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BIOCONTROLS SPECIAL REPORT

BIOCONTROL AND IPM

Use Biochemicals and Microbials Together p. 10

Applied in succession, these biopesticide tools can have synergistic benefits.

IN THIS REPORT:

Successfully Integrate Biocontrol Strategies Into Greenhouse Floriculture Production

The widespread adoption of biocontrol in Canadian floriculture greenhouses grew out of necessity. The lessons they learned can help you incorporate these tools in your production.

By Michael Brownbridge and Rose Buitenhuis, Vineland Research and Innovation Centre

HISTORICALLY, GREENHOUSE floriculture has relied on synthetic insecticides to meet its pest control needs. However, growers are increasingly faced with the loss or failure of pest control products, declining access to new chemistries, stricter environmental/health and safety regulations, and the need to produce plants and vegetables in a manner that meets the demands of a retail/consumer driven market. In Canada, the failure of Spinosad (Success) for thrips within 6 to 12 months of its registration prompted a sea of change in pest management philosophy and approach.

Faced with a lack of registered chemical alternatives, growers turned to biological control out of necessity. Necessity led to success. Today biological control forms the foundation for pest management programs in Canadian greenhouses. More than 70% of growers use some form of biocontrol and certain crops are grown from start to finish without pesticide interventions. It has been a steep learning curve requiring a whole new approach and a shift from enactment of reactive 'control strategies' to implementation of preventative 'management strategies.'

CONSIDERATIONS THAT LEAD TO SUCCESS

A series of drivers has created opportunities for broader integration of natural enemies and new biological products into integrated pest management (IPM) programs, but in turn, these programs are shaped by the bioproducts in which they are used. The diversity of floriculture crops grown and the variety of locations in which they are grown prevent a one-size-fits-all approach to biocontrol, and IPM systems need to be adapted to suit local conditions. There are some basic principles that transcend crops and location, and considerations of these help guide the development of a successful, biologically based, integrated crop management system.

Let's consider a crop system. Many interactive variables affect the growth of greenhouse crops, the incidence and impact of pests and diseases, and the performance of biological and chemical controls. These include:

- The type of crop and crop growth stage
- Production practices and inputs
- External environmental conditions (temperature, humidity, light).

Understanding how these factors interact with and affect the plant, pests and their control agents, is essential. Biological control agents are living organisms, and all of these variable factors directly affect them. Knowing the conditions under which they perform best helps guide the selection of natural enemies suited to the crop and growing environment. An understanding of issues that can impede or promote their activity then helps to refine and shape the IPM system.

IPM FROM START TO FINISH

The efficient use of biocontrols requires different assumptions and timing of actions than for chemicals. Methods developed to guide the timing of pesticide sprays — action thresholds, for example — are effectively redundant in a biological control program. Why? Because if you wait until thresholds are reached before initiating a biocontrol strategy, it will be too late; pest populations will be too large to be brought under control using a biological agent. Biocontrol strategies function most efficiently when pest numbers are low, as they prevent damaging populations from developing. Insecticides are reactive tools developed, by-and-large, to quickly kill large numbers of pests from a single application. To be successful in biocontrol, take measures early, before pests are readily detected in a crop, and sustain them to suppress pest populations (or disease incidence). Biocontrol agents work best when deployed within a sys-

BIOPESTICIDES CAN PLAY AN EFFECTIVE SUPPORTING ROLE WITHIN AN INTEGRATED SYSTEM WHERE THEY CAN SELECTIVELY CONTROL SEVERAL CHALLENGING PESTS (AND DISEASES) IN A MANNER THAT IS FUNCTIONALLY COMPATIBLE WITH OTHER NATURAL ENEMIES.

tem that supports their success, where a range of components within that system function together to provide the desired level of suppression. While a grower must conceive and implement an IPM program for the entire production period, he or she may consider different approaches for different phases in the crop cycle.

PREVENTION AND EARLY INTERVENTION

Prevention starts with good sanitation practices, ensuring young plants are brought into a clean production environment and pests are excluded wherever possible. No residues should remain from previous crops, benches and floors should be disinfected, weeds under benches removed, and algae cleaned from the floor. Ensuring that the greenhouse is clean from the get-go and preventing the entry of pests into the greenhouse helps on so many levels.

Experience counts. Being aware of potential threats and using this knowledge to put processes in place to facilitate early detection and/or early action to mitigate pests will get a biocontrol program started successfully. This includes the use of cultural practices that minimize pest build-up. For example, the use of production practices that optimize nutrient and water inputs to grow healthy plants. For some crops, there is a link between fertilizer rate (especially high nitrogen) and population growth of pests like thrips and aphids. Use of best practices will help create a more resilient productive crop that is less prone to pests and diseases.

Many crops are grown from propagative material produced in-house or imported from offshore. In spite of propagators' best efforts, cuttings frequently carry low numbers of pests. Detection of these insects, which are often cryptic in nature, is next to impossible, and for pests like thrips, the problem is worse because their eggs are laid in plant tissue. Many growers now assume that incoming cuttings will carry some pests. The decision then, is to introduce biocontrols immediately without waiting for sticky card catches to reach a certain threshold. Remember, for highly successful pests (thrips, whiteflies, spider mites, aphids), which have rapid life cycles and a high reproductive potential, early intervention is critical to success of a bio-based IPM program. A strategy often used in the early stages of production is to front-load a biocontrol program to mitigate problems early by overwhelming pests with an army of biologicals. Predatory mites are often used as front-line troops; selection of species depends on the time of year and the pests anticipated.

Another way to alleviate pests on cuttings is by dipping. Immersing cuttings in biopesticides such as insecticidal soap, horticultural oil, or BotaniGard reduces hitchhiking Bemisia whiteflies. Dipping provides thorough coverage, is quick and effective, uses relatively little product, and is readily integrated into the workflow. Risks of disease transfer appear to be low, and can be mitigated through good sanitation practices and regular changes of the dip solution/suspension. The rates for soaps and oils typically have to be reduced from those used when spraying, owing to increased risks of phytotoxicity. Check the labels for guidance.

STRENGTHENING YOUR BIO PROGRAM

In spite of the increasing sophistication of biocontrol programs in floriculture crops, pests can sometimes get ahead of the biologicals. While there are many reasons why this can occur, it means growers need to take steps to bring pest numbers down to levels where the biologicals can catch up. Pesticides can do this, but there are inherent disadvantages to using many chemicals. Choose pesticides with care to ensure they are compatible with the biologicals being used. Consider the whole program when deciding which product to select; materials used to regulate the target pest may have unintended effects on beneficials being used against another.

This is where biopesticides can play an effective supporting role. Within an integrated system, they can selectively control several challenging pests (and diseases) in a manner that is functionally compatible with other natural enemies. Their integration strengthens a biologically based IPM program, resulting in a more robust and (generally) more efficacious system. Several microbial biocontrol agents are registered for pest and disease management in greenhouse crops. Others based on biologically derived materials are also increasingly available.

IPM AND BIOLOGICALS: THE WAY FORWARD

The actions of the past have created the path to the future. Biological control still has a way to go before it totally displaces traditional chemistries, but used as part of an IPM program, it can get us a long way down that path. ■

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SILICON: a Biocontrol Agent that Boosts Plant Immunity

Biological plant protection can come from some unexpected sources. This trace element can help shore up your crop's defenses against both insect and disease pests.

By Wendy L. Zellner, The University of Toledo

QUALITY AND PROFITABILITY are two important factors that drive our agricultural markets. We have fine-tuned our cultivation processes over centuries to obtain higher yields with lower inputs to protect both our environment and our bodies.

The biocontrol market contains a diverse set of less-toxic alternatives to aid in the overall goal of environmental stewardship. One set of materials contain a bioavailable form of silicon, important for enhancing the plant's natural immune system.

Silicon is an essential trace element important for animal and human health. It also has an important role in plant health.

SILICON PROTECTS AGAINST SOME DISEASE AND INSECT PESTS

Studies show that adding silicon to the growing media significantly reduces the presence of powdery mildew in a variety of plants, including cucumber, tomatoes, strawberries, grapes, melons, and lettuce. This nutrient also protects against bacterial and

SILICON REDUCES FOLIAR PATHOGENS

Diseases	Pathogens	Hosts
Alternaria	*Alternaria alternata*	Melon
Angular leaf spot	*Pseudocercospora griseola*	Bean
Anthracnose	*Colletotrichum lindemuthianum; C. orbiculare, C. acutatum*	Bean, Cucumber, Strawberry
Bacterial fruit blotch	*Acidovorax citrulli*	Muskmelon
Bacterial speck	*Pseudomonas syringae* pv. Tomato	Tomato
Bacterial spot	*Xanthomonas axonopodis* pv. Passiflorae	Yellow Passion fruit
Bacterial wilt	*Ralstonia solanacearum*	Tomato
Black rot	*Didymella bryoniae*	Cucumber
Brown spot	*Monilinia fructicola*	Peach
Crown and root rot	*Pythium ultimum* and *P. aphanidermatum*	Cucumber
Downy mildew	*Bremia lactucae*	Lettuce
Fusarium wilt	*Fusarium oxysporum* spp., *F. semitectum*	Cucumber, Lettuce, Melon, Tomato
Gray mold rot	*Botrytis cinerea*	Cucumber
Gummy stem blight	*Didymella bryoniae*	Watermelon
Leaf spot	*Mycosphaerella pinodes*	Pea
Pestalotia leaf spot	*Pestalotia longisetula*	Strawberry
Phytophthora root rot	*Phytophthora cinnamomi, P. sojae, P. capsici*	Avocado, Soybean, Bell Pepper
Pink rot	*Trichothecium roseum*	Melon, Muskmelon
Powdery mildew	*Podosphaera xanthii, Uncinula necator, Sphaerotheca xanthii, S. macularis, Oidiopsis sicula, Oidium neolycopersici*	Cucumber, Grape*, Melon, Muskmelon, Pumpkin, Strawberry, Tomato*, Zucchini Squash
Pythium root rot	*Pythium aphanidermatum*	Bitter gourd, Tomato
Stem blight	*Phomopsis asparagi*	Asparagus

Adapted from F. A. Rodrigues and L. E. Datnoff. Silicon and Plant Disease. 2015. Springer
*In some cases (e.g., Fusarium wilt in tomatoes, or powdery mildew in grapes or tomatoes), results of research were inconclusive.
The form and concentration of silicon in addition to the disease pressure added and age of the plant all can influence the outcome of the studies.

viral infections in certain plants.

Not only does silicon protect against disease, it also reduces the population of insects and mites feeding on silicon-treated plants.

For many years, it was thought that silicon provided a physical barrier associated with the plant cuticle, making it harder for insects to penetrate.

While this process is involved, recent studies show that arthropods feeding on silicon-treated plants produce fewer offspring, suggesting that silicon is altering some aspect of the plant material ingested by these menaces. Combining silicon with other biocontrol agents may lead to better protection and control over infestations.

TIPS ON GAINING NUTRITION FROM SILICON

There are many forms of silicon that can be taken up by plants.

Commercially available products include:

- Solid materials for media incorporation that come from mined rocks (wollastonite and ignimbrite)
- Recycled slag from the steel industry (also containing additional micronutrients and used as alternative liming agents)
- Recycled glass (used as solid substrate in hydroponics or aquaponics)
- Plant material (including rice hulls, coir, and biochar produced from plant material).
- Liquid materials that can be applied as a media drench or foliar spray (including potassium-, sodium-, and calcium-silicates).

These materials have unique characteristics and release varying amounts of plant-available silicon. It is important to match the material with your growing system.

The amount of silicon required to enhance growth and stress resistance varies greatly by plant type and even variety. There are no current recommendations for silicon concentrations in plant tissue.

As a general rule of thumb, many of the grasses and grains need large amounts (and can take up to 100,000 ppm or higher silicon), while dicots range in their foliar concentrations from 10,000 ppm (in cucumber) to 100 ppm (in onion). It is important to note that silicon protects both cucumber and onion in various stress responses, showing that foliar concentration does not predict protection.

Silicon fits in as a biocontrol because it enhances the plant's own immune response, allowing for a faster and more robust response to invading pathogens or herbivores. By providing plants with this nutrient prior to the onset of disease or early in the detection of nuisance arthropods, we can help our photosynthetic friends maintain their quality and yield, even in the presence of stress. ■

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DISPELLING THE RUMORS: Using Biologicals and Biochemicals in IPM Programs

Despite what you may have heard, these two categories of biological tools can be used together effectively. Here's how.

By Michael Larose, BioSafe Systems

WHETHER YOU'RE a grower, packer, processor, or retailer, you have experienced the dramatic shift in consumer preference for sustainable practices in the production process. Not only has this trend driven changes in the U.S., it's also dramatically impacted your ability to develop and service overseas markets. In many of these countries, chemical residue limitations and sustainability requirements have driven a larger emphasis on developing effective, economical, and sustainable practices that produce a quality crop without sacrificing profit.

It's no secret that the overdependence on synthetic chemical pesticides and the decades of uninhibited use of such chemistries has necessitated a change in practices. Those changes have mainly been focused on degraded soils and groundwater pollution resulting in nutritionally imbalanced and unproductive ground.

BIOPESTICIDE CATEGORIES

Biopesticides are becoming a critical tool in the increasingly limited tool box for conventional and organic growers alike. These materials provide a variety of implementation opportunities for your standard integrated pest management (IPM) program. Biopesticides are generally put into three primary categories:

Biochemicals are naturally occurring substances that control pests by non-toxic mechanisms, including:

- Broad-spectrum contact bactericides/fungicides (peracetic acid, or PAA; fatty acids; potassium bicarbonate; copper; sulfur and/or lime-sulfur)
- Plant extracts (neem oil/azadirachtin, giant knotweed, pyrethrum plant)
- Insect sex pheromones (monitoring, trapping, and mating disruption)

Microbial pesticides, or biologicals, consist of a microorganism as the primary active ingredient; many target specific pests and, thus, are less broad-spectrum.

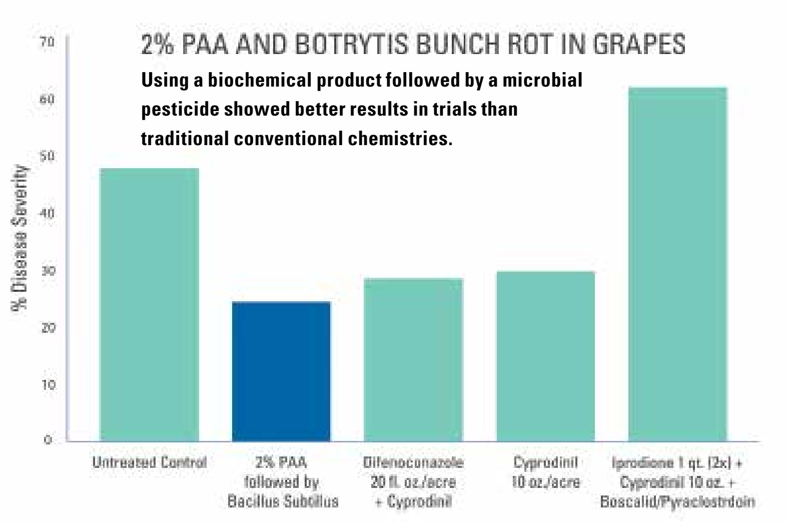
- *Bacillus* spp.
- *Pseudomonas* spp.
- *Trichoderma* spp.
- *Gliocladium catenulatum* spp.
- *Beauveria bassiana*

Plant-Incorporated-Protectants (PIPs) are pesticidal substances that plants produce from genetic material that has been added to the plant. The Bt gene from ***Bacillus thuringensis*** (Bt cotton and Bt corn) is an example.

BIOCHEMICALS AND BIOLOGICALS TOGETHER

The crop protection industry and the researcher community as a whole have been rapidly developing supporting research on these relatively new technologies and how they can be incorporated into an IPM program. One of the lingering myths that researchers, consultants, and manufacturers are working to address is the perception that two of these biopesticide categories, biochemicals and biologicals, are difficult to use together in an effective IPM program. Biopesticide suppliers are working with university researchers, Extension agents, and independent crop advisors to show how these two tools can be extremely effective in combination, and that they have proven synergistic properties that provide increased efficacy and performance when used as rotational partners in a grower's pest management program.

Biochemicals and biologicals provide a host of advantages in both curative and preventative programs. Biochemicals tend to be broad-spectrum, non-target-specific chemistries that are ideal for eradicating established fungal pathogens and their spores, as



2% PAA AND BOTRYTIS BUNCH ROT IN GRAPES

Using a biochemical product followed by a microbial pesticide showed better results in trials than traditional conventional chemistries.

well as established bacterial diseases and their inoculum, which is critical when trying to stop the spread of pathogens through a field. Biochemicals, such as peracetic acid (PAA) and potassium bicarbonate, are effective at cleaning the foliar surface and treated area, providing immediate knock down of pathogens and their dormant spores or inoculum.

The unique properties of biochemicals make them a critical partner when using biological tools to aid in preventive control of foliar and soil pathogens. Biochemicals must be applied prior to the use of a biological product, with the biochemical reducing the current high levels of fungal spores and/or bacterial inoculum. With most biochemicals providing kill immediately on contact and then converting into inert properties, biological tools can be quickly applied following the application of the biochemical. It's these unique principles that provide the synergistic properties between the biochemicals and biologicals:

- The biochemical provides curative properties of established pathogens on the foliar surface. When used in soil applications, it helps reduce the populations of soil-borne pathogens.
- Immediately following a biochemical application, growers can apply a biological product to the foliar surface or into the soil profile. Components of the biological fungicide can then rapidly populate on the treated surface without having to overcome high populations of dormant or active fungal or bacterial pathogens.

This is a major innovation in IPM. Biochemicals can play a major role in reducing the moderate to high populations of foliar and soil pathogens present in the field, providing a clean environment for the beneficial organisms used in biological products to populate around the leaf surface. Many of the biological products use beneficial strains whose primary mode of action is exclusion, meaning they populate at a rapid rate. Thus, they inhibit plant pathogens from re-establishing on the treated surface, without having to overcome or compete against existing high populations of both plant pathogens or other yeasts, molds, or fungus naturally present in the environment. This unique IPM approach has shown success in soil treatment studies, where a soil treatment such as PAA is chemigated through drip irrigation systems to eliminate soil pathogens such as Pythium, Phytophthora, and Fusarium prior to or just at planting. PAA quickly breaks down into inert components of oxygen and water and leaves no harmful by-products behind. Growers can then quickly inject beneficial organisms back into the soil profile, allowing them to colonize and populate rapidly and efficiently with competing organisms having been reduced by the biochemical application. ■

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WHAT IS CITRUS GREENING?

Greening (Huánglóngbìng — HLB for short) is a bacterial disease spread by the Asian citrus psyllid. There is no cure, and since its discovery in 2005, it has devastated yields and quality in Florida's signature crop. Researchers and growers are on the hunt for solutions to the problem.

The Grower's Take: Citrus, HLB, and Biological Control

There's no simple solution for citrus greening, but Uncle Matt's organic citrus is successfully working biocontrol into the mix.

Interview by Frank Giles, Editor, *Florida Grower,* fgiles@meistermedia.com

UNCLE MATT'S ORGANIC orange juice brand has enjoyed steady growth since its 2002 inception. The brand's success is due to the McLean family, which has grown citrus for four generations. Vice President of Operations Ben McLean manages the organic citrus grove.

HOW HAS GREENING IMPACTED THE GROVES YOU MANAGE?

Ben McLean: From 2008-2009, we have seen significantly reduced production in Florida. We have been impacted severely by the disease, like most citrus growing regions in the state.

McLean

As far as Uncle Matt's Organic juice brand, it has impacted our ability to source juice. Up until a few years ago, we sourced everything in Florida, but now we source outside the state to meet demand. But part of that is the demand for our juice has been growing, too, which is a good thing.

HOW DO BIOCONTROL PRODUCTS FIT IN YOUR PRODUCTION PLAN?

Ben McLean: My father regularly releases *Tamarixia radiata* [a natural parasitoid of the Asian citrus psyllid] in select groves. We have a grove that is about 60 acres where my dad has regularly released the wasp for seven or eight years running now, and it has kept the Asian citrus psyllid counts very low. When USDA does the trap counts, we are told that grove remains on the low to very-low end of psyllid counts across this region.

When it comes to biopesticide products, there are several we have had success with. We like Neemix (azadirachtin, Certis USA) and Aza-Direct (azadirachtin, Gowan). I have found those two neem products to be really effective. I grew some organic vegetables this spring [on] a 1-acre research farm. I grew tomato, pepper, cucumber, and squash. Regular applications of the Aza-Direct did an outstanding job keeping insect populations low.

When it comes to citrus, we follow the research results. Dr. Phil Stansly, an entomologist with the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS), discovered that there is some efficacy in the neem products, particularly combined with a 435 spray oil type of product.

I did some research work with Dr. Michael Rogers, an entomologist with UF/IFAS. We found Mycotrol (BioWorks), which is based on the beneficial fungus *Beauveria bassiana*, gave some good, statistically significant results of controlling the psyllids during certain windows of the year, particularly in the fall through the winter.

We also found with the young trees, sprays with Surround (kaolin, NovaSource) was effective to help protect against psyllids. But even with this and the other things, we still find a decent amount of infection in the young grapefruit by the time they are four and five years old.

Like all the products out there, conventional or organic, nothing has been able to get adequate psyllid control as a stand-alone throughout the year. In my opinion, even in the conventional citrus industry [where they] are spraying regularly, the psyllid counts remain high.

If you get on a good program with multiple tools, you can keep your psyllid counts pretty low. However, not low enough where greening is not still spreading through your grove.

Our long-term solution, organic or conventional, will be resistant and tolerant genetics. Our best grove now is a new 15-acre planting of 'Sugar Belle' [tangerine], where we are using these materials to control the psyllid. We are optimistic, because the research has shown the variety is much more tolerant to greening.

ARE YOU CONFIDENT A SOLUTION TO GREENING WILL BE FOUND?

Ben McLean: I am optimistic. Between USDA and UF/IFAS researchers, we are going to find some rootstocks and scions of Hamlin and Valencia oranges that will at least be like the 'Sugar Belle', with a tolerance that is better.

They may not be 100% resistant to greening, but there is enough tolerance to grow a good quality crop, enough to be profitable. Unfortunately, it is a long-term solution, and it will be five to seven years before our researchers can confidently say, "Yes, plant the scion on this rootstock, and the yield and quality will be this."

Ultimately we are optimistic in our own farm plan because we have seen some rootstocks like 'Cleopatra' mandarin that seem to be more tolerant that give us hope, as well as scions like the 'Sugar Belle'. We hope to continue the development of new varieties that will bring us more tolerance and/or resistance to replant the state of Florida and rebuild our tree inventory. ■

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