Martin-Gatton College of Agriculture, Food and Environment
Cooperative Extension Service

Plant Pathology Fast Facts

Organic Disease Management Guide for Specialty Crop Production

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A wide range of plant pathogens can cause disease in fruits, vegetables, ornamentals, hemp, and other specialty crops. Bacterial, fungal, and viral diseases can result in plant damage and yield loss. Factors that affect plant disease incidence and severity include pathogen presence, inoculum load (the concentration of pathogen that is present), host susceptibility (a plant's vulnerability to pathogen), and environmental factors including temperature and moisture/wetness.

An integrated pest management (IPM) program is recommended for preventing and controlling plant diseases in both conventional and organic production systems. Cultural approaches, which target practices that make an environment less conducive to pathogen development, should be incorporated into all commercial systems. These practices often aim to prevent disease by suppressing plant pathogens, altering the environment, or improving plant health.

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In some production systems, particularly monocultured fields and/or intensive production, applications of fungicides and bactericides may be necessary to further mitigate plant diseases. In organic systems, these products are derived from naturally occurring compounds. Organic fungicides and bactericides provide the greatest efficacy when applied preventively (prior to disease onset). Growers should proactively develop a spray schedule for each crop and each season to limit the impact of disease.

This document provides information on cultural and biological options for organic management of fungal and bacterial diseases; viral disease management is not covered in this publication. As in all systems, fungicides and bactericides should be combined with cultural practices such as crop rotation, resistant cultivars, and sanitation.

CUTURAL MANAGEMENT

Management of plant diseases using cultural practices typically focuses on altering production approaches to make situations less favorable for plant pathogens. These often include resistant cultivars, avoidance of sites with history of disease, and manipulation of environmental conditions such as moisture/wetness. Some cultural methods can have significant impacts on disease development, while others can have small but cumulative effects. In low- to moderate-risk situations, cultural practices alone can sufficiently manage disease. However, cultural practices are often combined with fungicides in commercial systems to ensure fewer disease outbreaks. Regardless, cultural practices should be the first consideration for growers, and as many practices as possible should be implemented.

Cultural practices presented in this publication are broadly discussed. Crop-specific information is available in the series *Cultural Calendars for Commercial Production* (available for fruit and vegetables) and in Plant Pathology Fact Sheets (PPFS) found on the UK Department of Plant Pathology webpage. Table 1 provides information on cultural practices that target common disease problems.

Cultural Practices

Preplant

- Select cultivars with tolerance or resistance to common diseases, when possible. Consult production guides and seed catalogs for information on resistant/tolerant cultivars.
- Purchase disease-free seeds or transplants.
- Use new or clean/sanitized pots and potting media when starting transplants.
- Inspect plants after purchase and/or prior to transplant. Check roots, stems, and leaves. Do not install plants that appear unhealthy or damaged.
- Rotate out of related plants (same plant family) for 2 to 3 years.
- Select fields that are well-drained and do not have a history of disease.
- Deep till between crops; use non-host cover crops, particularly in no-till production systems.

Production

- Use non-host cover crops between field seasons and between rows.
- Promote air circulation by increasing plant and row spacing, pruning, and staking.
- Open greenhouse vents to exchange humid air.
- Maintain relative humidity <70% for fungal diseases and <85% for bacterial and water mold diseases, when possible. Monitor greenhouse humidity.
- Apply a mulch layer (plastic, straw, wood chip, or cover crop) to limit transmission of pathogens from soil onto healthy tissues.
- Maintain plant health using appropriate planting practices, avoiding injury, irrigation during dry weather, and fertilization according to soil test results.
- Avoid or mitigate standing or pooled water (greenhouse) and poor drainage (field).
- Manage weeds and volunteer plants that can serve as reservoir hosts to prevent buildup of pathogens in fields and transmission of pathogens onto crops.
- Scout fields and greenhouses regularly. Utilize diagnostic lab services, as needed. Contact a local county extension agent for assistance with plant problems.

- Remove infected plant tissue throughout the growing season. When plants exhibit wilting, dieback, or decline, remove entire plants, including roots.
- Remove infected fruit/flowers/produce throughout the growing season. Avoid mixing diseased and healthy fruit during harvest.
- When removing diseased plants or plant tissue, dispose of them away from fields. Never leave debris in fields. Do not compost diseased plants, plant tissue, or fruit.
- Clean and sanitize all tools and equipment between fields and after each use.
- Clean shoes to prevent moving pathogens from field to field or zone to zone.

After harvest

- Remove all plants and plant debris at the end of the season.
- Disinfect tools and equipment; sanitize greenhouse floors and surfaces between crop cycles.
- Dispose of diseased plant tissue and clippings away from fields. Never leave debris in fields. Do not compost diseased plants or fruit.
- Deep-till fields at the end of the season to bury residual pathogens and infected debris.
- Plant non-host cover crops. If possible, consider planting biofumigant cover crops such as mustards and radishes.

Table 1. Cultural Practices for Common Diseases of Specialty Crops

	Leaf spots, fungal	Damping off	Downy mildew	Fusarium crown rot	Nematodes	Phytophthora root/crown rot	Powdery mildew	Pythium root rot	Rhizoctonia	Southern blight	Viruses	White mold
Clean seed/cuttings		x	x	x		x		x	x		x	
Crop rotation (2 to 3 yrs)		x	x	x	x	x		x	x	x		x
Deep till	x	x		x		x		x	x	x		x
Drainage and site selection		x		x	x	x		x	x	x		
Drip irrigation	x	x	x									
Environment (humidity/moisture)	x	x	x			x	x	x	x	x		
Insect management				x				x			x	
Minimize splashing (mulch)	x		x	x		x		x	x			
Plant spacing, air circulation	x		x	x		x	x		x	x		x
Plant vigor	x	x		x				x	x			
Raised beds, surface drainage		x		x		x		x	x			
Reduced wounding/injury				x		x			x			
Removal of diseased plants/tissue	x		x	x		x	x	x	x	x	x	x
Resistant cultivars	x						x				x	
Sanitation (tools/equipment/shoes)		x		x	x	x		x	x	x	x	x
Solarization		x		x	x	x		x	x	x		x
Weed management	x		x		x	x	x	x		x	x	

FUNGICIDES

Fungicides may be needed to help protect susceptible crops or crops in high-risk situations. This can include certain cultivars, weather conditions, or fields with a history of disease. Often, fungicide efficacy is improved when combined with cultural practices, as covered on pages 2-3.

This publication categorizes organic fungicides into three types: biological (Table 2), botanical (Table 3), and inorganic (Table 4). In most cases, fungicides are preventative or suppressive, not curative. Always use fungicides preventatively. Factors such as active ingredient, formulation, application timing, and external factors such as environmental conditions and inoculum load can also affect efficacy of products and overall effectiveness of disease management programs.

Biological Fungicides

Biological fungicides are made from microorganisms that can have one of three modes of action: antagonism, competition, or induced plant resistance (systemic acquired resistance SAR, immune response). Biological fungicides are dependent on the activity of the microbial agent. Manufacturers often select specific strains of fungi or bacteria based on pathogen antagonism, resiliency, or other traits. Many biological fungicides contain living organisms and may be affected by storage conditions, field conditions or other fungicides or bactericides. Read labels carefully before tank mixing with other products.

Table 2. Biological Fungicides

Active Ingredient[1,2]	Commercial Products	Target Diseases
Bacillus amyloliquefaciens	AmyloShield Cease Companion Maxx Double Nickel Stargus Triathlon	Most Effective Against Botrytis gray mold Cercospora leaf spot *Pseudomonas*/angular leaf spot/bacterial speck Timber rot/drop/white mold *Xanthomonas*/angular leafspot/bacterial spot Fungal leaf spots/leaf diseases, general Other Diseases Managed Alternaria leaf spot Anthracnose/*Colletotrichum* Fusarium crown/fruit rot Phytophthora root rot/blight Powdery mildew Rhizoctonia root/stem rot/blight Rust Southern blight
Bacillus mycoides	LifeGard	Diseases Managed Anthracnose/*Colletotrichum* Botrytis gray mold Cercospora leaf spot Downy mildew Timber rot/drop/white mold Fungal leaf spots/leaf diseases, general

Bacillus subtilis	Companion Serenade Subtilex Taegro 2	Most Effective Against Powdery mildew Other Diseases Managed Botrytis gray mold Timber rot/drop/white mold
Bacillus thuringiensis	Leap	Diseases Managed *Pseudomonas*/angular leaf spot/bacterial speck *Xanthomonas*/angular leaf spot/bacterial spot
Clonostachys rosea (formerly *Gliocladium catenulatum*)	Lalstop G-46 (formerly PreStop)	Diseases Managed Anthracnose/*Colletotrichum* Botrytis gray mold Fusarium crown/fruit rot Powdery mildew Timber rot/drop/white mold
Coniothyrium imintans	Contans	Diseases Managed Timber rot/drop/white mold
Pseudomonas chlororaphis	Howler EVO Zio	Diseases Managed Fusarium crown/fruit rot Pythium root rot Phytophthora root rot/blight Rhizoctonia root/stem rot/blight Timber rot/drop/white mold
Reynoutria sachalinensis	Regalia	Diseases Managed Downy mildew Powdery mildew Bacterial leaf diseases, general Fungal leaf spots/leaf diseases, general
Streptomyces lydicus	Actinovate	Diseases Managed Botrytis gray mold Fusarium crown/fruit rot Phytophthora root rot/blight Powdery mildew Pythium root rot Rhizoctonia root/stem rot/blight Bacterial leaf diseases, general Fungal leaf spots/leaf diseases, general
Streptomyces sp. (formerly *S. griseoviridis*)	LalStop K-61 (formerly MycoStop)	Most Effective Against Pythium root rot Rhizoctonia root/stem rot/blight Other Diseases Managed Fusarium crown/fruit rot Phytophthora root rot/blight Timber rot/drop/white mold
Swinglea glutinosa	EcoSwing	Most Effective Against Powdery mildew Rust Other Diseases Managed Botrytis gray mold *Pseudomonas*/angular leaf spot/bacterial speck Timber rot/drop/white mold *Xanthomonas*/angular leaf spot/bacterial spot

Trichoderma asperellum + *Trichoderma gamsii*	Obtego	Diseases Managed Fusarium crown/fruit rot Pythium root rot Phytophthora root rot/blight Rhizoctonia root/stem rot/blight Southern blight
Trichoderma harzianum + *Trichoderma virens*	Rootshield Plus	Most Effective Against Phytophthora root rot/blight Pythium root rot Rhizoctonia root/stem rot/blight Other Diseases Managed Black root rot/*Thielaviopsis* Fusarium crown/fruit rot
Ulocladium oudemansii	BotryStop	Most Effective Against Botrytis gray mold Timber rot/drop/white mold

[1]Biological fungicides containing living organisms may be deactivated by antimicrobial products, particularly copper and sulfur; check labels for compatibility before tank-mixing or applying in succession.
[2]Living organisms require proper storage to maintain viability. Check label for specific storage conditions.

Botanical and Other Biorational Products

In addition to biological fungicides, there are many biorational products on the market. These products are made of materials that are not considered a threat to humans or animals and can include botanical extracts, microbial by-products, mineral oil, or soap. While most biorational products are OMRI approved, some may not; always check labels.

Table 3. Botanical and Other Biorational Products

Active Ingredient	Commercial Products	Target Diseases
Acibenzolar	Actigard[1]	Diseases Managed Downy mildew *Pseudomonas*/angular leaf spot/bacterial speck *Xanthomonas*/angular leaf spot/bacterial spot Bacterial leaf diseases, general Fungal leaf spots/leaf diseases, general
BLAD (Banda de Lupinus albus Doce)	ProBlad Verde (formerly Fracture)	Diseases Managed Botrytis gray mold Brown rot/*Monilinia* Powdery mildew
Botanical oils such as garlic, capsaicin, thyme	varies by a.i.	Diseases Managed Fungal leaf spots/leaf diseases, general
Citric acid[2]	FungOUT Procidic	Diseases Managed Fungal leaf spots/leaf diseases, general Additional Uses Enhance efficacy of copper and other fungicides

Hydrogen peroxide/ peroxyacetic acid	Oxidate Sanidate ZeroTol	Uses Pre-plant dip Seed treatment Disinfection of equipment and tools
Neem oil	Rango Triact Trilogy	Diseases Managed Botrytis gray mold Downy mildew Powdery mildew
Polyoxin D zinc salt[2]	OSO PhD	Most Effective Against Downy mildew Other Diseases Managed Alternaria leaf spot Anthracnose/*Colletotrichum* Botrytis gray mold Gummy stem blight Powdery mildew Southern blight Fungal leaf spots/leaf diseases, general Additional Uses Enhance efficacy of copper and other fungicides
Potassium bicarbonate	Kaligreen MilStop	Most Effective Against Botrytis gray mold Downy mildew Powdery mildew Other Diseases Managed Cercospora leaf spot Rust Fungal leaf spots/leaf diseases, general
Rhamnolipid biosurfactant	Zonix	Most Effective Against Phytophthora root rot/blight Pythium root rot Other Diseases Managed Downy mildew
Silicon, calcium silicate	Sil-Matrix	Diseases Managed Botrytis gray mold Powdery Mildew

[1] Not all SAR products are OMRI approved; refer to label for OMRI certification.

[2] Citric acid and polyoxin D products are most effective when tank-mixed with other fungicides.

Inorganic Compounds

Some fungicides are derived from inorganic compounds yet are OMRI approved. Copper and sulfur are inorganic compounds that are commonly used as both conventional and organic fungicides. Some formulations of copper and sulfur may be OMRI approved when an alternative organic product is not available. Check product labels and/or consult with your organic certifier to verify products available for certified organic production systems.

Table 4. Inorganic Compounds

Active Ingredient	Commercial Products	Target Diseases
Copper[1, 2]	Badge Basic Cop Nordox NuCop	Most Effective Against *Pseudomonas*/angular leaf spot/bacterial speck *Xanthomonas*/angular leaf spot/bacterial spot Other Diseases Managed Alternaria leaf spot Anthracnose/*Colletotrichum* Cercospora leaf spot Downy mildew[3] Powdery mildew Target spot/*Corynespora*
Lime sulfur [1, 2]	Lime Sulfur Ultra Sulforix[2]	Diseases Managed Anthracnose/*Colletotrichum* Brown spot Cane blight Phomopsis cane/tip blight Powdery mildew Rust
Sulfur [1, 2]	Kumulus[2] Microthiol Disperss	Most Effective Against Powdery mildew Other Diseases Managed Downy mildew[3]

[1]Biological fungicides containing living organisms may be deactivated by antimicrobial products, particularly copper and sulfur; check labels for compatibility before tank-mixing or applying in succession (within 7 days).
[2]Not all copper and sulfur products are OMRI approved; refer to label for OMRI certification.
[3]Efficacy of copper and sulfur against downy mildew can be improved by tank-mixing with an SAR or citric acid product; refer to label for compatibility details.

Special Notes

Copper fungicides differ by types of copper compounds, amounts of copper ions (MCE, metallic copper equivalent), particle size, and product formulation. These factors affect efficacy, rate of release of copper ions, and risk for phytotoxicity. Because copper is an inorganic compound, it can accumulate in soils. Copper fungicides are antimicrobial and can degrade cells of animals, plants, and microorganisms, including beneficial organisms like earthworms; never apply to runoff. Not all copper products/formulations are OMRI approved; refer to label.

SAR (systemic acquired resistance, induced resistance) products help build plant immunity. These products include Actigard, Actinovate, Serenade Opti, Lifegard, Regalia, and Timorex. SAR products should be used preventatively. They also help improve the efficacy of copper and sulfur fungicides against certain diseases such as downy mildew.

Table 5. Biological and Biorational Fungicides with the Potential to Manage Common Diseases of Specialty Crops.

	Alternaria leaf spot	Anthracnose	Bacterial spot	Botrytis gray mold	Cercospora leaf spot	Damping off	Downy mildew	Fusarium crown rot	Phytophthora root/crown rot	Powdery mildew	Pythium root rot	Rhizoctonia crown rot	Rust	Septoria leaf spot	Southern blight	White mold, timber rot
Acibenzolar			x				x		x	x						
Bacillus amyloliquenfaciens	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bacillus mycoides	x	x		x	x		x			x				x		
Bacillus pumilus			x				x			x						
Bacillus subtilis	x	x	x	x	x	x	x	x	x	x	x	x	x		x	
BLAD				x						x						
Clonostachys rosea [1]				x		x		x		x						
Citric acid	x	x		x	x		x							x		x
Copper[2]	x	x	x	x	x		x	x	x			x	x			
Gliocladium virens [1]		x				x		x	x		x					
Hydrogen peroxide		x	x				x			x						
Neem oil										x						
Polyoxin Z salt	x	x		x			x		x	x		x	x	x	x	x
Potassium bicarbonate				x	x		x			x						
Pseudomonas chlororaphis	x	x		x		x	x	x	x	x	x	x				x
Reynoutria sachalinensis			x		x		x			x				x		x
Silicon, calcium silicate				x	x									x		
Streptomyces lydicus	x		x			x	x	x	x	x	x	x				x
Streptomyces grisioviridus						x		x			x	x				x
Sulfur				x						x						
Swinglea glutinosa			x							x			x			x
Trichoderma spp.				x		x	x	x	x		x	x			x	x
Ulocladium oudemansii				x												x

1 Note name change: *Gliocladium virens* current name is *Trichoderma virens*; *Clonostachys rosea* is formerly known as *Gliocladium catenulatum*.

2 Copper efficacy varies by compound and formulation.

ADDITIONAL RESOURCES

Additional information can be found at the following University of Kentucky Department of Plant Pathology website, including organic spray guides, cultural calendars, and fact sheets.

- https://plantpathology.ca.uky.edu/extension/publications

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