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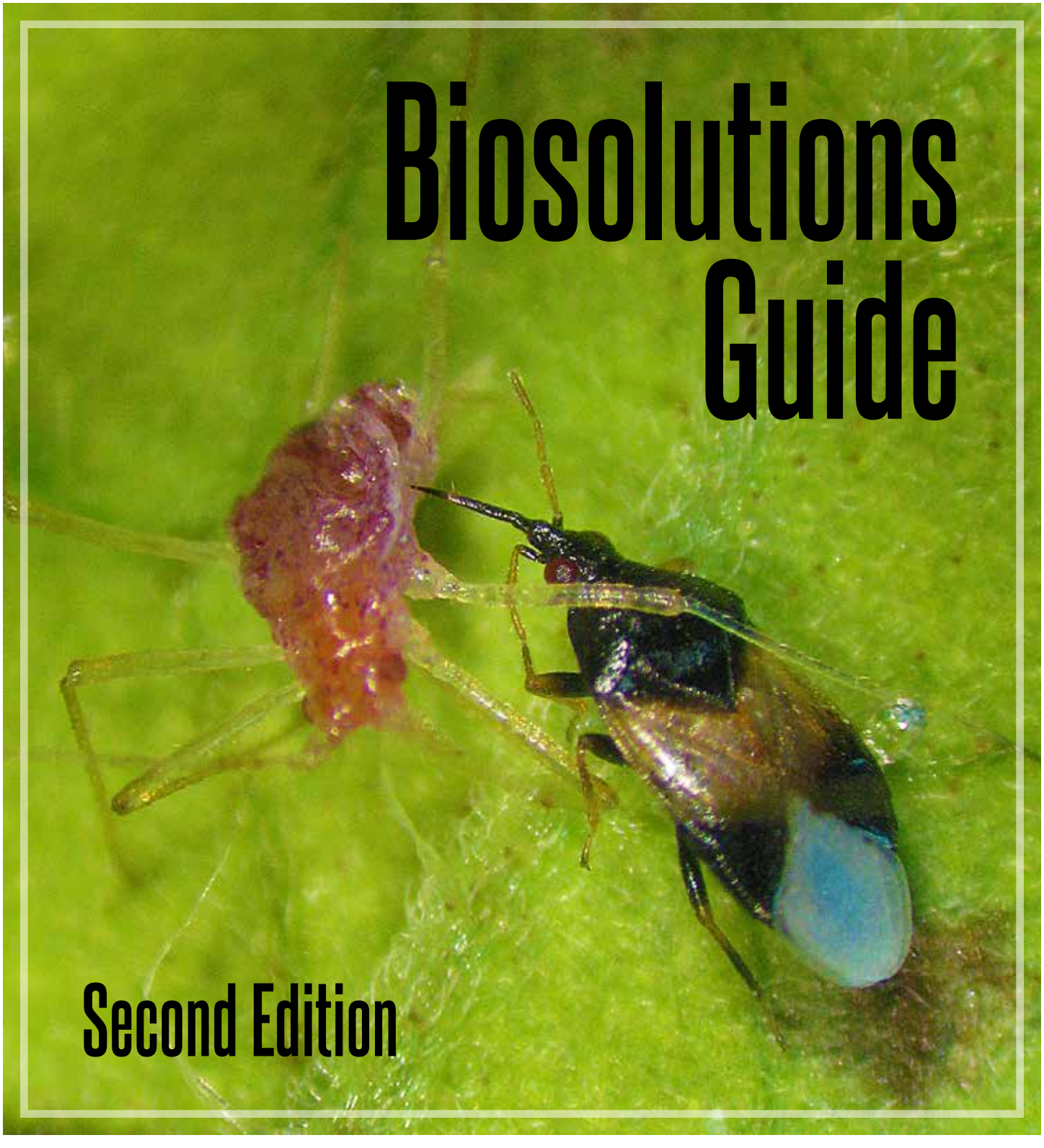
GROWERTALKS



Biosolutions Guide

Second Edition

ACTIVATE

YOUR INTEGRATED PEST MANAGEMENT PROGRAM

Creating a well-rounded IPM program doesn't have to be complicated. Whether you're a new or returning biologicals user, there's a simple way to integrate them into your operation and power up your programs. This approach works alongside your existing programs in a production cycle, joining and synergizing what is already working at your operation.

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1. Plan to start when pest pressure is low and pick one to two formulated biologicals for your most common pests.
2. Start with Foundational Fridays, every Friday: respond to changing pressure with rate adjustments.
3. You're already making conventional applications: if you want to add in macro-biological control agents (BCAs), shift conventionals to targeted chemistries and stagger your broad-spectrum insecticide applications, or use them only for rescue.

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Beneficial nematodes, like **Nemasys® beneficial nematodes** **Millenium® beneficial nematodes**	IGRs and MGRs	Predators
Biological fungicides	Oils and soaps, like **Ultra-Pure® oil***	Parasitoids
Other microbials	Fungicides and sanitizers	Pollinators
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We launched the *GrowerTalks* Biosolutions Guide last year with the goal of shining a light on one of the most dynamic discussions within the horticulture industry. Educational sessions related to the topic are always packed with attendees, new product displays are filled with bio-based items and much of our industry's cutting-edge research follows this path, as well. The conversation is not new, but it's top-of-mind for many greenhouse professionals. *GrowerTalks* has been helping vet and share information and strategies related to biosolutions for many years and it's been exciting to see what was once a niche approach to greenhouse production become mainstream. Be sure to snap the QR codes on page 5 to read some of the best articles we've published recently.

And that's where we stand now, with some of the largest greenhouses in North America adopting and fine-tuning bio-based production protocols. And growers at all levels of the industry trusting biosolutions for pest and disease management, plant health optimization, labor savings and improved worker safety. Biosolutions are critical ingredients in most growers' recipes for crop quality. Our industry is evolving quickly and new research, information and products in the biosolution space is coming available at equal speed.

The 2024 *GrowerTalks* Biosolutions Guide is filled with the latest data, trial results and innovative approaches proving effective in commercial greenhouse production. The experts who've submitted content are leaders in research and applied technology, and are constantly challenging our industry to consider new ways to implement bio-based strategies with the end goal of sending amazing quality to market.

With an attempt to merge data and application, we've asked some industry leaders in the biosolutions space to discuss what's new, and more importantly, what growers need to know to achieve success with products and approaches rising to the forefront.

Michael Brownbridge (BioWorks, Inc.) dives deep into microbial biofungicides; Ann Chase reports trial results from biofungicides derived from plant extracts and biopesticides based on *Bacillus* strains; and Suzanne Wainwright-Evans shares the latest on banker plants for pest management and answers some of the most frequently asked questions she hears from commercial growers. In addition, we reached out to experts from Mycorrhizal Applications and Koppert to explain ways to incorporate mycorrhizae into production plans and effectively apply biocontrol agents, respectively.

Over the next 30-plus pages, expect to find tons of hard data (check out the updated biofungicide and bioinsecticide charts), fresh approaches and proven strategies. Read these articles with an open mind and I promise you'll close the back cover with dozens of new ideas and plans to trial new products.

BILL CALKINS
Senior/Digital Editor—Ball Publishing
Editor—*Tech On Demand* newsletter

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ON THE COVER: Orius feeding on an aphid. Photo by Suzanne Wainwright-Evans.

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BALL PUBLISHING

GrowerTalks (ISSN 0276-9433) is published monthly by Ball Publishing, P.O. Box 1660, West Chicago, Illinois 60186, United States. Subscriptions are free to qualified readers in the US. Subscription price for non-qualified readers is $50 per year US and Canada. All other foreign subscriptions must pay $199/year to receive/continue to receive *GrowerTalks* and *Green Profit*. *GrowerTalks* is a U.S. registered trademark of Ball Horticultural Company. Periodicals postage paid at West Chicago, IL and at additional mailing offices. Postmaster: send address changes to *GrowerTalks* Magazine, P.O Box 1660, West Chicago, Illinois 60186, United States. Posted under Canada publications mail agreement #40732015. Canada returns to be sent to International Delivery Solutions, P.O. Box 456, Niagara Falls, ON L2E 6V2, Canada. Printed in the USA.

GreenProfit Supplement Enclosed

Further Reading

Snap the QR codes below to read some past biosolutions articles published by *GrowerTalks* and watch the magazine for many more to come.

Best Practices for Biocontrols (5-Part Series)—

John Sanderson, Suzanne Wainwright-Evans & Ronald Valentin (*GrowerTalks* 2021)

Part 1 Delaying preparation for your beneficial agents' arrival can cost you time and money

Part 2 How to release predatory mites to your crop

Part 3 How to release parasitoid wasps to protect your crop

Part 4 Beneficial nematodes are relatively easy to use and are applied similarly to conventional pesticides with some special precautions

Part 5 How to release Orius, Aphidoletes and lacewings to protect your crop

Control Botrytis Blight with Alternative Products—

Julie Martens Fortney (*GrowerTalks* November 2023)

Funded by AFE, research explored options to control Botrytis that don't induce resistance

Biological Progression—

Paul Pilon (*GrowerTalks* December 2023)

When used properly, biosolutions approaches can be effective at controlling numerous pests and diseases, as well as for improving overall plant health and appearance. Give them a try.

What Makes a Product OMRI-listed?—

A.R. Chase (*GrowerTalks* January 2024)

Here's a brief review of the history and what makes a disease-control product organic

Using Mycorrhizal Fungi Products in the Greenhouse

By **DR. ANISSA POLEATEWICH**—Senior Product Development Manager, Mycorrhizal Applications

What's the latest on the use of mycorrhizal fungi in container production? And what questions are growers asking and what do they need to know?

Mycorrhizal fungi are a ubiquitous group of soil microorganisms that colonize plant roots forming a mutually beneficial relationship or symbiosis. Currently, there are four types of mycorrhizal symbioses that differ in structure, function and host plant (photobiont): arbuscular mycorrhiza (AM), ectomycorrhiza (ECM), orchid mycorrhiza and ericoid mycorrhiza.

These small, but mighty, fungi play a major role in promoting plant health, and in turn, are key players in the productivity and sustainability of our agricultural and horticultural production systems. Do you take a probiotic to aid in digestion and absorption of nutrients in your gut? Mycorrhizal fungi and other soil microbes serve an analogous function for plants—by adding and promoting establishment of these fungi we can boost the "nutritional health" of our plants. At its core, the relationship terms are simple: the plant provides carbon (sugars and lipids) to the fungus, and in return, the fungus acts as an extension of the root system, providing the plant with water and nutrients.

The benefits mycorrhizal fungi have on plant health are widely recognized, leading to companies developing mycorrhizal-based inoculants. In greenhouse and container-crop production, crops are grown in soilless media that don't contain mycorrhizal fungi, so they need to be added either by purchasing premixed growing media or applied during production.

When should mycorrhizal inoculants be applied?

In general, an application made during propagation or before planting provides the maximum benefit. There are a few reasons why:

■ First, it takes time for the symbiosis to establish. The interaction requires communication between both plant and fungus. Since plants and microbes cannot "talk," they communicate via an exchange of biochemical signals. AM fungi can detect low concentrations of specific metabolites exuded by plant roots. These signals let ▶

Trial photo showing superior growth of lavender cuttings treated with MycoApply mycorrhizal product (right) compared to the control crop (left).

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the fungus know a host is nearby and even stimulate germination of fungal spores. The AM fungi respond by sending signals that allow the plant to identify the encroaching fungus as a friend and not a foe. Next, the fungus produces a specialized infection structure (hyphopodium) that enables internal colonization of the root tissue. It can take four weeks for AM colonization of plant roots to establish and up to eight weeks for benefits to be noticed. For this reason, the earlier the symbiosis is established, the better the results, particularly for short-term crops.

■ Second, early application in a smaller volume of growing media is the most cost-effective, as less product is needed compared to application at later stages of plant growth. In some cases, mycorrhizal fungi may be incorporated into the growing media before planting. Commercial products contain propagules (dormant spores and/or colonized root fragments) that essentially wake up in response to exudates produced by roots as they grow through the substrate.

■ Lastly, mycorrhizae help plants tolerate stressors such as transplant stress. When applied early and before transplanting, mycorrhizal fungi significantly improve transplant success and can shorten production time due to enhanced growth. Once mycorrhization is established, it can persist, so re-application post-transplant is generally not needed.

How should mycorrhizal inoculants be applied?

Mycorrhizal inoculants come in several formulations, ranging from dry to liquid and can be applied using a diversity of methods and equipment. Depending on the formulation, products can be applied to unrooted cuttings, incorporated into growing media, used as a seed treatment, or as a drench or dip. As described above, mycorrhizal fungi and their plant hosts engage in a dialog of biochemical signals that facilitate establishment of the fungus inside plant roots. *The key to this interaction is proximity.* It's important that propagules (spores or colonized roots) be in close proximity to plant roots so that secreted root exudates trigger germination of propagules. If the propagules are too far away, it could take longer for the two to "find each other."

Hyphae from germinating spores can grow and explore the soil in search of a host, but retract if they don't encounter one and wait to germinate later when a host is detected. Thus, if mycorrhizal fungi are incorporated into the growing media, it's important that the product is thoroughly mixed into the media. For other applications, it's important to apply the product with enough water to move the propagules into the root zone and ensure contact between the fungus and plant roots.

You may have come across recommendations related to mycorrhizae and fertilizer. Mycorrhizal inoculants can be applied with fertilizer, but over-fertilization should be avoided in the early stages of establishing mycorrhizae in the crop. Why? Going back to the nature of the transaction between plant and fungus, the plant is allowing itself to be infected by the hyphae of the mycorrhizal fungus because the fungus offers something the plant wants. If nutrients are in excess, the plant may simply say, "No, thank you" and turn the fungus away, at least initially.

How do I know it's working?

As is the case with many biologically-based tools, one cannot "see" the product on the plant or even see the benefit right away. Side-by-side comparisons of treated and non-treated plants are often the best way to observe the benefits. Some improvements growers have observed include seedling emergence, transplant success rate, crop uniformity and crop cycle time (growers have reported cutting weeks off the production cycle when using mycorrhizal fungi).

Protection from drought stress allows growers more time between watering and helps keep plants looking nice on the retail shelf when watering isn't always optimal. Another metric is reduced nutrient loss through leaching. A university study reported that mycorrhizal colonization reduced N and P in container leachate by 65% to 80%.

Lavender trial photo showing root growth of lavender plants treated with MycoApply mycorrhizal product (left) compared to the control crop (right).

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An Essential Part of Your Future

By Dr. Michael Brownbridge—Senior Technical Services Manager, BioWorks Inc.

Biofungicides are increasingly seen as essential components of Integrated Plant Health Management (IPHM) programs. How can they help you? More specifically, how can they help you produce healthier plants and a healthier bottom line? Let's start with some background information to set the stage for the discussion that follows.

Biopesticides are registered and regulated plant protection products that are defined by the EPA and Canada's PMRA as "... certain types of pesticides derived from natural materials such as fungi, bacteria, viruses, plants, animals and minerals." Biopesticides are then divided into three classes depending upon the active ingredient contained or expressed. Two are of importance to the greenhouse sector:

1. Biochemical pesticides
2. Microbial pesticides

In this article, the focus is on the use of biochemical and microbial biofungicides registered for management of foliar and soilborne diseases and their broader contribution to plant health and productivity.

Why consider using a biofungicide?

Biofungicides are a great fit in IPHM due to their inherent features and the value they bring to the program—proven efficacy and performance, safety and compatibility—and they have unique modes of action (MOA), which is important in resistance management. In addition, most biofungicides have short re-entry intervals (REI) and pre-harvest intervals (PHI), so they can be applied with minimal disruption to day-to-day crop management activities. It's important to remember, though, what they are not: They are not curative. Rather, they're best used in a preventative manner, ideally starting in propagation, and as part of an integrated solution applied into a production system that supports their success, i.e., other components of the system do not compromise their efficacy. And, yes, they can be used in programs that include conventional pesticides, either as tank mix partners or in rotations.

The disease triangle provides a simple way of understanding what's required for a plant pathogen to infect a host. First, a virulent pathogen must be present at high enough levels to infect healthy plants. Second, to develop, that inoculum needs a susceptible host. And, finally, environmental conditions must be favorable for disease development to occur (like temperature and humidity levels). Infection will only occur if all three elements are concurrently satisfied. If we eliminate or reduce any one of them, we significantly reduce the likelihood of disease developing and spreading within a crop.

Recognizing we can't control the weather, what can we do to protect plants? Good agronomic and sanitation practices are fundamental, including environmental management when crops are grown indoors. Beyond that, we can reduce pathogen levels using chemical or biological fungicides (biofungicides) or both. We can also reduce plant susceptibility to specific diseases through use of resistant varieties, and by increasing a plants' ability to tolerate and recover from abiotic (environmental) stress, as stressed plants are more prone to pathogen infections.

Biofungicides for foliar diseases

Both biochemical and microbial biofungicides are available for common foliar pathogens, such as Botrytis and powdery mildew (Figure 1). Bacterial products based on *Bacillus* (for example, Cease, Stargus, Rhapsody, Double Nickel, Serifel) and *Streptomyces* (for example, Actinovate, Mycostop, Lalstop K61) species primarily work by antagonism. These products contain viable spores, but activity resides in the bioactive metabolites produced by the bacteria during fermentation that are included in the formulations. These metabolites physically disrupt cell membranes and cell walls of actively growing fungi and bacteria, causing the cells to collapse and die.

Figure 1. At a glance: Common modes of action of biofungicides used against foliar diseases.

Antagonism
- *Bacillus* spp., *Streptomyces* spp.
- Metabolites (lipopeptides) produced during fermentation
- Physically disrupt cell membranes, inhibit fungal growth

Antagonistic Competition
- *Ulocladium oudemansii* strain U3 (BotryStop WP)
- Primary MOA: Out-competes Botrytis and bacterial leaf spot (BLS) for nutrients and space at sites where infections start
- Secondary MOA: Secretion of enzymes that break down pathogen cell walls

Physical MOA
- Biochemical fungicides
- K-bicarbonate: Desiccates fungal spores, destroys cell membranes
- Polyoxin D zinc salt: Inhibits the formation of chitin (fungal cell walls)

Induced Resistance
- Induce plant defenses
- Plants produce and accumulate specialized proteins and other compounds
- Inhibit bacterial and fungal diseases

The saprophytic fungus, *Ulocladium oudemansii* U3 strain (BotryStop WP), works by antagonistic competition. *Ulocladium* colonizes dead, damaged and senescing plant tissues, and outcompetes Botrytis for resources at these sites, preventing the disease from getting a foothold on a plant and building inoculum levels in the crop. As the fungus grows on the plant tissue, it also secretes enzymes that degrade pathogen cell walls, providing an additional MOA. This product also works well against bacterial leaf spot (BLS) diseases (caused by Xanthomonas and Pseudomonas)

on many plants, likely due to a very similar MOA, with the fungus colonizing leaf tissue compromised by the bacteria and effectively enclosing the disease and preventing its further development and spread.

Several foliar products classified as biochemical fungicides have a physical mode of action. Potassium bicarbonate (like MilStop SP and Kaligreen) is a well-known remedy for powdery mildew and Botrytis. Bicarbonate-based products work by desiccating fungal spores and actively growing hyphae on the leaf surface on contact, destroying cell membranes, leading to cell death. An application also raises the pH of the leaf surface, creating conditions that are unfavorable for fungal growth. Polyoxin D is a naturally occurring compound produced by *Streptomyces cacaoi* var. *asoensis.* Polyoxin D is very water soluble, so it's formulated as a zinc salt (Polyoxin D zinc salt, such as OSO) to provide longer residual activity on a leaf. Polyoxin D works by inhibiting the formation of chitin. Chitin is a vital component of fungal cell walls, so the product prevents fungal growth.

Botanical extracts derived from giant knotweed (Regalia) or *Swinglea glutinosa* (EcoSwing), as well as some *Bacillus* species (such as *B. mycoides* and LifeGard), have no direct effect on pathogens, but when applied to plants, stimulate production of antimicrobial proteins and other compounds that inhibit plant pathogens, thereby enhancing the plant's own natural defenses against infection.

Microbial biofungicides for soilborne diseases

Microbial biofungicides will prevent infection by common root diseases such as Fusarium, Pythium, Rhizoctonia, Phytophthora and Thielaviopsis. We know that infection by one may pre-dispose a plant to infection (and death) by another, so the availability of products with the capacity to control a broad range of diseases is clearly advantageous. That's another benefit provided by the microbial biofungicides that are registered for soil application. Most are based on fungi like *Trichoderma* and *Clonostachys*, or bacteria, like *Bacillus* and *Streptomyces* (Table 1). *Streptomyces* and *Bacillus* species colonize the rhizosphere, the thin layer of soil or growing substrate that surrounds the plant root, whereas *Trichoderma* species colonize the root surface itself. All utilize sugars and other root exudates to grow. While several different species are represented in the registered products, they provide protection via a combination of competition, antagonism, parasitism and their capacity to induce plant resistance. However, not all strains have multiple MOA.

Let's consider the MOA of *T. harzianum* T-22, one of the two strains in RootShield PLUS, as an example to understand how these microbes work. As the fungus grows around the plant root, it competes with pathogens for resources (such as sugars and space) at the root surface and prevents them from establishing (competition). Actively growing T-22 also secretes metabolites that inhibit germination and growth of pathogens (antagonism). This fungus can also parasitize and "consume" pathogens in the soil.

Lastly, as the fungus grows, other biochemicals it produces are detected by the plant roots; this activates metabolic pathways in the plant that result in the upregulation of plant defense genes, so the plant is primed to defend itself against pathogen attacks (induced resistance). Having multiple MOA means that it's difficult for diseases to develop resistance to these microbial biocontrol agents, making them ideal standalone products and excellent rotational partners in resistance management programs. Some metabolites produced by the fungus work as phytohormones, stimulating root growth and development. (More on this in a moment ...)

Figure 2. Understanding application terminology on the label.

Fogging
- Should not see much if any evidence of applied product on leaves

Spray to Glisten
- Small droplet deposition and sheen on plant surface—no runoff

Spray to Wet
- Larger droplet size, may include more surfactant, begin to runoff

Spray to Runoff
- Spray is visibly running off edges of foliage

Sprench
- High-volume spray (large droplets) liquid flows down stems to moisten growing medium and base of plant

Drench
- Soil application with adequate volume to saturate growing medium and root zone
- Use more water volume compared to systemic chemical

Chemigation
- Apply through driplines; ensure application is made towards the end of the irrigation cycle

Dip
- Immerse cuttings or plugs in a suspension or solution of the biofungicide

Application essentials

Think of it this way: You need to put the right product in the right place at the right time, using the right equipment to be successful. Incorrect timing and poor coverage are primary causes of biopesticide failure. But isn't that true of all fungicides, whether conventional or biological? Here are a few things to consider:

Product selection. First off, make sure that the products you're considering using are registered. There are many microbial products out there, but relatively few are EPA-registered. Educate yourself on the different types of biofungicides that are available for foliar and soilborne disease control. Ask questions of the manufacturers so you select the best product for your crop and needs. ▶

Table 1. At a glance: Modes of action of biofungicides for soilborne diseases.

Type of microbe	Product examples	Mode of action
Fungi *Trichoderma*, *Clonostachys* species	RootShield PLUS, Asperello, LalStop G46	**Competition:** Colonize roots, out-compete pathogens for resources **Antagonism:** Metabolites/enzymes inhibit or kill other microorganisms **Parasitism:** Microbial agent can attack, parasitize and "consume" the pathogen **Induced resistance:** Metabolites produced by the microbe activate plant defenses
Bacteria *Bacillus* species *Streptomyces* species	Cease, Stargus, Double Nickel, Serenade, Serifel, Triathlon Actinovate, Mycostop, Lalstop K61	

Figures 3A & 3B. Enhanced root development and health following application of A) RootShield PLUS (BioWorks, left) on Romaine lettuce (control: grower standard, right); and B) in greenhouse pepper following application of RootShield PLUS (*Trichoderma harzianum* T-22 and *T. virens* G-41). Note healthy white roots growing through the coco-medium.

Consider the application equipment you have available and where you're looking to utilize the material. Although biofungicides share many characteristics, they're also different. Familiarize yourself with the label and the recommendations around product use, rates and re-application intervals. Ask for data to support claims and understand how products interact with other crop inputs and the environment.

Timing. Biofungicides provide the best protection when applied proactively, *before* disease symptoms are observed in the crop. Few work curatively (there are some exceptions—potassium bicarbonate products like MilStop-SP, for example, can be applied at preventative or curative rates) and they all work best when disease pressures are low to moderate. This is true for foliar and soilborne diseases.

In greenhouse crops, applications of microbial biofungicides to protect plants against root diseases should begin in propagation. When plants are dying in prop, it's too late to remediate the disease(s). It's better to protect roots from the get-go and the plants will thank you for the added benefits these products bring. (Note: Growers can also apply biofungicides after a recent chemical application to lower pressure. Or, if compatible, mix a biological with a chemical for curative, then preventative, protection.)

As with any fungicides, biofungicides need to be re-applied while disease pressures persist. Foliar diseases spray intervals are often similar across crop types and will be influenced by disease pressures or the onset of weather conditions that are conducive for disease development. This is also true for soilborne diseases, but the type of growing medium used also affects the interval between treatments. Timing varies for plants grown in peat, coco or rockwool media, for example.

Application. Different terms are used on labels to describe how products should be applied (Figure 2). It's important to understand what these terms mean to use spray or other application equipment correctly to achieve the desired outcome in terms of getting a biofungicide where it needs to be, whether that equipment is even appropriate for that product and whether that method of application is actually on the label—application by dipping or fogging, for example, aren't approved methods of delivery for many biofungicides. Performance is then a product of the equipment selected, how well it's maintained and calibrated, and how well the applicator uses that equipment.

A wide range of equipment can be used to apply biopesticides, from simple backpack sprayers to more advanced hydraulic, low-volume and electrostatic sprayers. While the sprayers utilize different methods to produce and deliver spray droplets onto the plant, in all cases, the goal is to get thorough coverage of all plant surfaces and good penetration of the plant canopy by those spray droplets. For most foliar biofungicides, "spray to glisten" ▶

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(meaning apply a light coating of spray droplets to leaf surfaces) or "to wet" (leaves are wet, but no runoff) are often recommended spray practices. The goal should always be to avoid runoff. We can get significantly better coverage if we use a sprayer that generates fine droplet sizes. Smaller droplets also move deeper into the canopy and provide superior coverage over all surfaces. Selection and use of the right spray equipment for the product and targeted use are essential to achieving the desired end result.

Drenching via a Dosatron-type system or through the driplines is the most common method used to apply WP or liquid formulations of biofungicides for soilborne diseases. It's worth emphasizing again that early application allows the microbes, that can, to establish on and protect the young roots, with products re-applied at different stages of the production cycle to provide ongoing protection. Critical to efficacy again, though, is coverage, ensuring that the biofungicide is applied in sufficient water to move the spores though the growing medium and into contact with the roots. Granular formulations of these biofungicides can be directly incorporated into the growing medium prior to use, so that the granules, and hence the inoculum, are evenly distributed throughout the medium and available to roots as they grow through the medium. As an alternative, granular biofungicides that grow can be top-dressed onto the media. When watered, the spores are moved into the medium, and will germinate and grow on the roots to defend the plant and reduce plant stress.

Integration

New chemical fungicides don't come to market very often; it's crucial that we maintain them for as long as possible and manage their use accordingly to avoid or delay development of disease resistance. A common misconception is that you can't use biofungicides with conventional products. The reality is some biofungicides can be used to aid resistance management programs that include conventional pesticides, either as tank mix partners or in rotations.

And there are other scenarios where it makes sense to use chemistry and biology together. When disease pressures are high, for example, chemistry can provide a quick knock-down effect and biology can be used thereafter to provide extended disease protection. In many cases, the efficacy of programs can be improved through these approaches. Use of chemistry and biology together, though, requires that they're both physically and biologically compatible. Information on compatibility is generally available from the manufacturers.

Other plant health benefits

Not only do *Bacillus* and *Trichoderma* species colonize and protect roots from diseases, but they also provide numerous other plant health benefits. Strains have the capacity to solubilize phosphorus, and improve the bioavailability and *in planta* movement of other macro- and micro-nutrients. They produce auxins, small peptides, volatiles, phytohormones and other active metabolites that promote seed germination and root development, leading to additional growth benefits. Collectively, these and other effects also help plants cope with abiotic stress (Figure 4).

A final word of caution

There's no shortage of microbial products that claim to protect plants from disease or sources for them, including several multi-strain products that allegedly contain bacteria and/or fungi that are the same as those in registered plant protection products. But are they? Take a closer look at the label on your *EPA-registered* biofungicide. It'll tell you what species of bacterium or fungus it contains, and the strain number.

For example, *Trichoderma harzianum* T-22; *T. virens* G-41; *T. asperellum* T-34; *Streptomyces griseoviridis* K-61; *S. lydicus* WYEC 108; *Bacillus amyloliquefaciens* MBI600, D747; and F727 *B. subtilis* QST713. These specific strains have proven the capacity to control plant diseases and deliver other plant health benefits. There are many *isolates* of *Trichoderma, Bacillus* or *Streptomyces*, but a name is just that—a name. Strains are key and numbered strains in registered products distinguish them from other isolates with the same name.

Acknowledgements: *Thanks to my BioWorks' colleagues and friends through the industry for providing the images used in this article. Special thanks to Dr. Chris Hayes, Sr. Biological Solutions Advisor in the Southeast, for providing valuable feedback on earlier versions of this piece.*

Figure 4. The benefits of *Trichoderma* (RootShield PLUS) on rooting and growth performance when used in propagation of woody perennials, cacti and herbaceous perennials.

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Biofungicides Efficacy Table

Table 1: Examples of common biofungicides used in floriculture and nursery in the U.S. and their target diseases.
(+ indicates some activity, +++ indicates high activity).

Active Ingredient or Organsim	Product	Use Rates	Application Methods	Use Sites	Alternaria	Bacteria	Botrytis	Cercospora
Streptomyces lydicus WYEC 108	Actinovate SP	3-12 oz./100 gal.	S, D	G, N, L	+	+	+	
Ulocladium oudemansii Strain U3	BotryStop	2-4 lb./acre	S	G, N		++	+++	
Bacillus subtilis Strain QST 713	Cease	2-8 qt./100 gal.	S, D	G, N	+	++	+++	+++
Bacillus amyloliquefaciens ENV503 (*Bacillus subtilis* Strain GB03)	Companion	16-64 oz./100 gal.	S, D	G, N, L		+		
Swinglea glutinosa	EcoSwing	1.5-2.0 pt./100 gal.	S	G, N, L		++	++	
Copper Octanoate	Grotto	0.5-2.0 gal./100 gal.	S	G, N	+++	+++	++	++
Copper Hydroxide	Kalmor	0.5-2.0 lb./100 gal.	S, D	G, N, L	++	++	+	+
Bacillus mycoides isolate J	LifeGard WG	4.5 oz./100 gal.	S	G, N	+	+	++	++
Potassium Bicarbonate	MilStop SP	1.25-5.0 lb./100 gal.	S	G, N, L	+	+	+++	+++
Streptomyces Strain K61	MycoStop	40 g/100 gal.	S, D	G, N	–		–	
Trichoderma asperellum Strain ICC 012 *Trichoderma gamsii* Strain ICC 080	Obtego	2.5-7.5 oz./100 gal.	D	G, N				
Gliocladium catenulatum Strain J1446	PreStop	0.1% to 1%	S, D	G, N		–	++	
Reynoutria sachakinensis	Regalia CG	32-128 fl. oz./100 gal.	S, D	G, N	+	++	–	+
Trichoderma rifai Strain T-22 *Trichoderma virens* Strain G-41	RootShield Plus WP	3-8 oz./100 gal.	D	G, N, L	–		+	
Bacillus amyloiliquefaciens Strain F727	Stargus	0.5-4.0 qt./100 gal.	S, D	G, N	++	++	++	+
Bacillus amyloiliquefaciens Strain FZB24	Taegro ECO	2.6-5.2 oz./100 gal.	S, D		–	+		
Extract of Neem Oil	Triact 70	0.5-2.0 gal./100 gal.	S	G, N, L	+	–	++	+
Bacillus amyloiliquefaciens Strain D747	Triathlon BA	0.5-6.0 qt./100 gal.	S, D	G, N, L	++	+++	+++	++

S = Spray
D = Drench
F = Fog
A = Aerosol

GH = Greenhouse
N = Nursery Production (Outside)
L = Landscape

Information as of June 2024.
The exclusion of trade names other than those listed in the table above is not intentional and does not imply that products not listed are ineffective.

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	Colletotrichum	Cylindrocladium	Downy Mildew	Fusarium	Phytophthora	Powdery Mildew	Pythium	Rhizoctonia	Rust	Sclerotinia	Sclerotiium	Thielaviopsis
	+	+	+	++	++	+	++	++	+	–	–	–
	–									++		
	+		+	+	+	++		+				
		–	–	–			+	–				–
			+			+++			+++			
	++	+	++			++			+			
		+	++		++	+		+	–			
	–		+				++	–		+		
	+		+++			+++			++			
				+++	++		+++	+++			–	+
				+	++		+	+			–	+
	++			–	–	++						–
	–		+	–	–	++	–			–		
		++		++	+++	+	+++	+++				–
	–		–	+	+++		+	++		++		
			–	+	–	+++	–	–				
	+	–	–			+++			+++			
		+++	+	+		++	+	++	++		+	

– none
+ some
++ good
+++ very good

Biofungicides Derived From Plant Extracts

By **A.R. CHASE—Chase Agricultural Consulting**

Dr. Ann Chase shares trial results for a range of biopesticides increasingly used in ornamental crop production.

One of the easiest types of biopesticides to successfully use are those derived from plants. Since they're essentially chemicals, the need to keep them alive is eliminated. On the other hand, since some of them are oils, you need to test mixtures for compatibility and crop safety.

Table 1 shows some of the information on the labels of the five products covered in this article. While I included the FRAC listing for these products, two of them haven't been categorized. It appears that neither thyme oil product is EPA-registered. Be sure to read labels carefully and follow their directions to stay legal and achieve the best results.

Regalia: One of the first products to launch in this category was Regalia. It was originally developed by BASF (mid-1990s) and eventually landed with Marrone Bio Innovations. I worked on this plant extract in the early 1990s. Regalia was created from *Reynoutria sachalinensis* (giant knotweed) and causes the plants to activate an internal defense system that prevents growth of certain fungi, especially powdery mildew and gray mold. The extract is approved for use on ornamental plants grown in greenhouses.

Triact 70: During the same timeframe, extracts from the neem tree were under development as insecticides and also tested for disease control capacity. The extract from neem tree oil is currently sold as Triact 70 through OHP. We worked on Triact 90 and then Triact 70 in the 1990s in Northern California. (Table 2 shows all the trials I could find. I decided to group the trials by disease type.)

EcoSwing: EcoSwing is a botanical fungicide created using proprietary plant extracts that's been a leader in fungicidal control of several key pathogens globally for many years. The product is OMRI-listed, has a caution label and a four-hour REI.

EcoSwing should be applied at the first sign of infection or when conditions are conducive to disease. Apply 1.5 to 2 pints per acre (usually agreed as 100 gal. for container production). It's important to get good coverage and a spreader sticker adjuvant is recommended. Repeat applications every seven to 10 days for best results.

EcoSwing's primary mode of action is to act as a contact desiccant and cell wall disruptor to the fungal hyphae. This is shown with very good results on many powdery mildew diseases (gerbera daisy and zinnia). Preliminary research also suggests that EcoSwing may aid in triggering the plant's natural defense mechanisms against bacterial and fungal pathogens. These are referred to at times as Systemic Acquired Resistance or SAR.

This helps explain the differences between pathogens and crops that become apparent as more and more trials are reported. It's typical for products that trigger a SAR reaction to work better on some crops than others. If the only action were as a desiccant and cell wall disruptor, not all of the pathogens from bacteria to rust to mildews would have an equal chance to respond.

Proud 3 and PathoCURB: The first thyme oil product was Proud 3 and was evaluated by IR-4. Proud 3 is from Huma Gro and consisted of 5.6% thyme oil. It was trialed at 1% as the use rate against a wide range of pathogens, including Botrytis, bacteria, powdery mildew and Pythium. Overall results were not very good on any of the pathogens tested. It was also found to be phytotoxic and resulted in an increase in disease in a few trials. ▶

Table 1. Table information on some plant-based biopesticides.

Product	Manufacturer	Active ingredient	FRAC code	REI
EcoSwing Botanical Fungicide	Gowan	Extract of *Swinglea glutinosa*	Not classified	4 hours
PathoCURB	Kemin Industries	Thyme oil	BM01	0 hours
Proud 3	Huma Gro	Thyme oil	?	?
Regalia Biofungicide	Marrone Bio Innovations	Extract of *Reynoutria sachalinensis*	P5	4 hours
Triact 70	OHP	Clarified hydrophobic extract of neem oil	NC-FRAC M-IRAC	4 hours

Table 2. Summary of trial results for some plant-based biopesticides on all crops for diseases.

Product	Alternaria	Bacteria	Botrytis	Cercospora	Colletotrichum	Downy mildew	Myrothcium	Powdery mildew	Rust
EcoSwing		none/ excellent	good			some		some/excellent	very good/ excellent
PathoCURB	none	none	none		some				
Proud 3		none/very good	none				none	some/excellent	
Regalia	none/some	none/good	none/ some	some	none	none/good		none/very good	
Triact 70	none/some	none/some	some/ good	slight/some	some/good	none		good/excellent	very good/ excellent

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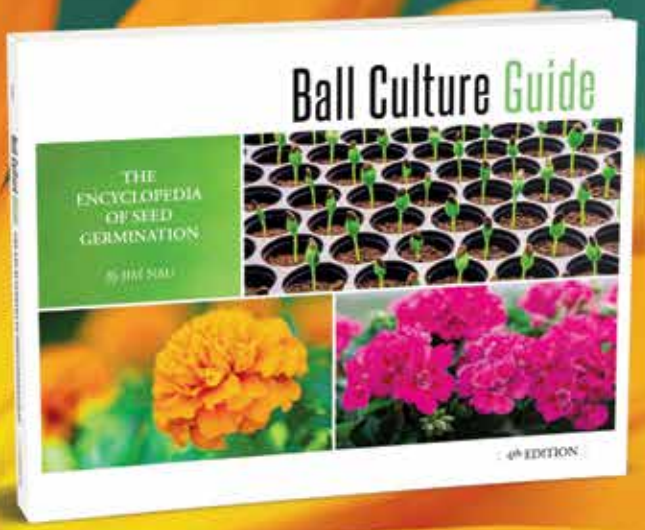

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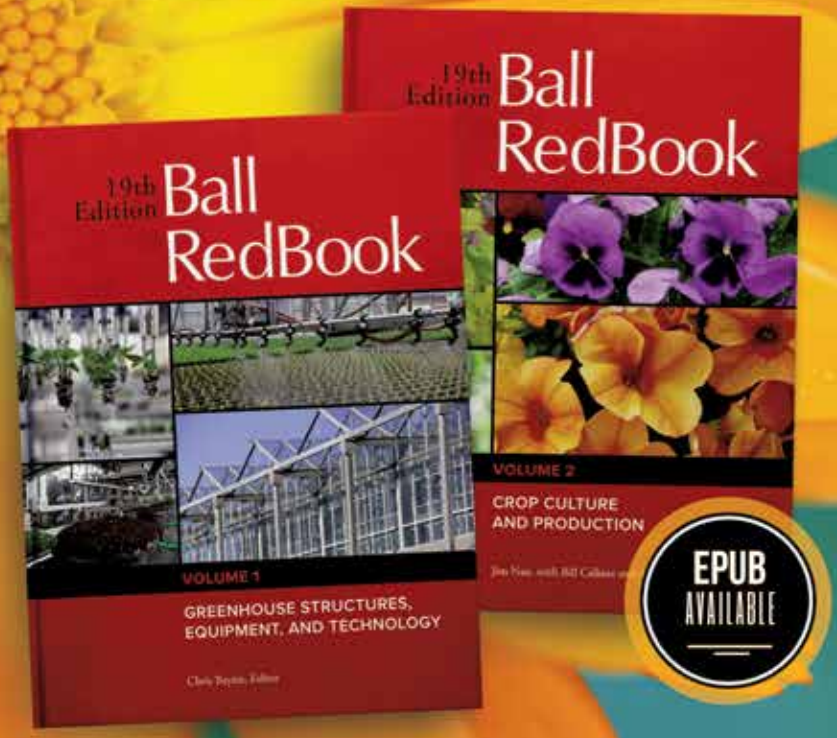

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The second thyme oil product included in IR-4 trials was PathoCURB by Kemin Industries (it was originally called Tril-21). In a few trials, both Proud 3 and PathoCURB were included. PathoCURB is 15.5% thyme oil and was tested at 0.5% on a variety of bacterial and fungal foliar diseases.

Trials results for PathoCURB were not very different than those for Proud 3. Many trials were conducted on various species of Botrytis on a variety of crops with almost no positive results. As with the other thyme oil product, phytotoxicity was reported occasionally and sometimes disease was worse with the application of PathoCURB than the inoculated control.

Table 2 lists results of trials on ornamentals and many other crops for the five products discussed above. I used the same standards for level of control as I have for results, which were often variable due to differences in the many pathogens and crops tested. It was also common to see variable results from none to good on a single type of disease on a single crop. The bacteria column included trials on Pseudomonas and Xanthomonas. ■

Bacillus-based Biopesticides

The first *Bacillus*-based biopesticide we worked on was originally called Rhapsody and is made from *Bacillus subtilis* QRD 713. We probably have more information on using Rhapsody/Cease for control of ornamental diseases than any of the other products created from strains of *Bacillus subtilis* or *B. amyloliquifaciens*.

Since OHP brought us Triathlon BA, we've worked on it in a wide variety of trials. Then we started to work on Stargus (Marrone BioInnovations) and most recently a number of newer or experimental products based on other strains of this bacterium.

Some of the products have been registered recently (AmyloShield), while the majority of products registered from this group have been liquid formulations. We're now working on two different formulations, which are wettable powders, and another liquid formulation from Harrell's.

Table 1 (page 22) lists some of these products, including their exact strain and their manufacturers. Specific strain identification and strict product processes are critical. Each of the products I decided to include has a four-hour REI (except AmyloShield) and is OMRI-listed, making them user-friendly, especially for growers who produce edibles as well as ornamentals.

Buying a product without a strain identification is a risk. Products that are strain-identified are more likely to produce reliable, consistent results. Just like conventional chemicals like strobilurins or sterol inhibitors are not interchangeable, not all *Bacillus amyloliquifaciens/subtilis* are the same. A large effort has been underway for over 40 years to determine how they work. The *Bacillus* strains in these products share many of the same features.

■ **Antibiosis** is the creation of anti-fungal metabolites. Some are created once the products are applied, but many of the current products are created during production of the product itself (lipopeptides, enzymes, siderophores and salicylicates). These products are effective in directly damaging the plant pathogens.

■ **Competition** by growing in the area a pathogen would normally occur crowds them out.

■ **Induced resistance**—many if not all of the effective *Bacillus* products stimulate the plant's defense systems.

- Production of gibberellins and cytokinens that directly attack the fungal or bacterial pathogen or enhance plant growth.
- Promoting roots or seed germination can result in the plant outgrowing the damaging effects of soil-borne pathogenic fungi.
- Promoting plant resistance to toxic metabolites form fungi, increased photosynthesis and delayed senescence.

Trial efficacy summary

Some of these products work better on foliar diseases while others work better on soil-borne diseases. Some work better on bacterial leaf spots than the others. It would be impossible to choose a single product to cover the range of diseases one might encounter in ornamental production.

Table 2 and 3 (page 22) summarize research trials with these *Bacillus* products on all crops (not just ornamentals). In some cases, the trials were primarily performed on edible crops, especially in Table 3. In others, a large number of trials have been conducted on ornamentals.

Finally, the fact that these are living organisms makes their full benefits dependent on more factors than use of a conventional fungicide or bactericide. It's easier to affect a living organism with pH, salinity, temperature or even storage of the product than a conventional chemical.

Bacillus products can be very effective in a rotation with other biopesticides or conventional products. Some of their effects are based on the natural chemicals they create during their production. You can check manufacturer websites for compatibility of their *Bacillus* product with other effective choices for specific crops or diseases. Read the labels carefully! They usually include critical information on successful use of the product. The blanks indicate no trials that I could find.

In 2023, we performed four trials with AmyloShield: Botrytis blight on pansy, Botrytis blight on cyclamen, powdery mildew on gerbera daisy, and rust on snapdragon. Results are shown in Table 4 (page 22). Products were applied once before inoculation (all trials) and then again on a weekly interval for powdery mildew and rust trials. Trials were conducted with different conventional standards, as well as Triathlon BA (1%) in each trial.

■ Botrytis trials had Astun (17 oz./100 gal.) and the disease rating for both Botrytis trials was the number of infected flowers.

■ The powdery mildew trial had Broadform (4 oz./100 gal.) with the disease rating for the powdery mildew trial was the number of powdery mildew colonies.

■ The rust trial had Terraguard (4 oz./100 gal.) and disease rating was number or pustules.

Disease results showed that both rates of AmyloShield in both Botrytis trials, the powdery mildew trial and the rust trial were as effective as the standard. We did see some phytotoxicity in the gerbera daisy trial. Both rates of AmyloShield caused slight burning on leaves and flowers. This was not seen in any other trial. Check the product labels for legal use rates, application intervals and targets. Be sure to test all products for safety on your crops under your specific conditions. ▶

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Table 1. Some *Bacillus* products with known strain identification.

Product	Active agent	Manufacturer
AmyloShield (12 hr REI)	*Bacillus amyloliquifaciens* strain PTA-4838	Mycorrhizal Applications
Cease	*Bacillus subtilis* QRD 713	BioWorks Inc.
Companion Maxx (Bacillus A)	*Bacillus amyloliquifaciens* strain ENV503	Harrell's (DHB Biologicals)
Companion	*Bacillus subtilis* strain GB03	Growth Products
Serenade ASO (Landscape use only)	*Bacillus subtilis* QRD 713	ENVU (Bayer)
Stargus	*Bacillus amyloliquifaciens* strain F727	Marrone Bio Innovations
Subtilex NG, Serifel NG	*Bacillus subtilis* strain MBI 600	BASF Corp.
Taegro 2	*Bacillus subtilis* var. *amyloliquefaciens* strain FZB24	Novozymes
Triathlon BA	*Bacillus amyloliquifaciens* strain D747	OHP (Certis)

Table 2. Trial summary for foliar diseases on all crops.

Product	Alternaria	Bacteria	Botrytis	Cercospora	Colletotrichum	Cylindrocladium	Downy mildew	Powdery mildew	Rust	Sclerotinia
AmyloShield			very good					very good	very good	
Cease	some	good	very good	very good	some		some	good		
Companion		some	none			none	none	some		
Serenade ASO	none	none			some			good		
Stargus	good	good	good	some	excellent		none	very good		good
Taegro 2	none	some					none	very good		
Triathlon BA	good	very good	good	good	none	very good	some	good	good	

Table 3. Trial summary for soilborne diseases on all crops.

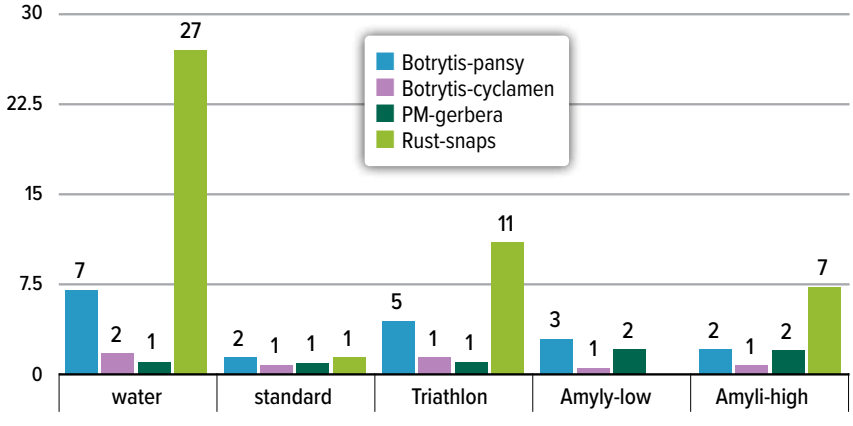
Product	Cylindrocladium crown/root rot	Fusarium crown/ root rot, wilt	Phytophthora root rot	Pythium root rot	Rhizoctonia crown/root rot	Sclerotium (So. Blight)	Thielaviopsis (black root rot)
Cease	some	some	some	some	some		
Companion	none	none		some	none		none
Serenade ASO			none				
Stargus	good	good	very good	some	good		
Subtilex				none	very good		none
Taegro 2		some	none	none	none		
Triathlon BA	very good	some		some	good	some	

Conclusions

Using *Bacillus*-based organic fungicide/ bactericides can be as effective as conventional products for Botrytis, powdery mildew and rust. Many of the organic products currently available, as well as those in development, are proving to be an effective choice either in an organic program or in a conventional program. Even tank-mixtures with copper can work, although why use them together when an effective rotation is less costly?

Early testing with Cease and copper showed its tolerance (resistance) of copper was quite high. Read labels carefully to make sure you don't try to make something work on a disease that the product isn't labeled for. It's always less costly to prevent a problem than to try to correct one.

Table 4. Disease severity with AmyloShield, conventional and *Bacillus*-based (Triathlon BA) standards. Higher bars show more disease.



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Bioinsecticides Efficacy Table

Table 2. Examples of common bioinsecticides used in floriculture and nursery in the U.S. and their target pests. (+ indicates some activity, +++ indicates high activity).

Active Ingredient or Organsim	Product	Use Rates	Application Methods	Use Sites
Azadiractin	Aza-Direct, Azatin O, Molt-X, Ornazin	4-16 fl. oz./100 gal.	S, D, F	GH, N, L
Azadiractin + Fats and Glyceridic Oils Margosa	DeBug Turbo	16-104 fl. oz./100 gal.	S, D	GH, L
Bacillus thuringiensis, subsp. *israelensis* Strain AM 65-52	Gnatrol WDG	3.2-26 oz./100 gal.	D	GH
Bacillus thuringiensis, subsp. *kurstaki* Strain ABTS-351	DiPel DF	4-16 oz./100 gal.	S	GH, N
Beauveria bassiana Strain ANT-3	BioCeres WP	1.5-3.0 lb./100 gal.	S, D	GH, N
Beauveria bassiana Strain GHA	BotaniGard 22WP, BotaniGard ES, Mycotrol WPO, Mycotrol ESO	0.5-2.0 lb./100 gal.	S, D, F	GH, N, L
Beauveria bassiana Strain PPRI 5339	Velifer	3-13 fl. oz./100 gal.	S	GH
Burkholderia spp. Strain A396	Venerate CG	2-4 qt./100 gal.	S, D, F	GH, N
Capsicum oleoresiin Extract, Garlic Oil, Soybean Oil	Captiva Prime	1-2 pints/100 gal.	S	GH, N
Chromobacterium subtsugae Strain PRAA4-1	Grandevo CG	1-3 lb./100 gal.	S, F	GH, N
Garlic Oil	Gemsei	40-55 oz./100 gal.	S	GH, N
GS-omega/kappa-Hxtx-Hv1a	Spear-T	1-3 gal./100 gal.	S	GH, N
Horticultural Oils	Suffoil-X, TriTek, Ultra-Pure	1-2 gal./100 gal.	S	GH, N
Isaria fumosoroseus Strain FE 9901	Isarid, NoFly	16 oz./100 gal.	S, D, F	GH, N
Isaria fumosorosea Apopka Strain 97	Ancora, Preferal WG	14-28 oz./100 gal.	S, D, F	GH, N, L
Metarhizium brunneum Strain F52	Lalguard 52 OD	8-32 fl. oz./100 gal.	S, D, F	GH, N
Neem Oil (extract)	Triact 70	0.5-2 gal./100 gal.	S	GH, N, L
Peppermint Oil, Clove Oil and Sodium Lauryl Sulfate	EpiShield	9-12 fl. oz./100 gal.	S	GH, N, L
Pyrethrins	Evergreen Pro 60-6	2-12.6 fl. oz./acre	S, D	GH, L
Pyrethrins	PyGanic 5.0	16-32 fl. oz./100 gal.	S, D, F	GH, N
Pyrethrins	Pyrethrum TR	2 oz. can/ 1,500-3,000 sq. ft.	A	GH
Pyrethrins + Canola Oil	Pycana	1-2 gal./100 gal.	S, F	GH, N
Rosemary Oil	TetraCURB	32-256 fl. oz./100 gal.	S	GH, N
Saccharopolyspora spinosa	Conserve	6-22 fl. oz./100 gal.	S, D, F	GH, N, L

Information as of June 2024.
The exclusion of trade names other than those listed in the table above is not intentional and does not imply that products not listed are ineffective.

S = Spray
D = Drench
F = Fog
A = Aerosol

GH = Greenhouse
N = Nursery Production (Outside)
L = Landscape

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	Aphids	Broad Mites	Caterpillars	Fungus Gnats	Mealybugs	Spider Mites	Thrips	Whiteflies
	++		+++	++	+		+++	+++
	+		++			++	++	++
				Larvae ++				
			++					
	++			++	++		++	++
	++		+	++	++	+	++	++
	+				+	++	++	++
	+		+++		+	+	+	+
			+			+	+	+
	++	+	++			++	+	++
	++	+	++	+	+	+	++	++
	+	++				++	+	+
	++				+	++	+	+
	+		+	Larvae +++	+	Eggs	Pupa ++	Nymph +++
	+		+	Larvae +++	+	Eggs	Pupa ++	Nymph +++
	+			++		+	++	+
	++	+	++	++	++	+++	++	++
	++	++			+	++	+	+
	+++		++	++	++		++	++
	+++		++	++	++		++	++
	++		++	++	++		++	++
	+++	+	++	Adults ++	++	++	+++	++
	++	+		+	+	++	+	++
			+++			++	+++	

+ some
++ good
+++ very good

Banker Plants: On the Rise (Again)

By **SUZANNE WAINWRIGHT-EVANS**—Buglady Consulting

We've been talking about using banker plants in greenhouse systems now for more than 20 years. It's a program that isn't for every facility, but when you have the right grower, the right conditions and the right target pests, banker plants can work extremely well.

Banker plants can be the backbone of an excellent pest management program while also reducing costs. For a while, many growers experimented with banker plants, but several didn't achieve the expected success. This could be because of a few reasons—one of the most common being a lack of care for the banker plans. Watering them correctly can be a challenge because often their irrigation requirements are different than the primary crop, but they often receive the same amount of irrigation. This can lead to overwatering or underwatering. Also, overhead irrigation isn't ideal for banker plants because it can remove the feeder insects, as well as wash beneficials off the plants. Another issue was bankers being exposed to pesticides. Forgetting to remove the bankers when on benches next to crops having pesticide applications (insecticides, miticides, fungicides or PGRs) can harm the program.

Some growers have gone to hanging bankers above the crops to reduce pesticide exposure. If your bankers are on the same drip line, don't forget to remove drip emitters from bankers if chemigating pesticides. It's best to start from seed to know the pedigree of your banker. If ordering plants instead of growing them yourself, buy from someone who's growing plants specifically for banker plant use to ensure plants haven't been treated with pesticides.

Lately, there's been a resurgence in implementing banker plant systems as growing operations look to become more sustainable. Additionally, there's a growing demand for fresher, high-quality beneficials and nothing beats in-house-reared beneficials, especially when you can rear ones that aren't commerially available.

Banker plants can work in two ways: First, their intended purpose of providing an alternate food source for your released beneficials in your greenhouse. And second, we're finding that when you have a food source, it can attract your local beneficial population to feed and breed at your facility. GT

Plant	Program	Benefit	Target Pest	Tips
Barley/Oats (grains)	Bird cherry-oat aphids *(Rhopalosiphum padi)* are grown on grains as a food source for *Aphidius colemani*. Aphids are often fed on by other naturally occurring beneficials, like syrphids and ladybird beetles. Growers can either order new bankers biweekly or buy initial starter plant and inoculate their new grain plants every two weeks. Order starter bankers from suppliers. Inoculate pots of grains with aphids and keep them caged. Every two weeks take infected plants and add them to the growing area. Have aphid bankers ready four to six weeks before aphids are expected. Rate: 2 per acre	Honeydew for adult parasitoids Produce better quality parasitoids Keeps number of parasitoids up—even when few aphids in the crop	Smaller aphid species Green peach aphid *(Myzus persicae)* Melon aphid *(Aphis gossypii)* Cannabis aphid *(Phorodon cannabis)*	• Do not overhead irrigate. • Do not remove plants until all parasitoids have emerged (around 12 weeks). • Monitor for hyper-parasitoids (July through August). • If growing taller grains, you may need to stake plants.
Pepper Purple Flash	Peppers are grown for pollen to feed the minute pirate bug *(Orius insidious)* Start peppers to have them flowering for early January. Inoculate plants weekly with pirate bugs for four to six weeks until established. Can supplement-feed pirate bugs with *Ephestia* eggs cards to increase number of eggs laid by pirate bugs. One card per plant weekly. Once established, move into the crop. Rate: 2 per 1,000 ft. or necessary for your crop.	Pollen for the minute pirate bug *(Orius insidiosus)*	Thrips spp. Other pests	• Do not overhead irrigate. • *Orius insidiosus* needs 12 hours of light per day. • Placing *Neoseiulus cucumeris* sachets in bankers can help prevent thrips issues.

Plant	Program	Benefit	Target Pest	Tips
Mullein	Mullein *(Verbascum thapsus)* grown to support populations of *Dicyphus hesperus* Start mullein from seed or order mullein plants in. Start seeds eight weeks before first *Dicyphus* release. Release four weeks in a row, until *Dicyphus* is established. Can supplement-feed *Dicyphus* with *Ephestia* eggs at a rate of 10 grams per 100 plants each week. Can use a salt shaker to apply or use *Ephestia* cards (3.3 g./100 cards). Rate: 40 per acre or as necessary for your crop	Food source for *Dicyphus hesperus*	Whitefly Thrips spp. Spider mites Caterpillar eggs	• Do not overhead irrigate. • Use large enough pots because mullein is a large plant. • Keep *Ephestia* eggs frozen until used. • Requires less watering than most crops. If on drip irrigation, place emitter near edge of pots. • Use well-drained soil.
Sweet Alyssum	Alyssum (*Lobularia* spp.) can be used to rear *Orius insidious*. Other beneficials like parasitoids and syrphid flies benefit from the flowers. Some series that have shown success include Snow Princess, Clear Crystal, Stream and Giga. It should be blooming by January for spring crop. Once filled out and blooming, inoculate with *Orius*. Inoculate every week for 3 to 4 weeks, then move into crop. Rate: Will vary depending on pot size and crop	Pollen for *Orius* Resources for other beneficials	Thrips spp. Other pests	• Do not overhead irrigate. • Orius needs 12 hours of light per day. • Placing *Neoseiulus cucumeris* sachets in bankers can help prevent thrips issues. • Can be used as trap crop for *Thrips parvispinus.* • Seed-raised alyssum is less expensive to use, but has pollen that can feed thrips. • Lobularia from vegetative cuttings has far less pollen and some series are marketed as sterile.
Fava Beans	Pea aphids *(Acyrthosiphon pisum)* are grown on fava beans *(Vicia faba)* as a food source for *Aphidius ervi.* Aphids are often fed on by other naturally occurring beneficials like syrphids and ladybird beetles. "Vroma" fava bean has proven to work well. Start fava beans, in large pots. Once plants are about 1-ft. tall, stake plants and order starter aphids from supplier. Inoculate fava beans. If possible, cage or cover with Reemay to allow aphid population to grow. Release parasitoids two weeks after aphids have been introduced onto the fava beans. Apply *A. ervi* directly to plant or use blister pack release system. Start new fava beans regularly because pea aphids can take over the plant quickly. May keep small pots of aphids as stock to re-inoculate plants as needed. Rate: 2 per acre	Honeydew for adult parasitoids Produce better quality parasitoids Keeps number of parasitoids up even when few aphids in crop	Larger aphid species Potato aphid *Macrosiphum euphorbiae* Foxglove aphid, *Aulacorthum solani* Cannabis aphid, *Phorodon cannabis*	• Try to grow this banker in its final location because the movement can cause pea aphids to drop off plants. • Try to keep plants from high-traffic areas. • Do not overhead irrigate. • Do not remove plants until all parasitoids have emerged • Placing *Neoseiulus cucumeris* sachets in bankers can help prevent thrips issues. • Monitor for hyper-parasitoids (July through August). • Pea aphids can feed on lupines and sweet peas.

Hey, Buglady! I Have a Question ...

By **SUZANNE WAINWRIGHT-EVANS**—Buglady Consulting

The Buglady, Suzanne Wainwright-Evans, travels extensively visiting growers across North America. During her travels, she often receives many questions, but there are some that are more frequent than others. Below, Suzanne compiled a few commonly asked questions encountered in the past year.

Q. Which beneficial nematode species should I use?

A. Nematodes are truly remarkable creatures. The estimated number of nematode species is uncertain, but some estimates place it at more than a million. Nematodes can be challenging to identify, but with today's DNA mapping, more and more species are being discovered. Nematodes play a crucial role in our ecology, with one particular group drawing significant attention for their potential as biological control agents: the entomopathogenic nematodes (EPNs)

The term "entomopathogenic" is derived from the combination of "entomo," meaning insect, and "pathogenic," meaning causing disease. In the case of nematodes, they utilize a specific bacterium they harbor in their bodies to kill insects. Researchers have explored this system and developed methods to commercially produce these nematodes, providing growers with a valuable tool for pest management.

EPN's are commercially produced using two distinct methods: "in-vivo" and "in-vitro" production. In in-vivo production, nematodes are cultivated within a living host, typically wax moths or mealworms. They undergo their life cycle within the host and are then harvested from the cadavers. While effective, this method can be costly and labor-intensive, prompting the development of the in-vitro system. In this approach, nematodes are cultured in large vats containing a nutritive medium along with their bacterial symbiont. This method enables mass production at a more affordable cost.

There's been a lot of debate on which system is better. You'll often find the rates for use between the products are very different. It's important to use the rate recommended by the manufacturer for their product. Ultimately, neither rearing system is definitively better than the other; each offers its advantages and growers may need to experiment with different products to determine the most suitable option for their specific growing methods.

The two main genera the commercial beneficial nematodes come from are *Steinernematidae* and *Heterorhabditidae*. Each group possesses distinct characteristics and targets different pests. Some nematodes are cruisers, actively seeking out their prey; while others are ambushers, lying in wait for hosts to pass by. Additionally, some species exhibit intermediate behaviors, combining both traits. It's important to note that different EPN species may only provide effective control within specific soil temperature ranges, emphasizing the importance of monitoring media temperatures when selecting nematode species.

Steinernema feltiae is the most commonly used species in the greenhouse industry. It employs both cruiser and ambusher behavior to locate its prey efficiently. Its primary targets include western flower thrips, onion thrips, fungus gnat larvae and other soil-dwelling pests.

Steinernema carpocapsae is the second most commonly used species in the greenhouse industry. As an ambusher, it's less active in the media, often standing on its tail on the soil surface to await its prey. It's particularly effective in managing shore flies, but can also target thrips pupae in the soil, as well as other pests like flea beetles. Additionally, it's effective against soil-dwelling caterpillar pests, such as armyworms and cutworms.

Research conducted at Cornell University by Anna Giesmann indicates that *S. carpocapsae* is the most heat-tolerant beneficial nematode currently available on the market. Because of this, growers will switch to this species during the summer months when the media has become too warm for *S. feltiae*.

Heterorhabditis bacteriophora is the third most commonly used species in the greenhouse industry. As a cruiser, it actively moves through the soil in search of its target prey. It's known for controlling white grubs, which are the larval stages of pests such as the European chafer, Oriental beetle and Japanese beetle. It's also very effective against black vine weevil. However, it's important to note that this species is less effective in cooler soils and may not perform below 68F (20C).

Steinernema kraussei is more commonly utilized in nursery production for the management of black vine weevil. As a cruiser, it actively moves through the soil in search of prey. Originating from Europe, this species is particularly effective in cooler soil temperatures, capable of functioning in conditions as low as 41F (5C).

Steinernema riobrave is primarily used for outdoor pests like white grubs, mole crickets, weevil larvae and corn earworms. Originally isolated from the Rio Grande Valley of Texas, it's demonstrated efficacy even at soil temperatures as high as 95F (35C). This species exhibits both cruiser and ambusher behaviors.

Heterorhabditis indica, originating from India, has been utilized for many decades, but due to limited production, its popularity has declined. It's still employed for managing hive beetles by beekeepers. This species is characterized as a cruiser.

Q. Thrips species—Does it matter?

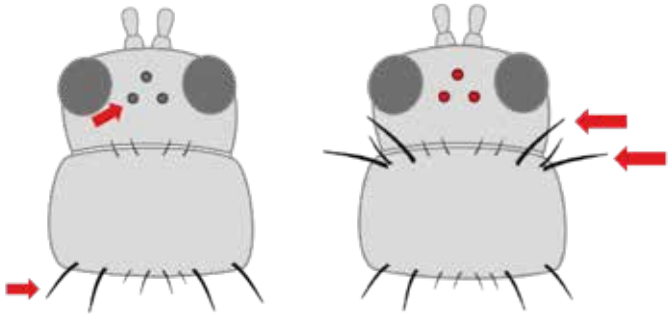
A. If you've been following any of the enewsletters and webinars over the past year, you'll have noticed the abundance of mentions of a new thrips species causing significant trouble in the floriculture industry. *Thrips parvispinus*, commonly known as the pepper thrips, caught many growers off guard. Initially assumed to be just another common thrip species, growers soon discovered that traditional biocontrol and spray programs were ineffective in managing this pest, causing millions in losses. This is why it's crucial to dedicate time to scouting and accurately identifying insects and mites on crops before making management decisions. This is especially important now, as different thrips species have different economic thresholds and need different management programs.

Amblyseius cucumeris is just one predatory mite species that comes in slow-release sachets.

A row of banker plants (in baskets) suspended above a large crop.

Beneficial nematodes are applied mechanically to an indoor crop.

Simple Key to Important Thrips Pests



Onion Thrips
(Thrips tabaci)

Western Flower Thrips
(Frankliniella occidentalis)

Example of useful thrips ID illustrations found by snapping the QR code.

Illustrations courtesy of Sarah Jandricic, Floriculture IPM Specialist for the Ontario Ministry of Agriculture and Food and Rural Affairs (OMAFRA).

Currently, floriculture growers are dealing with a few different thrips species: western flower (*Frankliniella occidentalis*), onion (*Thrips tabaci*), poinsettia (*Echinothrips americanus*), pepper (*Thrips parvispinus*) and chilli (*Scirtothrips dorsalis*). One of the most valuable resources available to growers for identifying these thrips species is "A Simplified Key to Pest Thrips of Ontario," authored by Sarah Jandricic and Ashley Summerfield. This guide covers the thrips listed above along with several others. It uses illustrations, easy-to-understand terminology and is very grower friendly. It applies to most of the United States and Canada, being we share a lot of the same greenhouse pests.

Western flower thrips (WFT; *Frankliniella occidentalis*) is the most commonly encountered species of thrips in floriculture crops and has been successfully managed in recent years through the use of biological control programs. However, managing this pest with traditional pesticides has posed challenges due to resistance issues. Therefore, it's crucial to accurately identify the species and research which pesticides remain effective against it. Many growers are adopting hybrid programs that integrate beneficial nematodes, microbial pesticides, predatory mites and conventional insecticide applications to effectively suppress this pest below an economic threshold. Soaps and oils are also growing in popularity, but applications must be timed correctly if using biological control agents. Mass trapping with yellow cards or sticky ribbon is another tool to kill as many adult WFTs as possible.

Onion thrips (*Thrips tabaci*) have become more common in floriculture in recent years and are also commonly found in cannabis crops. They can be easily mistaken for WFTs, so it's important to closely examine the hairs on the pronotum (see illustration) and count the number of antennal segments. Onion thrips have seven antennal segments, whereas WFTs have eight. Onion thrips also have three gray ocelli (simple eye) on the back of their heads; on WFTs, they're red.

Biological control programs for onion thrips are being used, but they don't appear to be as effective as those for WFTs. Ongoing research at the Vineland Research & Innovation Center in Canada is trying to understand why. Because of this, some growers may ▶

turn to conventional insecticides, insecticidal soaps, horticultural oils and microbial pesticides for their program. Here, too, you would want to look up and see which conventional pesticides are still effective for onion thrips because there can be resistance issues. Yellow sticky traps and ribbons do work for trapping this species.

Poinsettia thrips (*Echinothrips americanus*) may not be the most common thrips species, but it can pose significant challenges for many growers. Visually distinct from previously mentioned thrips, it's black with light spots on its shoulders. Its damage also differs markedly, resembling that caused by twospotted spider mites. Poinsettia thrips have a unique biology compared to other thrips species, and research has shown that biological control programs utilizing mites and nematodes are ineffective against them. Therefore, growers typically resort to conventional spray products, soaps, oils or microbial products containing *Beauveria bassiana*, which have demonstrated effectiveness in managing this pest. Unfortunately, blue and yellow sticky cards have been ineffective for trapping, but work is being done looking at green for this species.

When pepper thrips (*Thrips parvispinus*) showed up in crops, some initially mistook them for poinsettia thrips or dark-form WFTs, only to discover that their usual thrips management strategies were ineffective. Even those employing biological control programs for western flower thrips found them ineffective against this species and there was confusion as to what was going on. Once identified, it became clear what was happening. Fortunately, identifying pepper thrips is relatively straightforward with just a hand lens. It looks distinctly different from WFT and onion thrips. The adult females are two distinct colors—lighter on their heads and upper wings, and darker on their lower halves. Meanwhile, males are very small and yellow. Mass trapping (yellow and white) does work for this thrips species and is an important part of managing it in a greenhouse.

Chilli thrips (*Scirtothrips dorsalis*) was first discovered in Florida in 2005, causing significant damage initially. However, the population in floriculture crops has declined over the years. This thrips species is notably smaller than western flower thrips, measuring about half its size, which makes it easy to overlook. Unfortunately, biocontrol hasn't proven to be very economical or always the best control option for this thrips in floriculture, leading most growers to rely on a spray program instead. Yellow sticky traps and ribbons do work for this species.

Be sure to label your banker plants (like this pea plant) so they're not sprayed or treated with chemicals.

Q. Predatory mites—Sachets or loose product?

A. Currently in the United States there are 10 different species of predatory mites available to commercial growers. In the past, they were only available as a loose product, which could be sprinkled on the foliage or applied to the soil. However, with the introduction of slow-release sachets in the 1990s, growers were given a new way to apply mites.

A slow-release sachet is a small packet or pouch containing a colony of predatory mites, along with a substrate or food source to sustain them. This keeps a constant population of predators on the crop, even if there are no pests present. The number of mites emerging are on a release curve, peaking at around Week 3 to 4 (depending on product and humidity). Unfortunately, not all mite species are available in sachets. Sachets are typically used in hanging baskets, mum crops, cannabis or crops that cannot have a carrier on the foliage. Sachets are best used as a preventative measure.

Loose product is typically used when a fast result is needed. As soon as the mites are applied to the plant, there are high enough numbers of predators needed to either prevent a pest issue or take out a low-level population. The mites can die of starvation if there isn't enough food for them, and thus often needing biweekly applications. Some growers will add alternate food sources like artemia cysts, astigmatic mite eggs or pollen to help support the mite population. Loose product is often used in propagation, crops needing a fast knockdown, crops with tight canopies (so carrier and mites don't fall to the floor) or when the mite needed is not available in a sachet.

Q. Lacewings—Which life stage should I use?

A. Green lacewings (*Chrysoperla* spp.) are a beneficial insect that's been commercially produced for decades, although it hasn't always been prominently showcased. However, times are changing, and this beneficial insect is increasingly being utilized both indoors and out as part of pest management programs. One of its standout qualities is its versatility as a generalist predator. It's capable of feeding on a wide range of pests, including aphids, spider mites, whiteflies, thrips and many others. Another advantage of lacewings is the ability to purchase them in various life stages and for different application methods. Lacewings, especially in the egg stage, can be very economical.

Eggs (best as prevention):

- Loose eggs can be sprinkled on foliage, but they often fall off and then have a low hatch rate.
- Eggs on cards are a great way to get larvae onto the plant foliage, but need to be hung and can get concentrations of larvae. Great for larger plants, greenhouse vegetables, cannabis and interiorscapes.
- Spraying eggs on foliage is a new application method that allows for a quick and even distribution of large quantities of eggs. Eggjuvant is a powder that, when mixed with water, enables eggs to adhere to plant foliage when sprayed. This ensures that the eggs remain on the leaves until lacewings hatch. Eggjuvant is available from Koppert.

Larvae (will start feeding once applied to crop):

- In a carrier to be sprinkled on plant foliage or put in release boxes.
- Hex cells are straight larva (no carrier) that need to be applied to the foliage. Can be a substrate and a food source.

Adults (best as a prevention):

- Typically, not recommended, as there are limited food resources for adults within greenhouses. Additionally, the time it takes from release to having larvae actively feeding may be too long to effectively address a pest issue. GT

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BCA Release Systems & Methods

By **JEREMY WEBBER**—
Crop Team Manager, Koppert

Predatory mites

Mites are typically introduced either through breeding sachets or by distributing bulk product over the top of the crop. There are a few basic rules that apply with this group of BCAs that (when accounted for) can greatly increase predictability and overall performance.

Predatory mites are blind and they aren't that bright. Yes, they can sense certain chemicals and home in on prey, but that doesn't help much in a mostly clean crop of potted plants. Bottom line: Do not overestimate their ability to move from plant to plant unless your crop is pot tight and well-grown together. This makes the uniformity of bulk applications mission critical, especially early in the production process when each little plant (or cutting in propagation) is really its own little island. It either gets mites for protection this week or it doesn't. Growers who spend the time treating bulk applications like an irrigation event have the most consistent and repeatable results. Would you rather water with calibrated irrigation nozzles or your thumb over the end of the hose?

Bulk applications are best done with some form of handheld blower unit and there's a range of homemade and commercial solutions available on the market. If you go the homemade route, make sure to evaluate distribution on a long strip of black fabric and really get in there with a hand lens to make sure that they weren't damaged during the application. Generally, survivability from anything launching more than 15 ft. with the traditional leaf blower model hasn't been great. Ideally, they land like paratroopers and not water balloons; the black fabric test tells no lies.

Once you have your applicator unit of choice dialed in for greatest predator survivability (assuming you built your own), really focus on the application methodology. How would you irrigate or apply a PGR to 200 linear feet of bed space? Shoot for the same level of distribution uniformity and your program will take a huge jump forward in reliability.

While the blow-in application method is usually preferred over sachets due to overall cost, there's a lot to be said for a method that works when the crop is 10 to 15 ft. over your head for the last month and a half of the spring season. The same rules apply to breeding sachets—you'll need to install at least one per plant if the crop isn't touching.

Another key point to remember is that the breeding system is facilitated by humidity within the bag itself. Keep it protected within the canopy of the plant whenever possible. Assuming they don't get crispy (or completely waterlogged), most sachets will run for a minimum of four weeks, and some run for as long as eight weeks or more when they find the humidity Goldilocks zone.

A grower using Koppert's Mini-Airbug applies loose *A. swirskii* predatory mites over the top of a yucca crop.

Nematodes

Holding the title for "The Most Widely Adopted Biocontrol in Horticulture," our favorite collection of round worms is ubiquitous in most greenhouse facilities to some extent or another. Following is a collection of best practices that may or may not be on your radar:

- **Always keep the focus on uniform applications.** For apps through an injector, use an air stone. They help immensely with keeping the nematodes suspended in the concentrated stock bucket. For apps with a sprayer, make sure to keep some of the pump's flow rate dedicated to recirculation and agitation. You want to apply the same number per gallon of solution from start to finish.
- **Watch your application volume.** Do you really need to soak that 4-in. pot all the way to the bottom? Your targets are likely within 0.5 in. of the media surface, so keep that application volume in that area as well for best results. In other words, don't overly dilute the nematodes through the entire soil column when you really just need them on the surface.
- **Maybe use a sprayer?** While reduced application volume introduces a few more variables than irrigating through an injector, it does allow for a much faster application. Nematodes are tank mix compatible with nearly everything as well, but not absolutely everything, so reference a side-effect guide like the one on Koppert's website to play it safe (koppertus.com). It's entirely possible to add them to existing rotational applications you may already be doing. Just keep the pressure below labeled rates and remove any filters or screens. Always pull a sample of the finished solution and check them over with a hand lens to make sure that you're seeing good activity, regardless of application method.

Attaching the blower to a cart has shown to consistently improve the introduction uniformity and overall program efficacy.

Steinernema feltiea (such as Entonem or Nemasys) has been the BCA "gateway drug" for decades at this point, but they don't appreciate hot soil temperatures. Once you're in the blazing heat of summer, try switching over to *Steinernema carpocapsae* (such as Capsanem or Millenium). They have a significantly higher heat tolerance and are also highly lethal to most caterpillars as well.

Finally, most modern greenhouse coverings filter out the UV light that damages nematodes. While we've always applied them on cloudy days or early mornings, those precautions are just for the outdoor growers among us. Mornings are still generally the best time of day to wet down a crop, but don't fret over some sunshine, either, as long as you're under plastic or glass. GT

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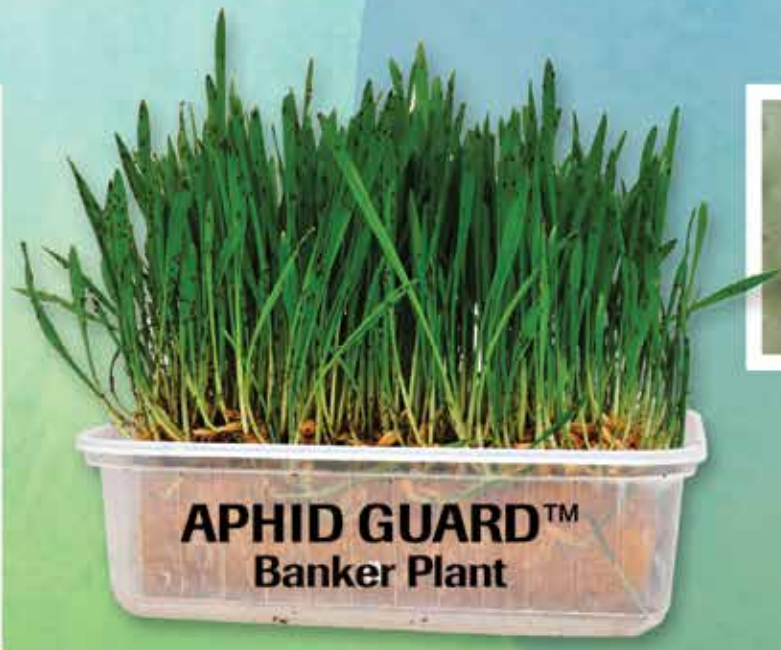

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In conclusion

I hope you enjoyed the second edition of the Biosolutions Guide. This guide wouldn't be possible if it weren't for the strong and continued interest in growers using softer chemistries, biopesticides and biological control agents to manage their pests and diseases in their greenhouses and nurseries.

I like to think of the shift towards biosolutions as a journey. Although some of you may have taken biosolutions pest management strategies from the onset, most growers currently using biosolutions have gradually transitioned (or are in the process of transitioning) into more widescale use of them.

My interest and use of biosolutions management strategies has gradually progressed over my 30-plus-year career and I recently discussed this journey in *GrowerTalks'* December 2023 issue. Like the messages our experts have shared often, my success with biosolutions products is centered on having a basic understanding of what they are, how they work and what they're compatible with. When used properly, biosolutions approaches can be effective at controlling numerous pests and diseases.

Biofungicides, bioinsecticides and biological control agents are great tools for preventing plant pathogens and pests from attacking crops. Depending on the product applied, microorganism used or BCA released, biosolution strategies provide control in various ways. These include antagonism, antagonistic competition, desiccation, disruption fungi and bacteria development. They can also enhance the plant's natural defenses against infections (induced resistance).

Biosolutions strategies aren't curative and must be applied preventatively before pest and disease pressure escalates. I'd like you to refer back to Michael Brownbridge's article on page 10 where he discusses application essentials. In this section, Michael says, "Think of it this way: You need to put the right product in the right place at the right time, using the right equipment to be successful; incorrect timing and poor coverage are primary causes of biopesticide failure." He then continues with a great discussion on product selection, timing and application methods.

His commentary doesn't just pertain to biological applications, but applies to all pest management applications. The key to successful pest management (insects and diseases) depends on your understanding of this section and your ability to apply the right product at the right time using proper application methods. With all the great content contained in this guide (and there's a ton of it), this is perhaps the biggest take-home message.

The beautiful thing with biosolutions strategies is they're often quite compatible and can be used independently or in conjunction with conventional strategies. Growers can ease into them by implementing biosolutions on a crop-by-crop basis, utilize them in a specific environment such as beginning in propagation, or jump all in and treat all crops across the board.

Success comes with knowledge, and this guide will go a long way towards helping you understand biosolutions approaches and which products to use to manage particular pests and diseases. Please return to this resource often as your biosolutions journey continues.

The Biosolutions Guide wouldn't be possible without our contributors. I'd like to thank each of the experts, Ann Chase, Michael Brownbridge and Suzanne Wainwright-Evans, who provided the great content contained within this guide, as well as Anissa Poleatewich and Jeremy Webber. Additionally, I'd like to thank Carlos Bográn (OHP) for his help compiling the Bioinsecticide Table published in the inaugural guide last year, which served as the foundation for the updated version contained within. We appreciate each of you and your contributions to the industry.

GrowerTalks is dedicated to leading the biosolutions discussion and serving as your primary source of information. We'll continue to feature content from our industry's top researchers, market leaders and innovative growers through a variety of platforms, including our magazines, world class newsletters, future guides, podcasts and webinars.

We anticipate the interest and popularity in biosolutions products to continue for many years. As I just mentioned, *GrowerTalks* is committed to pass along the best biosolutions content in the industry. We encourage you—our loyal readers, cutting-edge researchers and innovative manufacturers—to pass along information on new biosolutions products, efficacy data and how to optimize the use of these great tools. If you have any information to share, please contact Senior Editor Bill Calkins at bcalkins@ballhort.com.

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Bio-Solutions that Scale. No matter the size of your business our innovative technologies, including drone and high-powered blower systems, simplify application at any scale.

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