Disease Control

General Principles

For a vegetable plant to become diseased, several conditions must be present: a susceptible host plant, a pathogenic organism, a method of distributing the organism and the proper environment for the organism to exist, enter the plant and thrive. When all these conditions are met at the same time, infection can occur, and a disease agent can become established.

The choice of disease-control measures must be based on accurate knowledge of the pathogen, its life cycle and the time of infection, as well as the part of the plant involved, the method of agent distribution and certain economic considerations. Effective control methods include:

- **Resistance:** Many vegetable varieties are resistant to certain diseases. Use them whenever possible.
- **Avoidance:** Avoid introducing plant pathogens into the field. Use certified, disease-free seeds and transplants. Do not transport soils or tools from diseased areas to disease-free areas. Rotate crops to disease-free fields to avoid buildup of pathogens in the field.
- **Eradication:** The removal or plow down of diseased plants from the field, if practical, can help prevent the spread of some diseases to healthy plants.
- **Sanitation:** Removal or plow down of old plant parts, weeds and trash is important to eliminate inoculum for the spread of the disease and new places for its development.
- **Pesticides:** Approved disease-control pesticides should be applied, following label directions, for specific diseases. Applications should be directed at the plant parts attacked and must be applied at the proper time.
- **Insect and weed control:** Many disease organisms persist in weed hosts or are spread by insects. Effective control of these pests also is an important part of a good disease control program.

In order to initiate timely disease-control practices, crops should be routinely inspected for developing diseases. Growers should consider using integrated pest management (IPM) systems where available.

Using the Disease Control Recommendations

Growers should use the recommendations in this bulletin by:

1. Identifying the disease problems you have or anticipate having. Many common diseases may be identified using reference materials with good quality photographs. (See Diseases and Pests of Vegetable Crops in Canada, edited by Howard, R.J., Garland, J.A. and Seaman, W.L. 1994. Entomological Society of Canada, Ottawa, Ontario, ph. 613-725-2619; also OSU Yard and Garden Fact Sheets at **http://ohioline.osu.edu/lines/vegie.html**.) If you are not sure, contact your county agent. Samples can be sent to the Plant and Pest Diagnostic Clinic in Columbus for identification.

   Collecting and mailing plant samples for diagnosis:

   a. Select material showing the symptoms in question—Send several samples in different stages of disease development. Be generous, however, do not send rotten or decayed material, or plants which are completely dead.
   b. Collect specimens fresh from the field, carefully shake off dew or excess water before packing.
   c. Vegetable samples should be wrapped individually in dry newspaper and shipped in a suitable box. Do not put in plastic bags.
   d. For mailing, use strong containers like corrugated boxes or mailing tubes that will not crush in transit.
   e. Fill empty spaces in mailing cartons with crushed or shredded paper to protect the specimen.
   f. Use overnight mail services or mail packages early in the week to avoid weekend layovers at the Post Office.

   When nematodes are suspected, both plant roots and soil require examination. Collect a mixture of roots and soil from the root zone in at least 10 locations until 1 qt of soil is obtained. Samples taken after host plants are plowed down can be misleading and should not be used. Send only one blended sample from a field. Do not mix samples from several fields. Place the sample in a plastic bag to prevent drying out. Do not let soil samples overheat by placing them in direct sunlight or heated automobile interiors; temperatures above 95°F are too high.

   Samples should be sent to:
   Plant and Pest Diagnostic Clinic
   Kottman Hall
   2021 Coffey Road
   Columbus, OH 43210

2. Checking this bulletin for control recommendations and registered fungicides effective against the disease.
3. Integrating control recommendations into current production systems. Growers should apply registered fungicides consistent with the label on the package, taking into consideration crop, disease, fungicide rate, spraying interval, method of application and safe use.

In most cases, fungicides are compatible with insecticides, but limitations and label directions should be checked carefully before mixing materials.

"Alternative" Disease Control Strategies

The following products have been introduced recently as "biological control agents" or "biopesticides." These include living microorganisms, "natural chemicals" such as plant extracts, and "plant activators" that induce resistance in plants to disease. For most of these products, independent evaluations are just underway. The following table lists products targeted to vegetable crops. Except where noted (see "Remarks"), evaluations are not complete and inclusion in this list does not imply recommendations for the products.

Product	Company	Pest Control Spectrum	Crop	Remarks
Actigard *Acibenzolar*	Syngenta	Induces resistance to bacterial diseases	Tomatoes*	Reduces bacterial spot and speck
Agriphage *Antibacterial virus (phage)*	OmniLytics	Bacterial spot and speck	Tomatoes** Peppers**	No OH data
Biosave *Pseudomonas syringae*[1]	EcoScience	Fusarium	Seed/storage potato*	No OH data
Contans *Coniothyrium minitans*[2]	Sylvan Bioproducts	Sclerotinia	Lettuce** Celery** Beans**	Under evaluation
DiTera *Myrothecium verrucaria* strain AARC-0255[2]	Valent Bioscience	Plant parasitic nematodes	Various	No OH data
eKsPunge Potassium	Lido Chemical	Powdery mildew	Tomatoes* Peppers* Cucurbits*	No OH data
Greenleaf *Elexa: extract from inula plant*	SafeScience	Downy and powdery mildew; gray mold	Cucumbers*	No OH data
Kaligreen & Armicarb *Potassium bicarbonate*	Toagosei, Church and Dwight	Powdery mildew	All crops**	Control in OH variable in field
Messenger *Harpin protein*	Eden Bioscience	Induces resistance to bacterial spots, wilts, blights and certain fungi	All crops*	Not effective in Ohio studies
Milsana *Bioprotectant; extract from knotweed*	KHH Bioscience	Induces resistance to powdery mildew, Botrytis	Cucurbits** Peppers**	Fair control of powdery mildew
Oxidate *Hydrogen Peroxide*	Bio Safe Systems	Broad spectrum anti-fungal, anti-bacterial	Range of vegetables	Inadequate control of powdery mildew of pumpkin in OH
Prestop *Gliocladium catenulatum*[2] strain J1446	Kemira Agro	Pythium, Rhizoctonia	Numerous veg crops**	Under evaluation
Pseudomonas fluorescens strain PRA-25[1]	Good Bugs, Inc.	Pythium seed rot and damping off	Pea* Snap bean* Sweet corn*	No OH data
Serenade *Bacillus subtilis*[1]	Agraquest	Broad spectrum protectant/induced resistance activity	Tomatoes* Peppers* Leafy vegs* Cucurbits*	Not effective in Ohio studies

[1] = bacterium
[2] = fungus
* = labeled for use
** = label pending

Uses of EBDC Fungicides

The U.S. Environmental Protection Agency has reestablished labeled uses for most of the EBDC (ethylene bis-dithiocarbamate) fungicides or mancozeb fungicides voluntarily withdrawn by the manufacturers prior to 1992 (see table below). However, growers should be aware of two problem areas when they use EBDC fungicides in control programs. First, labeled crop uses may have changed for products they customarily used prior to the manufacturers' voluntary restriction of uses. Most labels for the three main EBDC fungicides—mancozeb, maneb and metiram—have more restricted crop lists than previously, as indicated in the table. Growers should be careful to read the new product labels and select those having crop uses suited to their needs.

Second, growers should be aware that crops treated with EBDC fungicides in accordance with the legal, labeled uses may not be acceptable to processors and some consumers of the crops because ethylene thiourea (ETU) may be introduced. A closely related fungicide, Ziram 76 (labeled for tomatoes), is a dithiocarbamate which does *not* produce ETU. Before using any of the EBDC fungicides, growers should make certain that the market for which the crops are intended will accept EBDC-treated produce.

The EPA now allows the use of more than one EBDC fungicide on a crop during the same season, as long as the total amount of EBDC used does not exceed the *most restrictive* amount allowed for any one of the EBDC's.

Approved Uses of EBDC Fungicides

All EBDCs	Mancozeb only	Maneb only	Mancozeb & Maneb	Mancozeb & Metiram	Manex
Potatoes	Asparagus	Almonds	Bananas	Apples	Beans, dry
	Barley	Beans, dry	Cantaloupes		Broccoli
	Caprifigs[1]	Broccoli	Corn, sweet, pop		Brussels sprouts
	Corn, field[2]	Brussels sprouts	Cranberries		Cauliflower
	Cotton	Cabbage	Cucumbers		Cabbage
	Crabapple	Cauliflower	Grapes		Kohlrabi
	Fennel	Eggplant	Melons, honeydew		Chinese cabbage
	Oats	Endive	Melons, cassaba		Collards
	Peanuts	Kadota	Melons, crenshaw		Corn, sweet
	Pears	Kale	Onion, dry bulb		Cucumber
	Pineapple[3]	Kohlrabi	Papaya		Eggplant
	Potato	Lettuce, head	Squash, summer		Kale
	Quince	Lettuce, leaf	Sugar beets		Lettuce
	Rye	Onions, green	Tomatoes		Endive
	Wheat	Pepper	Watermelon		Melons
		Pumpkins			Onions
		Squash, winter			Pepper
					Potato
					Pumpkins
					Squash
					Tomatoes
					Turnip greens

[1]Caprifigs is a non-food use.
[2]Includes hybrid seed corn.
[3]Seed piece treatment only.

Fungicide Resistance Management

Many of the new fungicides introduced recently have relatively specific modes of action, and therefore fungal plant pathogens are more likely to develop resistance to them than to fungicides with a broader mode of action. A good example is the strobilurin group of fungicides, which contains Quadris and Cabrio, among others. Fungicide labels contain resistance management recommendations, which include:

1) Limiting the total number of applications per season;
2) Alternating fungicides with different modes of action;
3) Use of tank mixes of full-rates of fungicides with different modes of action; and
4) Prohibiting the use of fungicides with a narrow mode of action, such as strobilurins, in greenhouses.

It is important for growers to adhere to these management recommendations in order to extend the useful life of these products. Overuse or inappropriate use of one fungicide in a group with similar modes of action will result in resistance to all of the products in that group.

Fungicides have been categorized into groups based on their mode of action against plant pathogenic fungi. These groups are numbered and contain all fungicides with similar modes of action, whether or not they are in the same chemical class. Pathogens that develop resistance to one fungicide in a group are likely to be resistant to all fungicides in that group. Therefore, most label instructions for fungicides at risk for resistance development require alternating such fungicides with fungicides with a DIFFERENT mode of action. The Fungicide Group number is provided on the label, and shown in the table below. When deciding on which fungicides to use in alternation, choose fungicides that are 1) effective against the diseases of concern and 2) have different Fungicide Group numbers. Some products are a mixture of fungicides from two different groups, e.g. Groups 11 & 27 (Tanos); Groups 9 & 12 (Switch) and Groups 7& 11 (Pristine). Nonetheless, label instructions for these products require alternation with additional fungicides.

Fungicide Group number and risk of resistance development for some fungicides commonly used in vegetable disease management. Adapted from FRAC Fungicide List (1) (2003) (**http://www.frac.info/publications/frac_list02.html**). Not all fungicides labeled for use on vegetables are included.

Fungicide Group Number	Group Name	Product Examples	Risk of Resistance Development	Resistance Management Required
1	Methyl Benzimidazole Carbamates	Topsin M	High	Yes
2	Dicarboximides	Rovral Ronilan	Medium to High	Yes
3	De-Methylation Inhibitors	Nova Tilt	Medium	Yes
4	Phenylamides	Ridomil Gold Apron	High	Yes
7	Carboxamides	Endura	Medium	Yes*
8				
9	Anilinopyrimidines	Vangard	Medium	Yes
10				
11	Quinone Outside Inhibitors	Quadris Amistar Cabrio Sovran Flint	High	Yes
12	Phynylpyrroles	Maxim	Low to Medium	Yes
13	Quinolines	Quintec	Medium	Yes
14				
15	Cinnamic Acids	Acrobat	Low to Medium	Yes
21	Quinone Inside Inhibitors	Ranman	Medium to High	Yes
22	Benzamides	Gavel	Low to Medium	Yes

Fungicide Group Number	Group Name	Product Examples	Risk of Resistance Development	Resistance Management Required
27	Cyanoacetamide-oximes	Curzate	Low to Medium	Yes
28	Carbamates	Previcur	Low to Medium	Yes
29	Dinitroanilines	Omega	Low	
33	Phosphonates	Aliette	Low	
P	Host Plant Defense Inducers	Actigard	Resistance not known	
M (Multi-site contact activity)	Inorganics	Copper salts Sulfur		
	Dithiocarbamates	Mancozeb Penncozeb Dithane Maneb Manex Manzate	Low	
	Phthalimides	Captan		
	Chloronitriles	Bravo Daconil		

* For high-risk pathogens such as powdery mildews.

Soil Treatments

Control of below-ground diseases is more difficult than for diseases on leaves. Soil-borne diseases require special control measures.

Potato scab

Potato scab is difficult to eliminate. Fungicides are not effective. If available, use new land not previously cropped to potatoes; otherwise, rotate crops, use tolerant cultivars and keep soil pH low (5.2).

Caution: Low pH may interfere with some crops grown in the rotation. Irrigation at tuber-setting time if soil is dry may help to avoid excessive scab development. Do not apply manure to potato fields— it can make scab much worse.

Fusarium diseases (wilts, yellows)

Losses may be severe on tomato, celery, radish, cabbage or melons. Fusarium-tolerant varieties are the primary means of control. Check with seed suppliers for availability. Crop rotation with a susceptible crop only once in 3 years is an aid in reducing infections. It also aids in control of fruit rots caused by Fusarium.

Verticillium wilt

This disease causes its greatest loss on eggplant and potato in Ohio, but it also attacks pepper, tomato and many other vegetable crops. It is best controlled by treating the soil with fumigants if economically feasible. Crop rotation with clover and grass or grass-type crops such as corn or grains helps reduce the potential inoculum of this disease in the soil. Verticillium-tolerant cultivars are available in some cases.

Clubroot of crucifers

This disease is restricted to crucifer crops and is very difficult to control. Adjusting soil pH to 7.2 each year with hydrated lime and a long rotation with noncrucifers is helpful.

Terrachlor 75% WP in transplant water or as banded or broadcast applications may be helpful. See the product label for instructions.

Tolerant cultivars are available in a few cases.

Nematodes

Chemical control is often necessary. Soil-borne nematodes are typically controlled with soil fumigants such as Telone II, Telone C, or Vapam. Organic soils generally require higher chemical rates than mineral soils. Check chemical labels for these restrictions. Special conditions required for successful application of soil fumigants are discussed in the following "Soil Fumigation" section.

Contact/systemic nematicides such as Nemacur, Furadan and Temik are available for control of nematodes on a limited range of crops. These materials are usually applied preplant as granulars that are incorporated into the soil.

Many of these nematicides are injurious to plants in high concentrations. It may be necessary to delay planting 10-20 days or longer (depending on the chemical used and the soil type, moisture and temperature) after treatment of the soil.

When to treat: The ideal time to treat for nematodes is when the soil temperature at a 6-inch depth is between 60-80°F and soil moisture is adequate. Fall months are generally ideal. (See "Soil Fumigation" below for additional information.)

Note: Most of the mentioned soil treatments are comparatively expensive. Growers should check cost-profit possibilities before using any treatment.

Soil Fumigation

Successful Soil Fumigation in the Field

The goals of successful soil fumigation should be: (1) safe and accurate application, (2) effective control of the target pests and (3) rapid dissipation of the chemical from the soil after fumigation to allow safe and timely planting.

To ensure that these goals are fulfilled, the following influences on successful soil fumigation should be considered.

Soil Temperature

Most fumigants work best when temperatures are 60-80°F at 6 inches depth. When soil temperatures are lower, chemicals volatilize more slowly, and concentrations of fumigant high enough to control pests may not be reached. Also, at lower temperatures, phytotoxic concentrations of fumigant can be retained in the soil for long periods, thus delaying planting. If temperatures are above 80°F, the gas may leave the soil too rapidly to give effective control.

Soil Moisture

Too much water in the soil slows gas movement and results in a poor job of disinfestation. Under dry conditions, organisms can be in a resistant stage and may not be affected by the gas. Soil is at proper moisture levels when a handful of soil squeezed into a ball breaks apart with light finger-pressure. If the soil will not form a ball, it is too dry. If it will not break apart easily, it is too wet.

Soil Structure

Soil should be in good tilth. Large clods allow the gas to leave the soil too quickly for effective disinfestation. Disease-causing organisms inside clods are especially difficult to control because they are protected from the fumigant. At the time of fumigation, soil should be worked to good seedbed condition to the desired depth of treatment—usually, plow depth.

Organic Matter

All plant material should be well decomposed. Undecomposed plant material is not easily penetrated by fumigants, and pathogenic organisms within such materials will not be controlled. Undecomposed crop residue can form chimneys through which fumigants quickly escape to the soil surface. It also can prevent passage of injection chisels through the soil.

Fumigation Seals

Fumigants should be sealed into the soil to ensure that lethal concentrations and exposure times are reached. The type of seal used varies with the volatility of the fumigant.

High-volatility fumigants must be sealed with a gasproof cover, usually a plastic tarp sealed at the sides and ends with soil.

Lower-volatility chemicals can be sealed with water or by packing the soil with rollers or drags. Water seals generally are accomplished by a light watering sufficient to wet the top 1/4 inch of soil.

Soil Texture

Soil texture influences the amount of fumigant used. Because of adsorption of the chemical to organic matter, muck soils generally require twice the amount of fumigant that would be used on a mineral soil. Heavy soils require more fumigant than light soils. Follow label instructions regarding dosage and soil texture.

Time of Application

Fumigants are applied best in late summer or early fall. At this time, soil temperature and moisture generally are favorable for fumigation. Fall application after crop removal allows the chemical to dissipate over the winter, and spring planting can take place at the normal time. Spring fumigation often is delayed by cool, wet soils. As a result, planting can be seriously delayed after the required post-fumigation waiting period.

Wait Before Planting

Most fumigants are extremely harmful to living plants. A period of 2 weeks to 2 months must intervene between treatment and planting to avoid crop damage. The length of the waiting period depends on the fumigant used, the amount applied, soil texture, temperature, moisture and the organic matter content of the soil.

A general guide for medium-volatility fumigants is a waiting period of 1 week for every 10 gal/A of chemical applied. To ensure that all fumigant escapes from treated soil, soil should be deeply disked at least 1 week before planting.

Fumigants containing bromine leave residues in soil that can seriously damage bromine-sensitive crops, sometimes for several years following application. Cases are known where onions or carnations have grown poorly following bromine fumigation of organic soils. Future rotation of crops in a field should be considered when choosing a fumigant for application. If planting a bromine-sensitive crop, a fumigant without bromine should be considered.

Special Problems

Fumigants reduce populations of nonpathogenic as well as pathogenic organisms. This can create special problems for growers.

By temporarily reducing populations of nitrifying bacteria, fumigants can increase ammonium to levels that can damage early planted crops such as celery and lettuce. This problem is most common on high-organic soils. On these soils, late fall and early spring fumigation should be avoided so that bacterial populations recover before planting. Ammonium-type nitrogen should not be applied at planting under these conditions.

Soil fumigants reduce levels of nonpathogenic microbes that normally compete with pathogens. If soil is re-contaminated with pathogenic fungi soon after fumigation, these pathogens can grow through the soil rapidly and cause serious disease problems. All precautions to reduce re-contamination of treated soil should be taken. Use clean seed and planting stock, and be sure equipment is free of soil from untreated areas before entering a fumigated area.

Mycorrhizal fungi, required to transport minerals to the roots of many crop plants, also are killed by soil fumigation.

Although soil eventually is recolonized by these beneficial fungi, severe problems have arisen when seeds or cuttings of woody plants produced in sterile conditions have been planted in fumigated soil.