/16 inch) flies that appear fuzzy due to a covering of fine hairs. They are often trapped in wet or poorly drained growing areas.

Shore fly. (*Scatella stagnalis*) Family Ephydridae. These are medium (1/8 inch) stout-bodied flies that are dark in color. They have bristle-like antennae that are shorter than the head and not always visible. The wings (one pair) are dark gray and have three to five distinct white spots.

Thrips. (varied species, typically *Frankliniella occidentalis*)
Family Thripidae. Thrips are very small (1/32 to 1/16 inch) slender, elongated insects. They are usually the smallest insect on a trap and may be confused with specks of dirt. Thrips are black to yellow and have hair fringes on their wings. These fringes are not always visible on traps because the wings of the thrips tend to fold over its body.

Whitefly. (varied species) Family Aleurodidae. These are small (1/16 to 1/8 inch) insects with white wings and yellow to orange bodies. The white wings disintegrate quickly, leaving behind only the body, which can easily be confused with thrips. The wingless whitefly body tends to be shorter and stouter than the thrips.

Parasitic wasp. (varied species) Order Hymenoptera. Many parasitic wasps in the order Hymenoptera may be seen on yellow sticky traps. They are generally small (1/16 to 1/8 inch) with bodies that range from slender to stout. They often have long, elbowed antennae. Their abdomens tend to be pointed at the rear. Parasitoid wings tend to be clear, with only one large vein on the forewing. The hindwings are usually without veins and much smaller than the front wings.

5. Scout by key pests, plants, and locations

Be familiar with the key pests, plants, and locations for the crops grown in your greenhouses. Key pests are the insects, mites, and diseases most likely to cause problems on a plant. Key plants are the species or varieties most likely to have pest problems. Key locations are areas of a greenhouse that are most likely to be the site of pest problems, such as spots with poor floor drainage, benches near vents, or production areas near stock plants. Many plants are affected by fungus gnat larvae and damping off, which are a concern primarily during the first few weeks of production. Crop history also plays a role; check for a problem that has occurred regularly in the past until you are certain it is not present. Be vigilant with problems resulting from ongoing environmental circumstances, such as poor air circulation or standing water.

Systematically examine the tops and bottoms of leaves. Some arthropod pests, such as mites and whiteflies, are found primarily on leaf undersides, whereas aphids are most commonly seen on tender new growth. Most disease symptoms will be visible on the upper leaf surface, although downy mildew and powdery mildew can appear first on leaf undersides. For plants with six or fewer leaves, examine the entire plant. For larger plants, look over the entire plant, holding it above your head to see the leaf undersides. An Optivisor® is useful for this purpose. Select six leaves from all parts of the plant (upper, middle, lower) and examine them individually. Examine the length of all stems and branches for insects, mites, and disease symptoms.

Many arthropod and disease problems are specific to certain parts of the plant. Some aphids prefer terminal growth, whereas mealybugs may be located at any point, although often they are visible in leaf axils or where branches and stems meet. Western flower thrips adults and larvae are most commonly found in flowers. Sometimes they are visible on leaves and in leaf axils, or hidden within buds. Check stems and branches carefully for diseased areas—primarily at the root-stem junction, or where branches and stems meet. Leaf spots develop first on the older, lower leaves of seedlings.

Resources

WEB SITES

University of California

UC Integrated Pest Management Home Page: ucipm.ucdavis.edu
UC Integrated Pest Management Floriculture Page:
ipm.ucdavis.edu/PMG/selectnewpest.floriculture.html
Bedding Plant IPM Alliance: ucanr.org/sites/entomology/BPIPM
UC Cooperative Extension: ucanr.org

Biological Control

Koppert: www.koppert.com
Biobest: www.biobest.be

Pesticide Information

Insecticide Resistance Action Committee: www.irac-online.org
Fungicide Resistance Action Committee: www.frac.info
Herbicide Resistance Action Committee: www.hracglobal.com
California Department of Pesticide Regulation (CA DPR): www.cdpr.ca.gov

ELISA test kits for plant pathogens

Agdia, Inc.: www.agdia.com

PUBLICATIONS

UC IPM: Integrated Pest Management for Floriculture and Nurseries:
ipm.ucdavis.edu/IPMPROJECT/ADS/manual_floriculture.html
CA DPR: A Guide to Pesticide Regulation in California:
www.cdpr.ca.gov/docs/pressrls/dprguide.htm

Management Rotations for Integrated Pest Management of Bedding and Container Color Plant Insect and Mite Pests

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Bedding and container color plants have a short cropping time, high quality expectations, and multiple pests. Effective pest management in these crops includes monitoring, fast-acting biological control agents, and pesticide rotation. The following recommendations consider these factors and are intended to be used in conjunction with a monitoring program that uses yellow sticky cards and plant inspections.

MOA group = Insecticide Resistance Action Committee pesticide mode-of-action group

Fungus gnats and shore flies

Treatment	Yellow stick card counts	Trade name	Common name	Life stages targeted	MOA group
First	Release at start of crop	Entomite-M	*Hypoaspis miles*	Larvae	n/a
Second	Low	Gnatrol	*Bacillus thuringiensis israelensis*	Larvae	11A1
Third	Rising	Distance	Pyriproxifen	Larvae/reduces ovipositioning	7D
Fourth	Peak	Citation	Cyromazine	Immatures	17

Twospotted spider mites (TSSM)

Low to normal mite pressure:

Treatment	**TSSM lifestages observed**	**Trade name**	**Common name**	**Life stages targeted**	**MOA group**	**Compatibility with *P. persimilis***
First	Low	Spidex	*Phytoseiulus persimilis*	all	n/a	n/a
Second	Mostly eggs	Hexygon	Hexythiazox	Eggs/stops ovipositioning	10A	yes
Third	Immatures	Floramite	Bifenazate	All	25	no
Fourth	Adults	Akari	Fenpyroximate	All/stops ovipositioning	21A	no

Normal to high mite pressure with mostly eggs and immatures:

Treatment	**TSSM lifestages observed**	**Trade name**	**Common name**	**Life stages targeted**	**MOA group**	**Compatibility with *P. persimilis***
First *Select one based on count of eggs and immatures*	Mostly eggs	Hexygon	Hexythiazox	Eggs/stops ovipositioning	10A	yes
	Mostly immatures	TetraSan	Etoxazole	Immatures	10B	no
Second	Immatures /adults	Kontos	Spirotetramat	All/systemic	23	unknown
Third	Adults	Pylon	Chlorfenapyr	All/translaminar	12B	no
Fourth	Adults	Akari	Fenpyroximate	All/stops ovipositioning	21A	no

*Except if applied by drench and there were will be no contact with drenched material

Normal to high mite pressure with mostly adults:

Treatment	**TSSM counts**	**Trade name**	**Common name**	**Life stages targeted**	**MOA group**	**Compatibility with *P. persimilis***
First	All lifestages with adults predominant	Floramite	Bifenazate	All	25	no
Second	All	Kontos	Spirotetramat	All/systemic	23	unknown
Third	All	Pylon	Chlorfenapyr	All/translaminar	12B	no
Fourth	Adults declining, eggs increasing	Hexygon	Hexythiazox	Eggs/stops ovipositioning	10A	yes

*Except if applied by drench and there were will be no contact with drenched material

Western flower thrips

Low or normal thrips pressure:

Treatment	Yellow sticky card counts	Trade name	Common name	Life stages targeted	MOA group
First	Low	Azatin	Azadiractin	Immatures	18B
Second	Rising	BotaniGard or Naturalis	*Beauveria bassiana*	All	n/a
Third	Peak	Flagship or Safari	Thiamethoxam or Dinotefuran	All	4A
Fourth	Adults declining	Pylon	Chlorfenapyr	Immatures	12B
Fifth	Adults declining	Pedestal	Novaluron	Immatures	15

High thrips pressure or tospovirus present, with Conserve:

Treatment	Yellow sticky card counts	Trade name	Common name	Life stages targeted	MOA group
First	Low	Conserve	Spinosad	All	5
Second	Rising	Pylon	Chlorfenapyr	Immatures	12B
Third	Peak	Safari	Dinotefuran	All	4A
Fourth	Peak	Mesurol or Tame and Orthene	Methiocarb or Fenpropathrin and acephate	All	1A and 3
Fifth	7 days after adult peak	Pedestal	Novaluron	Immatures	15

High thrips pressure or tospovirus present, without Conserve:

Treatment	Yellow sticky card counts	Trade name	Common name	Life stages targeted	MOA group
First	Low	Aria	Flonicamid	All	9C
Second	Rising	Safari	Dinotefuran	All	4A
Third	Peak	Overture	Pyridalyl	All	unk
Fourth	Adults declining	Pedestal	Novaluron	Immatures	12B

Whiteflies

Low to normal whitefly pressure:

Treatment	Yellow sticky card counts	Trade name	Common name	Life stages targeted	MOA group
First	Low	BotaniGard	*Beauveria bassiana*	All	n/a
Second	Rising	Distance or Pedestal	Pyriproxifen Novaluron	Immatures/reduces ovipositioning Immatures	7D 15
Third	Rising	Judo	Spiromesifen	Immatures and pupae/translaminar	23
Fourth	Peak	Endeavor or Aria	Pymetrozine or Flonicamid	Immatures and adults	9B 9C

Normal to high whitefly pressure:

Treatment	Yellow sticky card counts	Trade name	Common name	Life stages targeted	MOA group
First	Normal to high	Safari Marathon Flagship Celero TriStar	Dinotefuran Imidacloprid Thiamethoxam Clothianidin Acetamiprid	Immatures and adults	4A
Second	Rising	Distance or Pedestal	Pyriproxifen or Novaluron	Immatures/reduces ovipositioning Immatures	7D 15
Third	Rising	Judo	Spiromesifen	Immatures and pupae/translaminar	23
Fourth	Declining	Endeavor or Aria	Pymetrozine or Flonicamid	All/stops ovipositioning	9B 9C