Biological Control

Thursday morning 9:00 am

Where: Grand Gallery (main level) Room D
MI Recertification credits: 3 (COMM CORE, PRIV CORE)
OH Recertification credits: 1 (presentations as marked)
CCA Credits: PM(3.0)
Moderator: Ben Phillips, Vegetable Extension Educator, MSU Extension, Saginaw, MI

9:00 am	Introduction • Ben Phillips, Vegetable Extension Educator, MSU Extension, Saginaw, MI
9:10 am	Microbial Bioproducts in Vegetable Crop Production: Facts, Experiences, and Hopes • Matt Kleinhenz, Extension Vegetable Specialist, Horticulture & Crop Science Dept., The Ohio State Univ.
9:45 am	Biocontrol Organisms in Compost, and Composting • Brooke Comer, Horticulture Dept., MSU
10:20 am	The Good Eating the Bad: Biological Control of Insects, with Insects (OH: 2B, 0.5 hr) • Adam Ingrao, Vegetable Entomology Lab, Entomology Dept., MSU
11:00 am	Break
11:10 am	Natural Enemies Identification (OH: 2B, 0.5 hr) • Adam Ingrao, Vegetable Entomology Lab, Entomology Dept., MSU • Ben Phillips, Vegetable Extension Educator, MSU Extension, Saginaw, MI
12:00 noon	Session Ends

Microbial Biofertilizers in Vegetable Crop Production: Facts, Experiences, and Hopes

Zheng Wang, Julie Laudick, and Matt Kleinhenz
Department of Horticulture and Crop Science, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, Ohio

Introduction

Most of the life in the soil is beyond our sight, too small to see without powerful magnification. Still, these microbes affect soils and crops significantly – pro or con in the eyes of growers. Identifying which naturally-occurring microbes can benefit crops is the first step in using them to enhance production. The idea has been to identify beneficial microbes, produce them in massive quantities, prepare them as inoculants, and apply them to crops and soils with the hope that they will stimulate or protect crops in some way. Microbe-containing bioproducts (MCBPs) that limit damage due to pests and diseases are known as biopesticides. MCBPs that can improve plant growth and health by other means are known as biofertilizers. Some biofertilizers work by extending the reach of the root system, giving crops access to more nutrients or water. Others convert nutrients in the soil to forms that crops can use while others encourage the plant to make hormones that speed growth. This presentation will focus on biofertilizers.

Facts

Product Abundance and Diversity: The number of different types of microbes in soils worldwide is many times greater than the number of different types of crops on the land, birds in the sky, or fish in the sea. Yet, it seems, only a small subset are, so far, fit to be used as biofertilizers. Most biofertilizers contain bacteria, fungi, algae, or a mixture of these types of microbes.

Many commercially available biofertilizers are advertised as being able to enhance crop growth, including vegetables. For example, we recently identified 160 products offered by 68 companies that were listed at the time as being allowable in certified-organic production (see https://u.osu.edu/vegprolab/research-areas/microbial-bioproducts/resources/microbe-containing-products/). Collectively, the products contain a large number of combinations of bacteria, fungi, and other microbes. These 160 products are only a fraction of the number of biofertilizers on the market.

How Biofertilizers Work: Biofertilizers tend to work in five different ways. First, they can increase nutrient availability through fixing nitrogen, solubilizing phosphorus, and chelating iron to ease its uptake by roots. Second, biofertilizers produce or prompt the plant to produce hormones that stimulate growth – the most important hormones being auxins, gibberellins, and cytokinins. Third, biofertilizers limit plant stress altering plant biochemistry, especially the production of ethylene, proline, or exopolysaccharides. Fourth, biofertilizers extend the reach of the crop root system by, for example, connecting fungal hyphae (similar to roots) to plant roots. This increases the plant's access to water and nutrients. Finally, biofertilizers can occasionally suppress some pathogens and/or kick-start the crop's defense system.

How Biofertilizers are Applied: Biofertilizers are applied as seed coatings or dustings, root drenches or dips, and as foliar sprays. Biofertilizer root drenches/dips and foliar sprays are almost always completed while plants are young (vegetative) for several reasons. First, the products are designed to stimulate growth – this is easier to accomplish when growth is occurring naturally, not after it is pre-programmed to slow (e.g., near fruiting or harvest). Second, biofertilizers may take several weeks to act fully. Third, biofertilizers can be delivered to roots directly and more reliably early in crop development. Allowing microbes in biofertilizers to form tight relationships with crop roots is essential to the function of some biofertilizers. It is also important to note that these relationships may require pairing certain microbes with certain crops due to host crop specificity. Some microbes and crops work well together, other combinations do not. For example, Brassica crops do not tend to form productive relationships with mycorrhizal fungi whereas the productive relationships between legumes and rhizobia are well known.

Experiences

Organisms found in biofertilizers usually have been studied extensively by scientists but the efficacy of products containing the same organisms has not been. A microbe performing well in some experiments does not mean it is guaranteed to offer growers a good return on their investment in a biofertilizer containing it.

On-farm experiences*:* Surveying organic certification records of Ohio organic vegetable growers revealed that their use of microbial bioproducts rose sharply in recent years; 30% of growers reported using a MCBP in 2009 and 76% of growers reported using a MCBP in 2014. The most commonly used types of biofertilizers were products containing multiple types of bacteria or fungi, rhizobia, and mycorrhizal fungi. In contrast, the most commonly used biopesticides contained a single type (species) of bacteria (*Bacillus thuringiensis* for insect control) followed by a variety of fungal antagonists. Overall, growers seemed to report neutral to positive experiences with microbial bioproducts. Some farmers have said that biofertilizers helped restore their degraded soils reduce the need for fertilizer.

Limited information from the industry: Biopesticides are highly regulated and must be rigorously tested – usually involving university and government scientists -- before they can be released for sale. Data from biopesticide testing are publicly available, widely reported, and included in production guides and other resources. Biofertilizers do not undergo the same level of independent testing and reporting. Independent data describing the outcomes of their use on research stations and commercial farms are in short supply. Several months ago, we invited the manufacturers of products listed in our database and scientists to share summaries of the results of their biofertilizer testing so that database users could access the summaries. We received very little feedback.

Research experiences: Microbial bioproducts may have valuable roles in vegetable production. In some tests, biofertilizers have shown that they can limit plant stress due to drought, salinity, and low fertility. For example, bioefertilizers used in combination with lower than normal rates of normal fertilizers have maintained yields at normal levels. This effect is important because biofertilizers are often less expensive on a per acre basis than chemical fertilizers, manures, or composts. Also, using some biofertilizers on low fertility soils typically results in greater yield increases than when biofertilizers are used on high fertility soils. Still, growers should balance maximizing the benefits of biofertilizers with maximizing yield in other ways. That is, some biofertilizers may be cheaper than some regular fertilizers up front, but not as effective at enhancing yield as other, more expensive fertility inputs.

It is also important to note that, except for microbes that fix nitrogen, biofertilizers do not introduce any new nutrients to the farm. Instead, biofertilizers make existing nutrients more available, and/or help crops use available nutrients more efficiently. So long as nutrients leave the farm as harvested crops and in other ways, those nutrients need to be replenished in some form to maintain soil productivity. Therefore, biofertilizers clearly cannot completely replace other fertility inputs. Overall, biofertilizers seem to have the greatest potential in low-input systems and unfavorable conditions.

Biopesticides and biofertilizers that produce plant growth hormones may be effective on more farms, regardless of their soil fertility levels or the presence of other types of crop stress. Limited research from our program suggests that biofertilizers can act as plant growth accelerators since treated plants grew faster as seedlings, and flowered and fruited earlier. In one case, biofertilizers shortened the time required to produce field-ready transplants. More research is needed to help growers maximize their returns on investments in biofertilizers. Application timing and method, effective crop-microbe combinations, and environmental conditions (i.e., temperature, soil moisture, soil fertility, etc.) under which products work must be clarified further.

Hopes

The biofertilizer industry is growing rapidly. It is our hope that manufacturers and university researchers will produce and disseminate information growers need to select and apply microbial bioproducts more effectively. A number of steps can be taken in that direction. For example, biofertilizers should be tested more rigorously by manufacturers and independent researchers and efficacy data should be more readily available. Also, it may be worthwhile to improve the standards for labeling and quality control of biofertilizer products. Finally, ideally, product manufactures, university research-extension personnel would collaborate to develop “best practice” guidelines for selecting and using biofertilizers.

Biocontrol Organisms in Compost and Composting

Brooke Comer
Department of Horticulture
Michigan State University
Plant and Soil Sciences Building
1066 Bogue St, Rm A430
East Lansing, MI 48824
E-mail: bcomer@msu.edu

Primary benefits of compost fall into one of three categories: physical, chemical or biological. When incorporated into field soils or soilless media, the physical characteristics affected by compost include affecting the bulk density, the water holding capacity, and improvements to soil structure such as aggregate stability. The chemical characteristics affected by compost include changes to the nutrient content, increases in cation exchange capacity (CEC), and stabilization of pH. Biologically, composts contain many thousands of microbes and can affect the microbiological community, cascading through higher trophic levels as well. Compost additions stimulate microbial growth and activity, may change the species composition in the soil, and suppress plant diseases. Due to these biological characteristics, compost used either directly or as an aqueous solution or "compost tea" can be used for biological control.

Compost "teas" are compost extracts that contain many of the benefits of composts, including transferring many of the nutrients and microbes into an aqueous phase. Compost tea is not the leachate that you might see coming out of a compost pile/bin, but rather mature compost that has been mixed with water. The quality of the tea being made correlates directly with the quality of the compost used. If the nutrients and microbes are not present in the starting compost material, they will not be present in the tea. The main benefits of using compost tea are that you can increase the populations of the microbes present, and the ease of application throughout the growing season.

There are many factors to consider when making compost tea. Besides deciding on a compost source, major decisions include the ratio of compost to water, whether to make teas with or without aeration, and with or without additives. Commercial brewers can be purchased or made from relatively simple materials such as buckets or barrels, PVC tubing and air pumps. Types of additives include, but are not limited to, molasses, kelp, humic acid, fish hydrolysate, rock minerals, etc. Modification of the compost prior to making the tea may also affect the microbes present in the resultant tea. Use of compost tea may be restricted or not allowed by organic certifiers, and it is always best to check with your certifier before applying anything in question.

Compost tea can be applied as either a foliar spray or a root drench. When incorporated as a root drench it can be added into irrigation/fertigation systems. The plant pathogens that have been most studied include many root rot pathogens such as *Pythium* spp. or *Rhizoctonia* spp., and wilt pathogens such as *Fusarium* spp. or *Verticiullium* spp. Foliar and fruit diseases compost tea may help suppress include molds such as *Botrytis cineria*, powdery and downy mildews, black rot, etc. For foliar applications, it is recommended to use a spreader-sticker to ensure good coverage.

It is possible to add additional biocontrol agents to composts or compost teas to increase their effectiveness against specific diseases of interest. Some of the more common commercially available microbial biocontrol agents being used are *Bacillus subtilis*, *Trichoderma* spp., *Streptomyces lydicus*, or *Beauveria bassiana*. These typically come in powdered formulations and can be added to either compost, or to compost teas to guarantee their presence and allow for simultaneous application. Such biocontrol organisms have been tested for specific plant diseases of interest including suppression of powdery and downy mildews, *Botrytis*, *Alternaria*, *Pythium*, *Phytophthora*, *Fusarium*, *Rhizoctonia*, or *Verticillium.*

Beyond compost tea being only as good as the starting compost, compost is only as good as its feedstocks. Compost made with manure will likely have very different nutrient concentrations than compost made with municipal waste such as leaves and grass clippings. Compost can be adjusted through specific additions as well. Adding feedstocks high in lignin has been shown to increase fungal populations in compost particularly when added during the maturation phase. More simple carbohydrates tend to favor bacteria. Other additions may include mined minerals, biochar, or effective microorganisms. Whether compost being used has been hot composted or worm composted will affect its biology. Compost blends can also be made to optimize nutrients and biological diversity.

The primary mechanisms by which compost and compost tea are able to suppress plant diseases include:

- Induced systemic resistance- stimulating a plant response that will make the plant ready to ward off any potential pathogen
- Competition- for both space, such as on the leaf surface, and for nutrients
- Parasitism/predation- directly attacking the pathogen organisms
- Antibiosis- producing chemicals such as antibiotics that adversely affect plant pathogens, either killing them or prohibiting them from successfully attacking plants
- Improvement in overall plant health

Variability in effectiveness of suppression of disease using compost or compost teas has made it difficult to make concrete recommendations to farmers. Use of compost tea in a regular spray schedule has been shown to be effective. It can also be incorporated in a spray schedule with other pesticides approved for organic production. Compost can be incorporated before planting, or as a top dressing during the growing season.

THE GOOD EATING THE BAD: BIOLOGICAL CONTROL OF INSECTS, WITH INSECTS

Adam Ingrao (ingraoad@msu.edu) and Zsofia Szendrei (szendrei@msu.edu)
Michigan State University - Vegetable Entomology
Lab website: http://vegetable.ent.msu.edu/

What is a natural enemy?

Natural enemies are beneficial insects that are important regulators of insect pests in agricultural and natural ecosystems. Generally, the term “natural enemy” encompasses two categories of beneficial insects; predators and parasitoids. One of the major distinguishers between predators and parasitoids are the number of prey insects they feed upon over their lifetime. Predators feed on multiple prey over the course of their life. Some common predatory insects include; hover flies, lacewings, lady beetles, ground beetles, praying mantis, dragonflies, damsel bugs, big eyed bugs, minute pirate bugs, and predatory stink bugs. On the other hand, parasitoids will only feed upon one prey insect during their lifetime. Some of the most commonly occurring parasitoids include wasps such as ichneumonids and braconids, and flies such as tachinids.

What is the life cycle of a predator?

Predators come in a variety of shapes and sizes, and have two types of life cycles. One type of life cycle a predator can have is incomplete metamorphosis, which means the predator starts its life as an egg, then undergoes several nymph stages that resemble the adult, and finally becomes an adult which has wings and the ability to mate. Predators with this type of life cycle include damsel bugs, minute pirate bugs, praying mantis, and predatory stink bugs. The second type of life cycle a predator can have is complete metamorphosis. These predators start life as an egg, undergo several larval stages that do not resemble the adult stage, become a pupa, and finally emerge as an adult with wings and the ability to mate. Predators that undergo this life cycle are beetles, hover flies, and lacewings.

What is the life cycle of a parasitoid?

Unlike predators, parasitoids only have one type of life cycle, complete metamorphosis. For parasitoids, egg placement plays a key role in larval survival. Adults will typically lay their eggs in, on, or near a suitable larva host. Upon hatching, the larva will feed on the host either internally or externally, pupate, and then emerge as an adult. The adult parasitoids typically feed on nectar and pollen from plants.

What is a specialist and generalist natural enemy?

Natural enemies can be classified as specialists or generalists. Specialists are insects who have a very narrow feeding range which may include one or maybe two specific insects. Conversely, generalists feed on a wide range of insect species. For the most part, predators tend to be more generalists in their feeding range, while parasitoids tend to be more specialists, however there are many exceptions to this.

How do natural enemies find and catch their prey?

Natural enemies have three main strategies used for catching prey: active, sit-and-wait, and trap-building. Active natural enemies use cues, such as visual and odor cues, to locate prey on the ground, in the plant canopy, and in the air. Some examples of active natural enemies are lady beetles, predatory stink bugs, ground beetles, and parasitoid wasps. Sit-and-wait natural enemies hide from their prey and wait for them to walk by before they strike. Insects that use this hunting strategy include; praying mantis and crab spiders. Finally, trap building insects use webs and pits to catch their prey and include web building spiders and antlions.

How do natural enemies feed?

Natural enemies have two types of mouthparts to feed on prey, these are: chewing mandibles and piercing/sucking stylets (straw like). Chewing natural enemies use their mandibles to chew up their prey and include predatory beetles. Piercing sucking natural enemies use their stylet like a straw which they use to pierce their prey and suck out its bodily fluids. Piercing/sucking natural enemies include damsel bugs, predatory stink bugs, and minute pirate bugs (Figure 5). However, exceptions to these two feeding categories do exist and one example is the lacewing which uses hollow sickle like mouthparts to penetrate the exoskeleton of its prey and suck out its bodily fluids.

How can I increase the number of natural enemies on my farm?

Increase the populations of natural enemies on your farm to lower pest numbers in your crops! No-till or strip-till, cover cropping, and planting flowering borders near fields are just a few examples of how to increase natural enemies on your farm. In no-till or strip-till systems soil disturbance is minimized, which preserves habitats for ground dwelling natural enemies such as ground beetles and tiger beetles. Cover cropping between crop rows can reduce soil temperature, increase soil moisture, and support natural enemy populations such as hover flies and predatory beetles by adding shelter, water, and food resources for them. Flowering border strips add pollen and nectar which are necessary food for many natural enemies. Planting flowers such as sweet alyssum, goldenrod, and blue lobelia for pollen and nectar can be successful for increasing natural enemies in agricultural fields.

Identifying Natural Enemy Insects

Instructors

Ben Phillips
Vegetable Extension Educator
MSU Extension
1 Tuscola St
Suite 100A
Saginaw, MI 48603
phill406@msu.edu
989.758.2502

Adam Ingrao
Vegetable Entomology Lab
Department of Entomology
Michigan State University
1129 Farm Lane, Rm 348
Food Safety and Toxicology Bldg.
East Lansing MI 48824
http://vegetable.ent.msu.edu/
ingraoad@msu.edu
951.237.5311

Insect Biocontrol "Modes of Action"

Predators
- Chewers, suckers

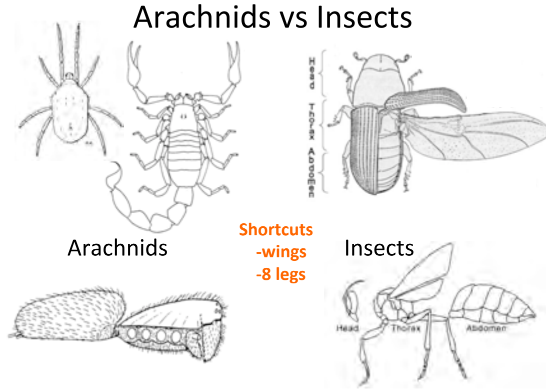
Parasitoids
- Specialists, generalists

Larvae/nymphs

Adults

How to identify them?

Arachnids vs Insects



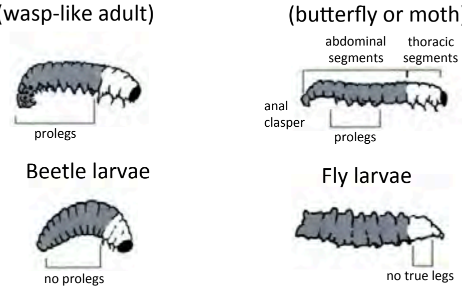
Larval insect body types

Sawfly caterpillar (wasp-like adult)

True caterpillar (butterfly or moth)

Beetle larvae

Fly larvae



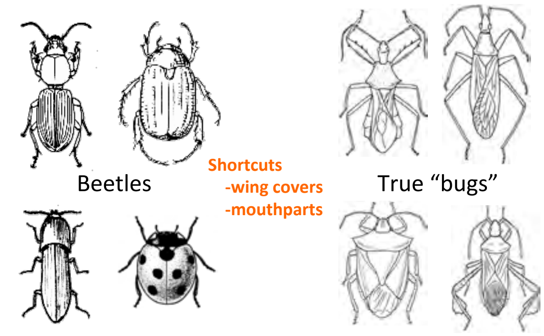
Pests of Landscape Trees and Shrubs: an Integrated Pest Management Guide, University of California Agriculture and Natural Resources

Larval insects pupate

Pests of Landscape Trees and Shrubs: an Integrated Pest Management Guide, University of California Agriculture and Natural Resources

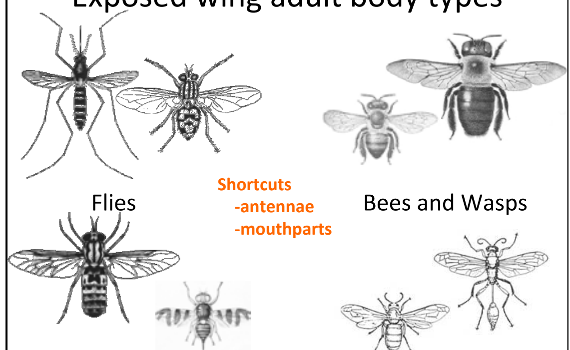
Nymphal insect body types

Hidden wing adult body types

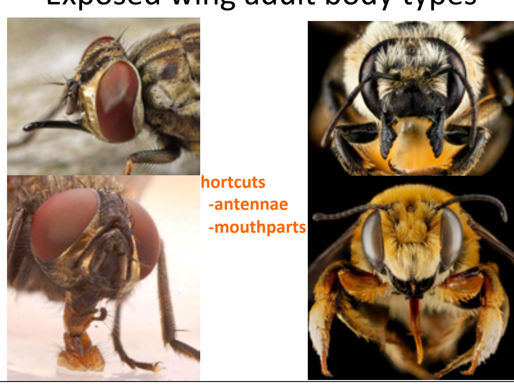


Hidden wing adult body types

Exposed wing adult body types



Exposed wing adult body types



Exposed wing adult body types