



BIOPESTICIDES FOR FUNGAL AND BACTERIAL DISEASE MANAGEMENT IN HORTICULTURAL CROPS

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INTRODUCTION

The key to disease management in organic farming systems is integrated pest management (IPM) practices to prevent disease introduction and development. Various products can be used to manage disease. Organic disease control products are generally derived from naturally occurring chemicals (ex. coppers, sulphurs), biologically derived compounds (ex. plant extracts, oils) or beneficial microorganisms for pest management. In recent years, there has been a push for the development and use of biopesticides by the agriculture industry at large, which, while biologically derived, are not always registered for certified organic production. There may also be differences between certifiers regarding which products are permitted. Organic products can be an effective addition to conventional pesticide programs as part of a holistic IPM program.

Many organic products have unique modes of action that require precise timing and close attention to application methods to maximize their efficacy. The goal of this factsheet is to provide detail on how the major groups of organic pesticides work so that they can be used most efficiently and effectively. The following breakdown of the major types of organic disease control products gives details on their mode of action, application methods and special considerations. For the most recent and specific product information, always refer to and follow directions on the product label. The label is the law, and it is the responsibility of the pesticide applicator to ensure they are following the label correctly. Labels can be found at [Health Canada's Pesticide Label Search](#). Any pesticides listed by trade name in this document are examples only and are neither an endorsement of the product nor a suggestion that similar products are ineffective. Be sure to check with your certifying body for a complete list of products permitted for use.

INORGANIC CHEMICALS WITH MULTI-SITE ACTIVITY (GROUP M1 AND M2):

Sulphur and copper are two of the oldest agricultural pesticides. Sulphur has been used since 1000 B.C. Bordeaux mixture (copper sulphate and slack lime) has been in use since the 1800s. Both sulphur (Group M2) and copper (Group M1) have multi-site activity and work by interfering with the biochemical pathways of pathogens, either killing them or reducing their growth rate.

Sulphur

Sulphur can be used as both a miticide and a fungicide and is generally available as elemental sulphur ex. Cosavet DF Edge. Sulphur products are applied foliarly and are contact fungicides which permeate the cell wall of germinating fungal spores and interfere with its metabolic functions. Sulphur products work as protectants and should be applied preventatively (before the onset of disease) when conditions are conducive to disease development.

IMPORTANT TAKEAWAYS

- Must be applied before disease development for maximum efficacy
- Particle size determines product's effectiveness
 - » Smaller particles are more effective against disease (more readily absorbable by pathogens)
 - » Smaller particle size may cause damage to the crop (phytotoxicity)
- Should not be applied when the temperature is over 32°C

Copper

Copper products need contact with the pathogen to provide broad-spectrum suppression/control against fungi and bacteria. Good coverage is essential for product efficacy. There are various formulations available, including copper hydroxide (ex. Kocide) and copper octanoate (ex. Cueva). Copper products are applied foliarly where they form deposits on the plant surface. When the deposits become wet, copper ions (Cu^{++}), which are toxic to pathogens, are released. Copper ions bind to pathogen proteins and hinder their biological function. Different formulations of copper products release copper ions at different rates. Higher rates of release can be more effective at controlling pathogens but can also cause phytotoxicity (**Figure 1**). Copper products should be applied preventatively when conditions are conducive to disease development, but before disease is present in the crop. Once applied, copper has residual effects for up to 7-14 days after application, depending on the product. Residual effects can be reduced by precipitation events, which can wash away residues (Figure 2). Periods of rapid plant growth can also reduce residual effect, as new plant tissue is not protected by copper residue, necessitating additional applications. Although copper is a useful disease management tool, it is also a heavy metal. Over time, copper can build up in the soil and water and have adverse environmental impacts. There have also been copper resistance issues documented for some bacterial diseases, such as *Xanthomonas* spp., commonly known as bacterial spot in tomato (Egel et. al., 2019). Copper products may have up to a 48-hour restricted entry interval (REI).



Figure 1. Phytotoxicity caused by copper application on grapes. Some hybrid varieties are sensitive to copper application—photo credit: Francisco Diez, Perennia.



Figure 2. Copper residue on grape leaves. Residue may be washed off by precipitation, reducing the residual effect of the product—photo credit: Jill MacDonald, Perennia.

IMPORTANT TAKEAWAYS

- Must be applied before disease development for maximum efficacy
- Can be effective against both fungal and bacterial pathogens
 - » Some resistance has been developed in certain bacteria populations
- Different formulations with different efficacy
 - » Some formulations may cause phytotoxicity (plant and variety-specific)
- Precipitation events or rapid plant growth may reduce the protection period
- Can accumulate in the environment with overuse
- Up to 48-hour REI

BIOLOGICAL FUNGICIDES WITH MULTI-SITE ACTIVITY (GROUP BM2):

Products within this group contain live beneficial fungal or bacterial species that prevent and suppress fungal diseases.

Trichoderma and related genera

Fungal species within this group are predominately from the genus *Trichoderma* or related genera, commonly occurring soil fungi. Products within this group include RootShield and Trianum-P, which are effective against soil-borne diseases caused by *Pythium*, *Fusarium* and *Rhizoctonia* spp. (**Figure 3**). RootShield can also be used foliarly to protect against *Botrytis* spp. The beneficial fungi in these products colonize the crop roots and prevent disease initiation through various modes of action. These beneficial fungi may act as antagonists by out-competing pathogenic fungi for nutrients and physical space on the roots, parasitize pathogenic fungi, produce antifungal compounds that are toxic to pathogenic fungi or secrete lytic enzymes that compromise the cell walls of pathogenic fungi. A study on the interactions of mycorrhizae and *Trichoderma* in maize showed that there were no negative effects on mycorrhizal establishment (Vázquez et. al., 2000). *Trichoderma* fungi can also help prevent disease by inducing resistance in the host plant. These products are applied either by incorporation into potting mix or growing substrate for transplants and indoor production or applied directly to the soil at planting. These products are preventative and need to be applied before disease development to colonize the plant and provide protection against disease.



Figure 3. Damping-off symptoms in cucumber. Damping-off can be usually be attributed to *Pythium*, *Fusarium*, and *Rhizoctonia* spp. fungi – photo credit: Talia Plaskett, Perennia.

IMPORTANT TAKEAWAYS

- Applied to the soil or growing media
 - » May protect against foliar diseases as well
- Best applied preventatively
- Soil temperatures must be above 10°C for the *Trichoderma* to become active
 - » Will not be effective if applied to cold soils
- More effective in neutral or acidic soils than in alkaline soils

MEMBRANE DISRUPTORS (GROUP 44 AND GROUP 46):

Products in group 44 and 46 disrupt the functioning of pathogen cell membranes.

Group 44 (Microbial disruptors)

Products in this group, such as Serenade products (Serenade OPTI, Serenade SOIL, etc.), contain a *Bacillus subtilis* strain of bacteria. These commonly occurring bacteria are recovered from soil, water, and air. *Bacillus subtilis* bacteria produce antimicrobial lipopeptides (iturins) that disrupt the function of fungal pathogen cell membranes and allows *B. subtilis* to outcompete fungal pathogens by killing them or reducing their growth rate. These products act as protectants and need to be applied preventatively before disease develops either as a seed treatment, soil drench or foliar application depending on the crop and targeted disease.

IMPORTANT TAKEAWAYS

- Must be applied preventatively before disease development
- Short re-entry and post-harvest intervals
- Complete and even coverage is essential for good disease control

Group 46 (Plant extracts)

Products in this group contain terpenes from plant extracts that can rupture fungal cell walls and membranes and induce natural defence mechanisms in the plant to combat certain fungi and bacteria. For example, Timorex Gold contains extract from *Melaleuca alternifolia* (Tea Tree oil) and provides broad-spectrum suppression and control of fungal pathogens such as powdery mildew and *Botrytis*. These products should be applied foliarly as preventative sprays when conditions are conducive for disease development to provide suppression or control of certain diseases. These products need to be applied multiple times throughout the season to provide continuous control and work well as resistance management tools in organic and conventional systems.

IMPORTANT TAKEAWAYS

- Must be applied preventatively before disease development
- Short re-entry interval after application
- Complete and even coverage is essential for good disease control

HOST PLANT DEFENSE INDUCING FUNGICIDES (GROUP P):

Group P fungicides are unique in that, unlike other fungicide groups, they are not inherently fungicidal. Instead, they trigger the host plant defence mechanisms (comparable to the innate immune systems in animals). The plant is stimulated for the production and accumulation of elevated levels of specialized proteins, compounds and cell wall/membrane strengtheners that provide broad-spectrum systemic suppression of plant pathogens. There are several sub-groups of group P that can induce plant host defences, but only certain products are registered for organic production in Canada. The main advantages of these organic products are that they pose very limited environmental or worker exposure risk and have short re-entry intervals.

Regalia Maxx is a group P5 fungicide that contains extract from Giant Knot weed (*Reynoutria sachalinensis*), a close relative of the locally invasive plant species Japanese knot weed (*Reynoutria japonica*). The extract contains a complex mixture of compounds, including anthraquinones (resveratrol, physicon and emodin), which elicit the plant's

defence response. When these compounds are taken up into the plant, they trigger the accumulation of phytoalexins and other simple phenolic compounds in their tissue that have antifungal activity. Because of the unique mode of action of this type of product, there is no curative effect and therefore needs to be preventatively applied when conditions are conducive to disease development, but before disease is present in the crop. Early application is key to these products being effective. It should ideally be applied 3-5 days before potential disease development to induce plant defense response to trigger the accumulation of defensive compounds. Repeat applications may be needed to maintain protection. These products specifically target host plant defence induction, but many of the previously mentioned fungal or bacterial based products have also been reported to induce certain host plant defences.



Figure 4. Extract of giant knotweed (*Reynoutria sachalinensis*) is used in a product that triggers host-plant defences with anti-fungal activity – photo credit plantsoftheworldonline.org

IMPORTANT TAKEAWAYS

- Must be applied preventatively before disease development
- Should be applied 3-5 days prior to potential infection periods
- Multiple applications may be needed to maintain protection

FUNGICIDES NOT CLASSIFIED (GROUP NC)

This group is a catchall of products that have non-specific modes of action and includes products that contain oils, bicarbonates, hydrogen peroxide and bacterial fermentation products.

Oils

Mineral and vegetable oil-based pesticide products such as Vegol Crop Oil and PureSpray Green Spray Oil are predominately used as insecticides for the control of sap-sucking insects (aphids, mealybugs, scales, etc.) and mites, but they are also registered for the suppression of powdery mildew in several crops including cucurbits and cane berries (**Figures 5 & 6**). Oil-based products are contact pesticides that appear to work against powdery mildew by suffocating the fungal mycelium and preventing spore germination. Oil-based products work best as suppressants and should be applied when disease first appears in the crop. Thorough coverage of crop surfaces is crucial for suppression. Multiple applications throughout the season may be necessary, especially if disease pressure is high or if the crop is growing quickly. Oil-based products do have drawbacks as they cannot be used in combination with some pesticides. During application, the spray mixture must be constantly agitated so that the oil does not separate from the water. Oils will be washed off in heavy rains, and if applied under high-temperature conditions (32°C), may cause phytotoxicity to the plant.

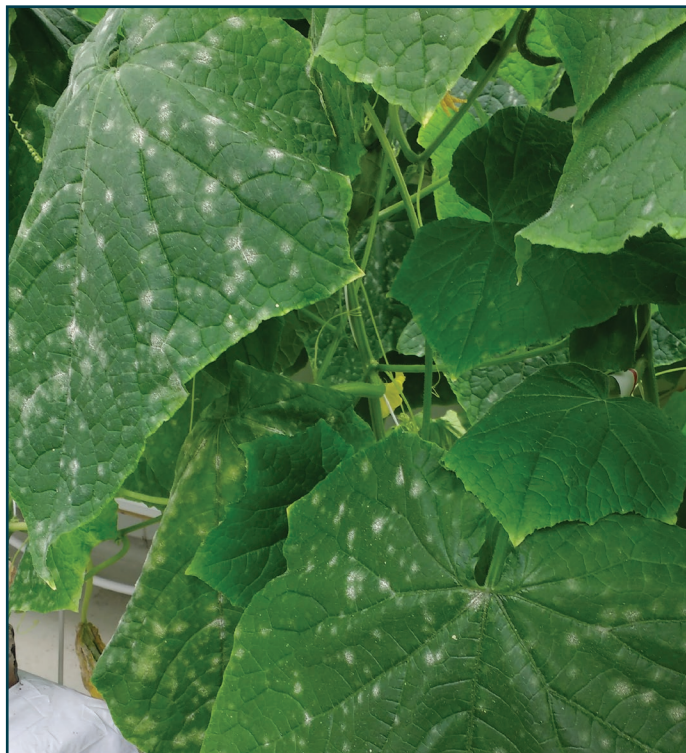


Figure 6. Powdery mildew on cucumber leaves in the greenhouse – photo credit: Talia Plaskett, Perennia.



Figure 5. Powdery mildew on strawberry leaves – photo credit: Sajid Rehman, Perennia.

IMPORTANT TAKEAWAYS

- Must be applied when disease first appears
- Thorough coverage of crop surfaces is crucial for disease suppression
- Multiple applications throughout the season may be necessary to maintain protection, especially if disease pressure is high or if the crop is growing quickly
- Cannot be used in combination with some pesticides (e.g. Sulphur within 30 days)
- Sensitive to weather conditions such as temperature, humidity, and rainfall



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Bicarbonates

Bicarbonates are naturally occurring compounds that, when concentrated, can be used as pesticides. Bicarbonate based products such as Milstop contain potassium bicarbonate as the active ingredient and provide non-specific protection against plant pathogens and are most effective against many strains of powdery mildew. These products work on contact by drawing moisture away from germinating spores and by inhibiting enzymes involved in fungal cell wall formation by raising the pH on the leaf surface. Bicarbonates must be applied with the onset of disease. Thorough coverage of crop surfaces is crucial for suppression. Multiple applications throughout the season may be necessary to maintain protection, especially if disease pressure is high or the crop is growing quickly. Bicarbonates are washed away easily by rain, so applications need to be made more frequently to maintain control under wet conditions and should also be applied to dry foliage.

IMPORTANT TAKEAWAYS

- Must be applied at the onset of disease
- Thorough coverage of crop surfaces is crucial for suppression
- Should be applied under dry conditions
- Residue is washed away easily by rain
- Multiple applications throughout the season may be necessary to maintain protection

Peroxides

Peroxide-based products contain concentrated hydrogen peroxide (often combined with peracetic acid) and are highly non-specific, providing suppression of a wide variety of fungal and bacterial pathogens (OxiDate, ZeroTol). Hydrogen peroxide and peracetic acid are highly reactive and work on contact by oxidizing components of cell walls, breaking them down and killing the pathogen, effectively sterilizing plant surfaces. Because these products are highly reactive, they break down very quickly and provide no residual control once the product has dried. Thorough coverage of crop surfaces and adequate wetting is crucial for suppression. Multiple applications throughout the season are necessary to maintain protection, especially if disease pressure is high or the crop is growing quickly. Although being highly reactive and non-specific has its advantages for disease control, hydrogen peroxide-based products can potentially cause plant damage and kill beneficial microbes on the plant surface. It is important to pay close attention to conditions at the time of their application, such as heat, moisture levels and plant vigour, to protect the crop from excessive damage.

IMPORTANT TAKEAWAYS

- Short residual effect, highly reactive, and breaks down very quickly
- Thorough coverage of crop surfaces is crucial for disease suppression or control
- Multiple applications throughout the season are necessary to maintain protection
- Can potentially cause plant damage and kill beneficial microbes on the plant surface, especially under adverse conditions.

Bacterial fermentation products

Fermentation products are organic compounds produced through the metabolic processes of bacteria and fungi. A common group of fermenting organisms are Lactobacillus bacteria, which produce lactic acid and other organic acids, and are the main biological agent involved in the production of fermented foods. When concentrated, these fermentation products can be used in disease management. Tivano is a fungicide and bactericide that contains lactic and citric acid produced as fermentation products of Lactobacillus casei strain LPT-111. Tivano is one of the few organic certified products registered for controlling foliar bacterial diseases other than copper. Tivano provides suppression upon contact by reducing the integrity of pathogen cell walls and drawing out moisture from pathogen cells. These products work best as protectants and should be applied preventatively when conditions are conducive to disease development, but before disease is present in the crop. Thorough coverage of crop surfaces is crucial for suppression. Multiple applications throughout the season may be necessary to maintain protection, especially if disease pressure is high or the crop is growing quickly. Organic acids are washed away easily by rain, so applications need to be made frequently to maintain pathogen control during wet conditions and should also be applied to dry foliage.

IMPORTANT TAKEAWAYS

- Must be applied preventatively
- Thorough coverage of crop surfaces is crucial for suppression
- Residue is washed away easily by rain
- Multiple applications throughout the season may be necessary to maintain protection



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CONCLUSION

There are a variety of organically derived disease management products that can be effective in both organic and conventional systems. Due to their unique modes of action, special considerations need to be taken regarding their spray timing and application method for effective disease control. Although all products listed above are examples of organic pesticides, there are differing regulations between countries and organic certifiers. Refer to the Organic Materials Review Institute (OMRI) or your certifier if you are unsure about applying a product. Always read the product labels before application. For additional information on organic disease control or other production-related questions, please contact your commodity's respective Perennia Specialist.

REFERENCES

Caldwell, B., Sideman, E., Seaman, A., Shelton, A., Smart, Christine. (2013). Resource Guide for Organic Insect and Disease Management. Cornell University. Retrieved from: <http://web.pppmb.cals.cornell.edu/resourceguide/pdf/resource-guide-for-organic-insect-and-disease-management.pdf>.

Egel, D. S., Jaiswal, A. K., Abdelrazek, S., Hoagland, L. (2019, December 4). Managing diseases of tomato in the Midwest using organic methods. E-organic, Oregon State University. Retrieved from: <https://eorganic.org/node/33835>

Jacobsen, B. J., Zidack, N. K., Larson, B. J. (2004, November). The Role of Bascillus-Based Biological Control Agents in Integrated Pest Management Systems: Plant Diseases. Journal of Phytopathology 4:11, 01. Retrieved from: <https://apsjournals.apsnet.org/doi/pdf/10.1094/PHTO.2004.94.11.1272>.

Maget-Dana, R., Peypux, F. (1992, February 28). Iturins, a Special Class of Pore-forming Lipopeptides: Biological and Physicochemical Properties. Toxicology 87(1-3):151-74. Retrieved from: <https://www.ncbi.nlm.nih.gov/pubmed/8160184>

Schilder, A. (2008, August 5). JMS Stylet Oil can be used to knock down powdery mildew on grapevines. MSU Extension, Michigan State University. Retrieved from: https://www.canr.msu.edu/news/jms_stylet_oil_can_be_used_to_knock_down_powdery_mildew_on_grapevines.

Singh, A., Shahid, M., Srivastava, M., Pandey, S., Sharma, A., Kumar, V. (2014). Optimal Physical Parameters for Growth

of Trichoderma Species at Varying pH, Temperature and Agitation. Virology and Mycology 3:127. Retrieved from: <https://www.longdom.org/open-access/optimal-physical-parameters-for-growth-of-trichoderma-species-at-varying-ph-temperature-and-agitation-2161-0517.1000127.pdf>.

Vásquez, M.M., César, S., Azcón, R., Barea, J.M. (2000, April 6). Interactions Between Arbuscular Mycorrhizal Fungi and Other Microbial Inoculants (Azospirillum, Pseudomonas, Trichoderma) and their Effects on Microbial Population and Enzyme Activities in the Rhizosphere of Plants. Applied Soil Ecology 15: 261-272.

Węgrzyn, E., Górczyńska, K. (2019). Influence of the fungal hyperparasite Trichoderma harzianum on the growth of Epichloë typhina, an agent of choke disease in grasses. Journal of Plant Disease Protection 126, 39–45. Retrieved from: <https://doi.org/10.1007/s41348-018-0184-2>.

Products labels and technical documents published by the manufacturers, and the OMRI Products List for Canada were consulted in the development of this factsheet.

FOR MORE INFORMATION

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