Organic Management of Vegetable Diseases, Part II: Foliar Pathogens[1]

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Introduction

The successful management of both soilborne and foliar diseases requires a multifaceted program, taking into consideration variety selection, cultural methods, biologicals, and chemical applications approved by the Organic Materials Review Institute (OMRI) and certified organic under the United States Department of Agriculture (USDA) National Organic Program (NOP). This review emphasizes the management of foliar disease and serves as a guide to assist growers in selecting strategies to manage disease in a sustainable system. The EDIS Publication PP254, *Organic Management of Vegetable Diseases, Part I: Soilborne Pathogens* (http://edis.ifas.ufl.edu/PP169), is a companion to this publication.

Management Techniques

Disease management is a key concern in organic vegetable production. Because few curative control methods are available, disease prevention practices are critical for both soilborne and foliar diseases. Effective disease management focuses on the integrated use of plant varieties that can resist or tolerate infection from a specific pathogen, combined with the use of cultural, biological, and chemical control strategies that reduce or eliminate pathogen inoculum. Inoculum is a term used in plant disease when referring to spores or the infectious parts of the pathogen that can survive or reproduce, furthering disease development. Foliar diseases create unique challenges; they are typically not predictable in timing and pressure, their source of origin can vary, and they are often best managed by using resistant varieties and OMRI-approved fungicides and/or seed treatments.

Variety Selection

The use of disease-resistant and/or tolerant varieties is the most effective and economical method of plant disease management. Although it is important for growers to select varieties that have marketable horticultural qualities, such as appearance, quality, color, and yield, strong consideration should be given for varieties that have disease resistance. Unfortunately, resistant varieties are not available for all diseases on all crops. In some cases, plant disease resistance can be overcome by the introduction or development of new strains or races of the target pathogen. Despite these disadvantages, the use of disease resistant plant varities remains the most important tool for disease management on the organic farm. In Florida, practical control of many vegetable diseases, particularly fungal and viral diseases, is achieved by variety resistance. Table 2 indicates the general availability of disease resistance in specific crops or crop groups. Further information on organic seed selection can be found in a database provided by the Appropriate Technological Transfer for Rural Areas (ATTRA) (http://attra.ncat.org/attra-pub/organic_seed/).

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Cultural Control

Cultural methods for disease control focus on managing the crop environment in order to 1) prevent the introduction of inoculum into the field, 2) reduce the survival and buildup of inoculum, 3) restrict the build-up of airborne inoculum in the field, 4) reduce the rate of infection, and 5) create conditions unfavorable for pathogen and disease development. The most effective programs integrate multiple disease management practices and do not rely on a single method for disease control. Depending upon the characteristics of a specific crop and disease, some cultural management techniques may be more effective than others. A comprehensive list of management tactics can be found in Table 2.

Field selection, sanitation, and preparation: Disease management benefits may be had by locating vegetable fields at a distance from potential inoculum and insect pests, such as unmanaged weedy areas, run-off ponds, hedge rows, or wooded areas. Avoid planting areas of fields that are known to have high disease pressure; such areas tend to be the low-lying portions of fields, where water may stand.

Many pathogens reside in plant debris after harvest; thus, field sanitation is important in reducing the amount of initial inoculum. Growers should also avoid depositing culled plant material back onto a production field. Rejected plant material may be diseased and/or may harbor pathogens, which can contribute to, or introduce, inoculum in a field.

Polyethylene mulches can limit weeds, and metallized mulches can repel some insects that vector virus. Plant nutrition and soil pH can also impact some diseases. Increasing soil pH by liming is a good strategy to reduce *Fusarium* wilt and *Botrytis* gray mold. Optimizing calcium nutrition and raising the soil pH can reduce bacterial wilt in the field. It is also important to have adequate soil calcium to minimize blossom end rot. The form of nitrogen fertilizer can influence plant disease incidence; nitrate forms of fertilizer may suppress *Fusarium* wilt of tomato. The ammonia form increases disease severity.

Seed treatments can also provide disease management. Tomato seeds, for example, can be treated with hot water (122°F for 25 minutes). Pepper seeds can be chlorine-treated in some cases (one part household bleach to four parts water, plus half a teaspoon of surfactant per gallon—then agitate for 1 minute, rinse for 5 minutes, and dry seed). Chlorine seed treatment is not accepted by all organic-certifying agencies. For this reason, be sure to check with your certifying agency prior to using this technique.

Planting material: The use of healthy, pathogen-free transplants is especially important for avoiding the introduction of a pathogen into a field or greenhouse environment. A transplant program that minimizes transplant shock and reduces excessive handling and maintenance is also of great benefit in maintaining healthy, disease-free plants.

Water and moisture management: To manage free water and excessive moisture in the plant canopy, it is necessary to use an efficient irrigation system, which limits the duration of leaf wetness. Staking and tying plants can also help to open up the canopy and keep moisture at a minimum. Additionally, growers should manage plant density (i.e., row spacing, limiting nitrogen) to allow for appropriate air circulation and to aid in providing effective chemical coverage when needed.

Environmental monitoring: To best manage foliar disease, it is important to understand weather conditions that impact target pathogen(s). Several disease forecasting systems for vegetables (i.e., FAST, Tom-Cast, Blite-cast) use environmental conditions to indicate critical periods for disease development. These forecasting systems use formulas, rules, tables, or algorithms patterned after the biology of specific pathogens to predict the risk of crop disease for a given period of time. In some cases, the calculations can indicate initiation of a chemical application or other action. Additionally, UF/IFAS has a database that associates climate with crop-disease risk. This databaseis available at the website, http://agroclimate.org/.

Biological Control

The use of biological controls for disease management is on the rise for organic growers. Biological materials can be safer than some synthetic chemicals for workers and the environment. Because biologicals are more stable in the soil environment than on foliage, they are primarily used to manage soilborne organisms. Biologicals are less active on foliar pathogens because the disease-management benefits that biologicals offer are less effective in the micro-environment of leaf and stem surfaces. Biological agents have been successful in controlling disease by inducing plant resistance, producing antibiotics, and out-competing pathogens. Table 1 provides examples of biorationals currently EPA-registered and approved for use in organic systems for the purpose of vegetable-disease management. All products listed in Table 1 are OMRI-approved. The successful application of biorationals hinges upon the grower having an in-depth understanding of the biology of the target plant pathogen(s). A more complete list of biorationals and up-to-date information regarding OMRI approval is available at the following website: https://attra.ncat.org/attra-pub/biorationals/.

Chemical Control

While the use of pesticides in organic agriculture is greatly restricted, some products are acceptable under the standards of the National Organic Program (NOP) and OMRI and may be effective for vegetable disease management. Before choosing a chemical substance, however, the organic vegetable producer must exhaust all proactive steps. A number of materials, including hydrogen peroxide, chlorine, and sodium hypochlorite, are available, primarily for sanitation. Few of the products available for organic disease management are active as curatives. Sulfur products can provide some disease control, especially for powdery mildew. However, sulfur can burn sensitive crops under certain conditions. Copper is commonly used in several current formulations depending on the crop and pathogen. The effectiveness of coppers varies with site, and copper usage must be closely monitored. Overapplication can lead to copper accumulation in the soil, contamination of run-off water, and subsequent toxicity to non-target organisms. Currently, there are reports of bacterial resistance to copper, but there are no reports of copper resistance in fungal pathogens. In some geographic areas, copper use has become limited and/or restricted.

In general, the groups of materials that are acceptable for organic production include bicarbonate salts, essential oils, plant and soil extracts, and compounds that induce resistance to disease and biological control organisms. These materials may provide some management, but have met with variable results. Potassium bicarbonate may reduce postharvest decay development and has been shown to manage foliar diseases in some crops. Table 1 includes examples of OMRI-approved products for disease management in vegetable production.

Summary

No single disease-control measure is adequate in limiting plant and yield losses in vegetable production. With a careful combination of disease-management approaches, including planting time, land selection and preparation, crop and variety selection, water management, and, when necessary, biological and chemical control, diseases in organic vegetable crops can be limited, and economic and environmental benefits can be achieved.

Table 1. Partial list of OMRI-approved biorationals for organic vegetable production. Certified organic growers must refer to their accredited agency prior to using any materials to ensure compliance with the NOP standards.

Product	Company	Active component
Actinovate	Novozymes BioAg, Inc.	*Streptomyces lydicus*
Ben-Sul 85	Wilbur-Ellis, Corp.	Sulfur
Bi-Carb Old Fashioned Fungicide	Monterey AgResources	Potassium bicarbonate
BlightBan A506	NuFarm Americas, Inc.	*Pseudomonas fluorescens*
Contans WG	SipcamAdvan	*Coniothyrium minitans*
Cosavet DF	Sulfur Mills Limited	Sulfur
EcoTrol EC	EcoSMART Tech., Inc.	Rosemary oil
Kaligreen	Toagosei Co., Ltd.	Potassium bicarbonate
Kumulus	Arysta LifeScience North America	Sulfur
MicroSulf	Nufarm Americas, Inc.	Sulfur
MilStop	BioWorks, Ltd.	Potassium bicarbonate
MycoStop	Verdera Oy	*Streptomyces griseoviridis*
Nordox 75 WG	Monterey AgResources	Copper oxide
PlantShield	BioWorks, Ltd.	*Trichoderma harzianum*
RootShield	BioWorks, Ltd.	*Trichoderma harzianum*
Serenade Opti and Serenade ASO	Bayer CropScience	QST713
SoilGard 12G	Certis USA, LLC	*Trichoderma virens*
Sonata	Bayer CropScience	*Bacillus pumilis* strain QST 2808
Special Electric	Wilbur-Ellis Co.	Sulfur
Sporan EC	EcoSmart Tech. Co.	Rosemary oil
Storox	BioSafe Systems	Hydrogen peroxide
Surround WP	Tessenderlo Kerley, Inc.	Kaolin
T-22 HC	BioWorks, Ltd.	*Trichoderma harzianum*
ThioLux	Loveland Products, Inc.	Sulfur
Trilogy	Certis USA LLC	Azadirachtin

Table 2. Disease resistance in modern commercial varieties.

Cole	**Broccoli:** Some resistance to head rot and downy mildew **Cabbage:** Some resistance to *Fusarium* yellows and black rot **Brussels sprouts:** Some resistance to *Fusarium* yellows
Cucurbits	**Cucumber:** Most have resistance or tolerance to angular leaf spot, anthracnose, downy and powdery mildew, virus, and scab **Cantaloupe:** Some tolerance to downy and powdery mildew; fruit is resistant to rots **Winter squash & pumpkin:** Limited tolerance to several diseases **Summer squash:** Limited resistance including virus resistance **Watermelon:** Some resistance to anthracnose race 1, *Fusarium* wilt
Eggplant	Some resistance to tomato mosaic virus, cucumber mosaic virus, and *Verticillium* wilt
Legumes	Many bean varieties are tolerant to some virus
Leafy Greens	**Lettuce:** Some resistance to downy mildew, virus, and corky root **Endive:** Some resistance to basal rot **Escarole:** Limited disease resistance
Minor Crops	**Beets**: Limited resistance to virus and downy mildew **Carrot**: Many varieties with resistance to one or more of the following diseases: Alternaria leaf blight, Alternaria, anthracnose, Cercospora, cavity spot, powdery mildew, and Pythium **Celery**: Some resistance to virus, late blight, bacteria, and *Fusarium* **Parsley:** Most varieties express broad disease resistance **Radish:** Limited virus, bacteria, and clubroot resistance
Okra	Limited resistance to yellow vein mosaic virus
Onion Family	**Onion:** Many varieties tolerant to pink root, limited resistance to pink root and Fusarium wilt **Leek:** Some resistance to rust, virus, and leaf spot
Pepper	Many varieties tolerant to bacterial spot, potato virus Y, tobacco etch virus, cucumber mosaic virus, pepper mottle virus, stip, tobacco mosaic virus, tobamovirus P_o
Potato	Many varieties tolerant or resistant to scab, *Veticillium* wilt, pinkeye, golden nematode, virus X, early blight, late blight, wart, southern bacterial wilt, mild mosaic, blackspot, silver scurf, and tuber net necrosis. Few varieties resistant to tobacco rattle virus.
Spinach	Some varieties tolerant or resistant to downy mildew and white rust
Sweet Corn	Many varieties resistant to smut, rust, northern corn leaf blight, common rust, Stewarts wilt, and maize dwarf mosaic virus
Sweet Potato	Some resistance to southern root-knot nematode
Tomato	Many varieties tolerant or resistant to *Fusarium* and *Verticillium* wilt, gray leaf spot, bacterial soft rot, tomato spotted wilt virus, root-knot nematode, Alternaria stem canker, tomato yellow leaf curl virus, bacterial speck, and early blight

Table 3. Management practices for disease control in organic vegetables.

Avoid field operations when leaves are wet.
Encourage air movement.
Use reflective mulch.
Avoid overhead irrigation.
Employ soil organic amendments.
Reduce mechanical injury.
Change planting date from spring to fall.
Apply insecticidal or horticultural oils.
Rogue diseased plants/fruit.
Change planting date within a season.
Control soil pH.
Use row covers.
Cover cropping with an antagonist.
Plant in well drained soil.
Use soil solarization.
Rotate with non-host crop (2-3 years).
Plant on raised beds.
Use pathogen-free planting material.
Deep plowing.
Use plastic mulch bed covers.
Use disease-resistant varieties.
Immediately destroy crop residue.
Employ postharvest temperature control.
Destroy volunteer plants.