DISEASE MANAGEMENT

Resistance Management

Pathogens may develop resistance to fungicides because of genetic mutations in the organism, through natural selection, or by the intensive use of high-risk fungicides which kill only the susceptible individuals within a given population. Thereby leaving only the resistant populations to reproduce and cause more disease. Use the practices outlined below to help reduce the chances for fungicide resistance development.

a. Long and proper crop rotations with a non-host crops will help break disease cycles and thus, decrease the need or overuse specific fungicide. This is especially important for controlling soil-borne pathogens.

b. Do not overspray. Attempts to kill every pest in the field by multiple applications or by using higher than labeled rates often eliminate the susceptible, but not the resistant pathogen population. Do not use less than labeled rates which allow low to moderately resistant populations to survive.

c. Always rotate fungicides with different modes-of-action (i.e., Fungicide Resistance Action Code (FRAC groups).

d. Fungicides are organized according to FRAC groups, based on chemical structure and Mode of Action (MoA). Fungicides within a given FRAC group control fungi in a similar manner and share the same risk for fungicide resistance development. Some fungicides are referred to as high- or at-risk fungicides because of their specific MoA's and therefore have a high-risk for resistance development. See Table E-12 for specific fungicides and fungicide FRAC groups. Groups of fungicides, such as the QoI's (FRAC group 11) or DMI's (FRAC group 3) are prone to resistance development due to very specific MoA's. Fungicides in high- or at-risk groups (in **BOLD** in Table E-12) should be rotated and/or tank-mixed with broad spectrum, protectant fungicides to delay or reduce the development of resistant strains of fungi. High-or at-risk fungicides have seasonal application restrictions which should be followed precisely.

e. Do not use high or at-risk fungicides as a rescue treatment for disease control. High-risk fungicides should be used according to the label in full season disease control program or not at all. Applying high- or at-risk fungicides only after a disease is present in a field increases the chances for the development of resistant populations of plant pathogenic fungi. If you feel control with a high-risk fungicide is no longer effective, stop using it and switch to other modes-of-action (i.e., fungicides in other FRAC groups)

List of FRAC groups and corresponding chemical groups for commonly-used fungicides in vegetable production:

P1-Salicylic Acid Pathway
M1-inorganic copper
M2-inorganic sulfur
M3-dithiocarbamate
M4-phthalimide
M5-chloronitrile
1-benzimidazole
2-dicarboximide
3-triazole
4-phenylamide
7-carboxamide
9-pyridinamine
11-quinone inside inhibitor (QoI)
12-phenylpyrroles
13-quinolines
14-aromatic hydrocarbons
17-hydroxylanilide
21-quinone outside inhibitor (QiI)
22-benzamides (toluamides)
27-cyanoacetamideoximes
28-carbamates
29-dinitroanilines
30-organotin compounds
33-phosphonates
40-carboxylic acid amides
43-benzamides (acylpicolides)
45-triazolo-pyrimidylamine

Seed Treatment

Seed treatment is essential to control seed-borne diseases in many transplanted crops. Failure to treat seed properly could lead to diseases in the plant bed that will reduce plant stands or that are carried into the field at transplanting. Crop failure could result. Seed treatment is especially important for asparagus, broccoli, brussels sprouts, cabbage, cauliflower, collards, eggplant, kale, kohlrabi, pepper, radish and tomato. In the case of peppers and tomatoes, a chlorine seed treatment or hot water seed treatment is essential for prevention of bacterial diseases (bacterial canker, bacterial leaf spot and bacterial speck).

Heat treatment of seeds is a non-chemical alternative to conventional chlorine treatments for the elimination of seed-borne pathogens. Heat treatment has the additional benefit of killing pathogens such as the bacterial canker organism of tomatoes that may be found within the seed coat. Heat treatment is particularly useful for tomatoes, peppers, and cole crops that are prone to seed-borne bacterial infections. Seed heat-treatment follows a strict time and temperature protocol, and is best done with thermostatically controlled dose water baths. Two baths are required; one for pre-heating, and a second for the effective pathogen killing temperature. The initial pre-heat cycle is for 10 minutes at 100ºF (38ºC) followed by the effective temperature cycle. The following (Table E-11) are effective temperature protocols for several important crop groups: See crop sections for specific seed treatment recommendations.

Table E-11. Effective Seed Treatment Temperature Protocols (2nd Bath) For Pathogen Eradication

Seed	Water temperature		Minutes
	°F	°C	
Brussels sprouts, eggplant, spinach, cabbage, tomato	122	50	25
Broccoli, cauliflower, carrot, collard, kale, kohlrabi, rutabaga, turnip	122	50	20
Mustard, cress, radish	122	50	15
Pepper	125	51	30
Lettuce, celery, celeriac	118	48	30

Immediately after removal from the second bath, seeds should be rinsed with cool water to stop the heating process. Afterward, seeds should be dried on screen or paper, and may be re-dusted with fungicide if desired. Pelleted seed is not recommended for heat treatment. Heat treat only seed that will be used during the current season.

Plant Growing Mix

For the best control of all soil-borne diseases, use the plant-growing mix described in Table R-4 or R-5. If this is not possible, use one of the following procedures.

Disease Control in Plant Beds

Preplant

The only practice that ensures complete sterilization of soil is the use of steam. When steam is used, a temperature of 180°F (82.2°C) must be maintained throughout the entire mass of soil for a period of 30 minutes.

Soil fumigation is a method used to provide disease control in plant beds. The following materials are suitable for small lots of soil:

chloropicrin--5 cc/cu ft
metam-sodium (Vapam HL)--1 qt in 5 gal of water per 1/2 cu yd of soil

For larger areas, such as plantbeds or seedbeds, the following materials are suitable:

chloropicrin--50 gal/A (3 cc/injection)
metam-sodium (Busan, Nemasol, Vapam HL)—
drench--1 qt/100 sq ft
injection--1 pt/100 sq ft

Potassium N-methyldithiocarbamate (K-Pam HL)--see label, rate varies with method of application

See the "Soil Fumigation" section for proper application techniques.

New restrictions on the use of soil fumigants is pending with the EPA, and their use in some areas of the mid-Atlantic region will become severely limited. Check with local county agricultural agent for updates on pending restrictions

Pre-and Postseeding treatments in transplant and greenhouse production

See specific crop section and Table E -14 for a list of seed treatment options and Table E-15 for a list of selected fungicides for use in greenhouse production.

Nematodes

Some 100 species of plant-feeding nematodes can seriously damage various crops. Before starting any nematode management procedure, one should determine what nematodes are present in the soil to determine if action is warranted.

How to Collect Soil and Root Samples for Nematode Detection

When nematode damage is suspected, both soils and roots should be examined to find out if and to what extent nematodes may be involved. The following procedure is suggested to ensure that samples are collected and handled properly so that the diagnosis made on that sample at a *Nematode Diagnostic Laboratory* is accurate.

Collecting and Handling. Only a single composited sample should be collected in each field. If the field is larger than 2 acres, divide the field into 2 acre blocks and collect a composite sample from each and label each bag accordingly. This will provide a more accurate assessment of the nematode population and enable more targeted management of nematode populations. Do not combine samples from several fields. Collect soil and roots from the edges of the affected area(s) in the field. Take a mixture of roots and soil from at least 10 scattered sites, or preferably, under 10 scattered plants in the affected area. Do not take samples from areas where plants are dead. One can dig plants with a shovel and take a small handful of soil and roots from each, or one can use a soil sampling tube (3/4-inch diameter). Combine the individual samples in a bucket to make a composite sample of at least one quart of soil. Mix the soil in the bucket, then place one pint of the mixed soil in a plastic freezer bag and seal it to prevent drying of the soil. Protect bagged samples from high temperatures and freezing which can kill the nematodes.

Take soil samples while the crop is still growing so that areas that are suspected of being stunted by nematodes can be seen and sampled, because these areas may be missed in random sampling. In general, samples can be taken from June through November. However, to plan your cropping sequence, it is best to take these survey samples after harvest in the fall before any fall tillage and before cold weather arrives. The reason for this recommendation is that nematode populations are generally the highest in the fall, and the chance of detecting damaging levels of plant pathogenic nematodes by soil sampling is also high. This timing is especially important for growers who need to monitor root knot nematode populations. The worst time to sample to detect root knot nematodes is in late spring just before planting.

Survey samples should be taken at a depth of 8 to 10 inches, and several inches from the base of the plants, between plants in the row. Do not take samples if the soil is wet. The moisture level should be less than field capacity and there should not be any free water in the plastic bag after adding the sample. Use a soil sampling tube and take 20 to 25 cores per sample in a random pattern in the field. Mix soil cores in a plastic bucket and immediately place a pint of soil in a plastic bag or a nematode soil sample kit purchased from a nematode testing laboratory.

Submitting Samples for Nematode Analysis. Samples should be sent to a *Nematode Diagnostic Laboratory* as soon as possible after they are collected. However, if there is any delay, the samples should be refrigerated until shipment. Provide some insulation such as several layers of newspaper, a padded envelope or styrofoam peanuts, around the sample during shipment.

The following information must be included with each sample:

1. Name and address of the grower and of the person submitting the sample
2. Date collected
3. Name of the present crop, the crop to be planted, and history of the affected area
4. Plant and field symptoms
   (Check with the laboratory to see if any additional information is required).

Attach the paper with this information to the **OUTSIDE** of the bag of soil. Do **NOT** place the information in the bag with soil. Mark the samples: "For Nematode Analysis." Forward the samples and the information to your Extension agent, or directly to the diagnostic laboratory. There is usually a fee for nematode analysis.

Nematode Management Strategies

Plant-parasitic nematodes are difficult to control after they have become established. The best strategy is to use preventive measures, including nematicides, soil fumigants, and / or cultural practices.

Chemical Management of Nematodes

Fumigants. Soil fumigation can effectively controls plant-feeding nematodes. See the "Soil Fumigation" section for specific fumigants, rates, and application techniques.

Nonfumigant nematicides. Several nonfumigant nematicides are currently available for selected vegetable commodities. These nematicides are listed in the sections dealing with the vegetables on which they are labeled. Some nonfumigant nematicides are not labeled in all states within the mid-Atlantic region, so consult the label carefully before applying a chemical.

These nematicides do not volatilize in the soil as do fumigants. Consequently, these chemicals are effective over a wider range of soil temperature and moisture than are fumigants.

Chemicals which are registered for use on selected vegetables include Counter (20CR), Mocap (10G and 6EC), Nimitz (4EC) and Vydate L. The first three are contact nematicides, and the last one acts as both contact and systemic nematicide. Consult the label before applying any of these chemicals.

Factors Affecting the Efficacy of Nematicides. As with any pesticide, the two factors that determine efficacy are concentration and exposure time. If toxic concentrations of a nematicide do not come in contact with the nematode for a sufficient period of time, then acceptable levels of control will not occur. Many factors can dilute the concentration of nematicide available in the soil and/or effectively shorten the time that nematodes are exposed.

Good site preparation is extremely important. The soil should be thoroughly tilled several weeks before application to break up clods and encourage decomposition of plant residues. Nematicides can adsorb to organic matter and thus reduce the amount of compound free in the soil. Soil clods can interfere with nematicide distribution and reduce efficacy.

Fumigant nematicides such as Telone or Vapam volatilize and move through the soil as a gas. The movement of a fumigant through the soil is strongly affected by factors such as temperature, moisture, and soil texture. Fumigants tend to move upwards through the soil and will dissipate quickly unless the surface is sealed after treatment. Follow the label to ensure that you are applying the correct dose for your conditions.

Most nonfumigant nematicides such as Vydate are organophosphate or carbamate pesticides, which are potent cholinesterase inhibitors. Nimitz is in a different class of chemistry than those mentioned above and kills nematodes via an unknown mode of action. All of these these compounds are extremely water-soluble, and their redistribution in the soil depends on water movement. Excessive rain or irrigation creates a risk of diluting the nematicide below the level needed to be effective. However, too little water may prevent the nematicide from being distributed effectively in the root zone. Nimitz has an additional concern of being phytotoxic to plants under cold stress. These plants basically grow much slower than those not treated with Nimitz. Nimitz applied to crops exposed to warmer periods of the growing season experience little phytotoxicity.

Organophosphate and carbamate nematicides act relatively slowly. Although high concentrations are lethal, the lower concentrations in soil generally kill by behavior modification. The affected nematodes typically are unable to move, find a host, feed, or find a mate. Eventually they die. If exposure to the nematicide is too short or at a low concentration, however, these behavioral modifications can be reversed and the treatment is not effective. Nimitz kills nematodes within the recommended dose range.

Nonchemical Management of Nematodes

Prevention of spread. Plant-feeding nematodes move only short distances under their own power, a few inches to a few feet. Nematodes are commonly spread by the movement of infested soil and/or infected plants by human activity. Sanitation and good cultural practices are the best preventive measures against nematodes. Obtain nematode-free transplants from reputable sources. Wash soil from machinery and tools before using them at another location. Nematodes may also be spread by wind, water, soil erosion, and animals.

Crop rotation. Rotation of crops is an effective and widely used cultural practice to reduce nematode populations in the soil. To be most effective, crops that are poor hosts or nonhosts of the target nematodes should be included in the rotation sequence.

Cover crops. Some plants commonly used as cover crops are naturally suppressive to certain nematode species, but no single crop is effective against all nematodes. The cover crop plant may be a nonhost and, therefore, the nematodes starve, their population being reduced as with fallow. Nematodes invade the roots of certain other cover crop plants, but they fail to reproduce. Yet, other "antagonistic" plant species exude chemicals from their roots that are toxic to nematodes, such as marigold and asparagus.

Green manures and soil amendments. In general, the incorporation of large amounts of organic matter into the soil reduces populations of plant-feeding nematodes. The decomposition products of some plants kill nematodes. These include butyric acid released during the decomposition of ryegrass and timothy, and isothiocyanates released during the decomposition of rapeseed and other plants in the genus *Brassica*. Maximum benefit of these "natural" nematicides is obtained when the plant material is incorporated into the soil as green manure. Green manure treatments are not equally effective against all plant- parasitic nematodes and therefore it is important to consult with a diagnostic lab or extension agent to make sure the treatment is appropriate for the nematode being controlled. For example, rapeseed is effective against dagger nematodes but not lesion nematodes. Also keep in mind that varieties of the same green manure crop can differ in the amount of toxic chemical components in their cell walls and therefore differ in the amount toxic byproducts released during decomposition.

For dagger nematode control, two years of rapeseed green manure is desirable, but it may be possible to realize the same benefit by growing two crops of rapeseed within one year. The following timetable is suggested for producing two rotations of rapeseed within one year:

- Prepare seedbed and plant rapeseed by late April or early May. (Plant only recommended winter rapeseed varieties.)
- Turn under green rapeseed by early September. Prepare seedbed and plant second crop by mid-September.
- The second crop should be turned under in late spring after soil temperatures reach 45°F or higher.
- Ideal conditions for incorporating the cover crop are similar to those required for obtaining the maximum benefit from fumigation (i.e., the soil should be above 45°F and moist).
- Alternatively, planting dates may be reversed so that the first planting is in the fall followed by a second crop planted in the spring. This would end the rotation cycle in fall of the following year.

Some rapeseed varieties are more effective at suppressing nematode populations than others, and some varieties will not over-winter (i.e. spring types) or they bloom too early in summer to be useful. The winter varieties 'Dwarf Essex' and 'Humus' work well for both spring and fall planting dates. If planted in the spring, these varieties grow vigorously to crowd out weeds and do not go to seed.

Tips:

- Rapeseed requires a firm, smooth seedbed that is free of weeds, heavy residue, and large clods.
- Seed may be drilled or broadcast. Seed at a depth of 3/8 inch and avoid planting too deep! If seed is broadcast, a cultipacker may be used to cover seed.
- A seeding rate of 7–8 pounds per acre works well.
- Rapeseed is sensitive to broadleaf herbicide carryover.
- Fall-planted rapeseed should have 8–10 true leaves and a 5- to 6-inch tap root with a 3/8-inch diameter root neck before the ground freezes.
- Sulfur is necessary for rapeseed to produce nematicidal compounds. Some soils may be deficient in sulfur. A soil test for sulfur may be beneficial.

Keep in mind that some biofumigant crops like rapeseed and sorghum-sudangrass are hosts for nematodes and it is not until incorporated into the soil as green manure that they will suppress nematode populations.

Plant nutrition and general care of the plant. The harmful effects of nematodes on plants can be reduced by providing plants with adequate nutrition, moisture, and protection from stress. These tactics may sometimes be of limited usefulness, because if susceptible crops are grown continuously, the nematode population may increase to levels that cause serious damage.

Fallow. Fallow is the practice of keeping land free of vegetation for weeks or months by frequent tilling or applying herbicides. In the absence of a host, nematodes gradually die out; however, eggs of some nematodes may survive for years in the soil. Because fallow may be destructive to soil and the land is out of production during that time, extended periods of fallow are not recommended.

Integrated management practices. Each of the practices mentioned above reduces the soil population of plant-feeding nematodes to varying degrees. Each practice has limitations and the degree of nematode control achieved depends on environmental factors, as well as the particular nematode and crop being considered.

Maximum benefit is realized when several of these practices are employed in an integrated crop management program. Because the host range of different nematode varies, the selection of cover crops, rotation crops, and green manures will be determined by the kinds of nematodes present. No single practice is a "cure-all" for all nematode problems.

Table E-12. Commonly Used Fungicides Registered for Vegetables
(The inclusion of a material in this table does not mean it is recommended, check specific crop recommendations to ensure efficacy on selected pests. The table is not all inclusive but focuses on commonly applied fungicides, see crop sections for more recommendations.)

	Actigard (acibenzolar-S-methyl)	**Aliette** (fosetyl A1)	**Aproach** (picoxystrobin)	**Aprova Top** (difenconazole + benzovindiflupyr)	**azoxystrobin**	**Botran** (dichloran)	**Cabrio** (pyraclostrobin)	**Cabrio Plus** (pyraclostrobin + metiram)	**Cannonball** (fludioxonil)	**Chlorothalonil**[a]	**Curzate** (cymoxanil)	**Elatus** (azoxystrobin + benzovindiflupyr)	**Endura** (boscalid)	**Fixed copper**[a]	**Fontelis** (penthiopyrad)	**Forum** (dimethomorph)
FRAC Group(s)*	**21**	**33**	**11**	**3+ 7**	**11**	**14**	**11**	**11+ M3**	**12**	**M5**	**27**	**11+ 7**	**7**	**M1**	**7**	**40**
Crop																
Asparagus		X110			X100					X190						
Beans, snap			X14	X14	X	X2			X7	X7			X7	X	X	
Beans, lima			X14	X14	X				X7	X14			X7	X	X	X7
Beets					X		X							X	X	
Broccoli	X7	X3			X		X			X7			X	X	X	X7
Carrots					X		X			X			X	X	X	
Celery		X3			X	X7	X		X	X7			X	X	X3	X7
Chinese cabbage	X7	X3			X		X			X7			X	X	X	X7
Cole crops	X7	X3			X		X			X7			X14	X	X	X7
Cucumbers	X	X		X	X1	XGH	X			X	X3		X	X	X1	X5
Eggplants				X	X		X			X3			X	X	X	X5
Garlic	X7				X		X7		X7	X7			X7	X	X3	X5
Greens, mustard	X7	X3			X		X						X14	X	X	X7
Greens, turnip	X7				X									X	X	X7
Horseradish					X		X			X14			X		X	
Leeks					X	X14	X7		X7	X14			X7	X	X3	X5
Lettuce	X7	X3			X	X14	X		X		X3		X14	X	X3	X7
Muskmelons	X	X		X	X1		X		X14	X	X3		X	X	X1	X5
Okra				X	X					X3				X	X	
Onions, dry	X7	X7			X	X14	X7		X7	X14			X7	X	X3	X5
Onions, green		X7			X	X14	X7		X7	X14			X7	X	X3	X5
Parsley		X			X		X		X				X14	X	X3	X7
Parsnips					X		X			X10						
Peas				X14	X								X21	X	X	
Peppers	X14			X	X		X			X3			X	X	X	X5
Potatoes					X14			X14		X7	X14	X14	X10	X		X5
Pumpkins/ winter squash	X	X		X	X1		X			X	X3		X	X	X1	X5
Radish					X		X								X	
Spinach	X7	X3			X		X		X		X1			X	X3	X7
Squash, summer	X	X		X	X1		X			X	X3		X	X	X1	X5
Strawberries	X	X			X		X							X	X	
Sweet corn			X7		X7					X14		X7		X		
Sweet potatoes				X14	X	X[b]							X10			
Tomatoes	X14	X14		X	X	XGH	X			X	X3		X	X	X	X5
Watermelon	X	X		X	X1		X		X14	X	X3		X	X	X1	X5

table continued next page

Table E-12. Commonly Used Fungicides Registered for Vegetables *(continued)*

	Gavel (zoxamide+mancozeb)	**Gem** (trifloxystrobin)	**Headline** (pyraclostrobin)	**Headline AMP** (pyraclostrobin+metconazole)	**Inspire Super** (difenoconazole + cyprodonil)	**iprodione**	**Luna Experience** (fluopyram + tebuconazole)	**Luna Priviledge** (fluopyram)	**Luna Sensation** (fluopyram + t rifloxystrobin)	**mancozeb**	**Merivon** (fluxapyroxad + pyraclostrobin)	**metalaxyl**	**Moncut** (flutolanil)	**Omega** (fluazinam)	**phosphonates**[a]	**Presidio** (fluopicolide)	**Previcur Flex** (propamocarb)
FRAC Group(s)*	**22+** M3	**11**	**11**	**11+ 3**	**3+ 9**	**2**	**7+ 3**	**7**	**7+ 11**	M3	**7+ 11**	**4**	**7**	**29**	**33**	**43**	**28**
Crop																	
Asparagus										X180		X					
Beans, snap			X7			X[e]						X		X14	X		
Beans, lima			X7			X[e]		X14				X		X30	X		
Beets		X7									X7	X				X7	
Broccoli					X7	X						X	X	X50	X	X2	
Carrots		X7				X					X7	X		X7		X7	
Celery		X7									X1	X			X	X2	
Chinese cabbage					X7							X		X20	X	X2	
Cole crops					X7							X	X	X20	X	X2	
Cucumbers	X5				X7					X5	X	X			X	X2	X2
Eggplants		X3			X							X		X30	X	X2	
Garlic	X7				X7	X				X7	X7	X		X7	X		
Greens, mustard					X7								X	X20	X	X2	
Greens, turnip					X7								X	X20	X		
Horseradish		X7									X7	X				X7	
Leeks					X7						X7	X			X		
Lettuce						X14					X1	X		X30	X	X2	X2
Muskmelons	X5				X7					X5	X	X		X30	X	X2	X2
Okra														X30			
Onions, dry	X7				X7	X7				X7	X7	X		X7	X		
Onions, green	X7				X14						X7	X			X		
Parsley											X1	X			X	X2	
Parsnips		X7									X7	X				X7	
Peas			X7									X			X		
Peppers		X3			X							X		X30	X	X2	X5
Potatoes	X14[d]	X7	X3			X14		X7		X14[d]		X	X	X14	X		X14
Pumpkins/ winter squash	X5				X7						X	X			X	X2	X2
Radish											X7	X				X7	
Spinach											X1	X			X	X2	
Squash, summer	X5				X7					X5	X	X			X	X2	X2
Strawberries						X[e]		X1			X						
Sweet corn			X7	X7						X7							
Sweet potatoes			X3									X				X7	
Tomatoes	X5	X3			X					X5		X			X	X2	X5
Watermelon	X5				X7		X7	X	X	X5	X	X		X30	X	X2	X2

Table E-12. Commonly Used Fungicides Registered for Vegetables ***(continued)***

	Priaxor (fluxapyroxad + pyraclostrobin)	**Pristine** (pyraclostrobin + boscalid)	**Procure** (triflumizole)	**Proline** (prothioconazole)	**propiconazole**	**Quadris Opti,** (azoxystrobin + chlorothalonil)	**Quadris Top** (difenconazole + azoxystrobin)	**Quash** (metconazole)	**Quilt** (propiconazole + azoxystrobin)	**Quilt Xcel** (propiconazole + azoxystrobin)	**Quintec** (quinoxyfen)	**Rally** (myclobutanil)	**Ranman** (cyazofamid)	**Reason** (fenamidone)	**Revus** (mandipropamid)	**Revus Top** (mandipropamid + difenoconazole)
FRAC Group(s)*	**7+ 11**	**11+ 7**	**3**	**3**	**3**	**11+** M5	**3+ 11**	**3**	**3+ 11**	**3+ 11**	**13**	**3**	**21**	**11**	**40**	**3+ 40**
Crop																
Asparagus												X180				
Beans, snap	X7				X7				X7	X7		X	X	X3	X1	
Beans, lima	X7				X7	X14			X7	X7			X	X3		
Beets					X14									X14		
Broccoli	X3		X1				X1						X	X2	X1	
Carrots		X			X14	X	X7		X14	X14			X14	X14		
Celery		X			X14	X7			X14	X14				X2	X1	
Chinese cabbage	X3		X1				X1						X	X2	X1	
Cole crops	X3		X1				X1						X	X2	X1	
Cucumbers		X	X	X7		X1	X1					X	X	X14	X	
Eggplants	X						X				X3	X	X	X14	X	
Garlic		X7			X14	X7	X7		X14	X14				X7	X7	
Greens, mustard	X3		X1				X1						X	X2	X1	
Greens, turnip	X3		X1				X1						X	X2	X1	
Horseradish														X14		
Leeks		X7			X14	X14	X7		X	X				X7	X7	
Lettuce			X								X1	X3	X	X2	X1	
Muskmelons		X	X	X7		X1	X1				X3	X	X	X14	X	
Okra												X	X	X14	X	
Onions, dry		X7			X14	X7	X7		X14	X14				X7	X7	
Onions, green		X7			X14	X14	X7		X	X				X7	X7	
Parsley			X		X14								X	X2	X1	
Parsnips														X14		
Peas	X7			X7												
Peppers	X						X				X3	X	X	X14	X	
Potatoes	X7					X14	X14	X1					X7	X14		X14
Pumpkins/ winter squash		X	X	X7		X1	X1				X3	X	X	X14	X	
Radish														X14		
Spinach													X	X2	X1	
Squash, summer		X	X	X7		X1	X1					X	X	X14	X	
Strawberries		X	X1		X		X			X	X1	X				
Sweet corn	X7				X14				X14	X14						
Sweet potatoes							X14	X1					X7	X14		
Tomatoes	X					X	X				X3	X	X	X14		X1
Watermelon		X	X	X7		X1	X1				X3	X	X	X14	X	

(table continued next page)

Table E-12. Commonly Used Fungicides Registered for Vegetables *(continued)*

	Ridomil Gold, UltraFlourish (mefenoxam)	**Ridomil Gold Bravo** (mefenoxam + chlorothalonil)	**Ridomil Gold Copper** (mefenoxam + copper)	**Ridomil Gold MZ** (mefenoxam + mancozeb)	**Ridomil Gold PC** (mefenoxam + PCNB)	**Scala** (pyrimethanil)	**Stratego** (propiconazole + trifloxystrobin)	**Sulfur** [c,e]	**Switch** (cyprodinil + fludioxonil)	**Tanos** (famoxadone + cymoxanil)	**tebuconazole**	**Terraclor** (PCNB)	**thiophanate-methyl**	**Torino** (cyflufenamid)	**Uniform** (mefenoxam + azoxystrobin)	**Vivando** (metrafenone)	**Zampro** (ametoctradin + dimethomorph)	**Zing!** (zoxamide + chlorothalonil)
FRAC Group(s)*	**4**	**4+** M5	**4+** M1	**4+** M3	**4+ 14**	**9**	**3+ 11**	M 2	**9+ 12**	**11 + 27**	**3**	**14**	**1**	**U6**	**4+ 11**	**U8**	**45 + 40**	**22+** M5
Crop																		
Asparagus	X							X			X180							
Beans, snap	X[b]		X7		X			X	X7		X14	X14	X14		X			
Beans, lima	X[b]		X3		X			X	X7		X14	X14	X14		X			
Beets	X							X	X7		X7				X			
Broccoli	X[b]	X7						X	X7		X7	X					X	
Carrots	X[b]	X7	X7					X	X7									
Celery	X							X	X				X7		X		X	
Chinese cabbage	X[b]	X7							X7		X7	X			X		X	
Cole crops	X	X7						X	X7		X7	X			X		X	
Cucumbers	X	X	X5	X5				X	X1	X3	X7		X1	X	X	X	X	X
Eggplants	X							X	X		X7					X	X4	
Garlic	X[a]	X7	X10	X7		X7		X	X7	X3	X7	X	X[a]		X		X	X7
Greens, mustard	X[b]							X	X7		X7				X		X	
Greens, turnip	X[b]							X	X7		X7							
Horseradish	X[a]							X	X7									
Leeks	X	X14	X10	X7		X7			X7	X3	X7				X		X	
Lettuce	X[a]							X	X	X1					X		X	
Muskmelons	X	X	X5	X5				X	X1	X3	X7		X1	X	X	X	X	X
Okra								X	X		X3					X		
Onions, dry	X	X7	X10	X7		X7		X	X7	X3	X7		X[a]		X		X	X7
Onions, green	X	X14	X7			X7		X	X7	X3	X7		X[a]		X		X	
Parsley	X								X7	X1					X		X	
Parsnips	X							X	X7									
Peas	X[b]							X							X			
Peppers	X		X7					X	X	X3	X7	X				X	X4	
Potatoes	X	X14	X14	X14		X7		X	X7	X			X21				X4	X7
Pumpkins/ winter squash	X	X	X5					X	X1	X3	X7		X1	X	X	X	X	X
Radish	X		X7					X	X7						X			
Spinach	X		X3					X	X	X1					X		X	
Squash, summer	X	X	X5	X5				X	X1	X3	X7		X1	X	X	X	X	X
Strawberries	X					X1		X	X				X1	X				
Sweet corn							X14				X7							
Sweet potatoes	X					X7		X	X7			X			X			
Tomatoes	X	X5	X14	X5		X1		X	X	X3	X7	X				X	X4	X5
Watermelon	X	X	X5	X5					X1	X3	X7		X1	X	X	X	X	X

*Numbers and letters indicate fungicide class (FRAC group). Bold numbers in shaded boxes identify those fungicides that have a higher potential for fungide resistance to develop if the fungicide is used on a continuous basis. These fungicides should be alternated or tank mixed (where recommended) with fungicides from another FRAC group in a spray program. [a] Seed treatment or soil use only; [b]Ultra Flourish is not labeled on these crops; [c] Sulfur rates above 4 lb/A applied during high temperatures may cause crop injury.[d] Only in DE, PA, MD, and VA. [e] See label for PHI; X=registered, Numbers = days to harvest; No number = 0 days to harvest, GH = greenhouse

Table E-13. Fungicides Registered for Seed Treatment

	42-S Thiram (thiram)	**Allegiance** (metalaxyl)[a]	**Apron** (mefenoxam)[a]	**Captan 400** (captan)	**Dividend Extreme** (difenconazole + mefenoxam)	**Dynasty** (azoxystrobin)	**Evolve** (thiophanate methyl + mancozeb + cymoxanil	**Kodiak** (*Bacillus subtilis* GB03)	**Maxim** (fludioxinil)	**Maxim MZ** (fludioxonil + mancozeb)	**Moncoat MZ** (flutolanil + mancozeb)	**Potato Seed Treater** (EBDC)	**Pro-Gro** (thiram + carboxin)	**Tops MZ** (thiophanate-methyl + mancozeb)	**Trilex AL** (trifloxystrobin + metalaxyl)	**Yield Shield** (*Bacillus pumilus* GB34)
FRAC Group(s)*	M3	**4**	**4**	M3	**3+ 4**	**11**	**1+** M3+ **27**	NC	**12**	**12+** M3	**7+** M3	M3	M3	**1+** M3	**11+ 4**	NC
Crop																
Beans, Snap	X	X	X	X		X		X	X						X	X
Beans, Lima	X	X	X	X		X		X	X						X	X
Beets	X	X	X	X					X							
Broccoli	X		X	X					X							
Carrots	X	X	X						X							
Celery			X						X							
Chinese Cabbage	X		X						X							
Cole Crops	X		X	X					X							
Cucumbers	X	X	X	X					X							
Eggplants	X		X						X							
Garlic			X						X							
Greens, Mustard	X		X	X					X							
Greens, Turnip	X		X	X					X							
Horseradish			X						X							
Leeks			X						X							
Lettuce	X		X						X							
Muskmelons	X		X	X					X							
Okra	X								X							
Onions, Dry	X		X						X				X			
Onions, Green	X		X						X				X			
Parsley			X						X							
Parsnips			X						X							
Peas	X	X	X	X				X	X						X	X
Peppers	X		X	X					X							
Potatoes				X			X		X	X	X	X		X		
Pumpkins/winter squash	X		X	X					X							
Radish	X		X	X					X							
Spinach	X		X	X					X							
Squash, Summer	X		X	X					X							
Sweet Corn	X	X	X	X	X	X		X	X							
Sweet Potatoes			X						X							
Tomatoes	X		X						X							
Watermelon	X		X	X					X							

*Numbers and Letters indicate fungicide FRAC group. Bold numbers in shaded fungicide boxes identify those fungicides (FRAC groups) that have a higher potential for fungicide resistance to develop if the fungicide is used on a continuous basis. These fungicides should be alternated with a labeled fungicide from another FRAC group. **1**-benzimidazole; **4**-acylalanine**; 7**-carboximide**; 11**-QoI inhibitor; **12**-phenylpyrroles; 33-phosphonate; M3-dithiocarbamate; NC-not classified; [a]Mefenoxam and fludioxinil are also ingredients in CruiserMaxx and CruiserMaxx Potato. See labels for instructions, formulations, and for crops that have a label for these materials.

Table E-14. Selected Fungicides and Bactericides Labeled for Greenhouse Use

Fungicide	Target Diseases	Labeled Crops	Comments
BASIC COPPER SULFATE (Cuprofix Disperss; United Phosphorus, Inc.) 48 hr. REI	Many diseases including angular leaf spot, downy mildew. *Alternaria* blight, *Anthracnose*, bacterial blight, etc.	Vegetables including cucumbers, eggplant, peppers, tomatoes, etc.	Crops grown in the greenhouse may be more sensitive to copper injury so the user should determine plant sensitivity.
BACILLUS PUMILUS (Sonata; AgraQuest) 4 hr. REI	Early blight, late blight, downy mildew, powdery mildew	Many vegetables including Brassicas, bulb vegetables, cucurbits, fruiting vegetables, leafy vegetables and root and tuber crops	OMRI approved.
BACILLUS SUBTILLUS (Companion, Growth Products, LTD). 4 hr. REI	Suppression of soilborne and foliar diseases including damping off, root rot and early blight	Many including fruiting and leafy vegetables, cucurbits, cole crops and herbs	May be used in hydroponic and soilless production systems. Most effective used preventatively.
CHLOROTHALONIL plus POTASSIUM PHOSPHITE (Catamaran; Luxembourg – Pamol, Inc.) 12 hr. REI	Late blight	Tomatoes	
CONIOTHYRIUM MINITANS (Contans, SipcamAdvan) 4 hr. REI	*Sclerotinia sclerotiorum*, *Sclerotinia minor*	Many vegetables including leafy vegetables, brassicas, legumes, fruiting vegetables and bulb vegetables	OMRI approved. Contains a beneficial fungus. Do not allow to stand overnight following mixture. Acts as a preventative.
COPPER HYDROXIDE (Kocide 101, Kocide 2000, Kocide 4.5LF, Kocide DF, DuPont) 24 hr. REI	Leaf spots, *Anthracnose* and bacterial spots	See labels for specific crops	See labels for specific usage instructions.
COPPER SALTS of fatty and rosin acids (Camelot, Whitmire Micro-Gen) 12 hr. REI	*Alternaria* blight, downy mildew, angular leaf spot, powdery mildew, scab, gray mold, bacterial soft rot, bacterial spot, *Cercospora* leaf spot, etc.	Vegetables such as broccoli, cabbage, cucurbits, tomato, etc.	The user should determine if Camelot can be used safely prior to use. Observe for 7 to 10 days for symptoms of injury.
CUPROUS OXIDE (Nordox, Monterey Chemical, Co.) 24 hr. REI	Bacterial spot and speck, Alternaria leaf spot, anthracnose, early and late blight, etc.	Eggplant, pepper and tomato	See label for specific usage instructions.
CYAZOFAMID (Ranman, FMC Corporation) 12 hr. REI	Pythium damping off Basil downy mildew	Tomato greenhouse transplant production and basil	Drench transplant tray with fungicide at planting or up until one week before transplant. See label for additional details.
DICLORAN (Botran, Gowan Company) 12 hr. REI	Pink rot, gray mold, *Sclerotinia* and *Sclerotium* rots, leaf blight and neck rot	Many vegetables including celery, lettuce, onions, garlic and shallots.	May cause leaf bronzing on lettuce. Use adequate volume of water.
FENHEXAMID (Decree, Arysta Life Science) 4 hr. REI	Botrytis	Tomatoes and lettuce	Protectant fungicide with some plant back restrictions. See label for details.
HORTICULTURAL OIL (Ultra-Fine Oil, Whitmire Micro-Gen) 4 hr. REI	Powdery mildew	Cucurbits, melons and squash	Application should be made when disease is first noticed. See label for information on plant safety. Use lower label rates in the greenhouse.
HYDROGEN DIOXIDE (Oxidate, Zerotol, BioSafe Systems LLC) 1 hr. REI	*Anthracnose*, downy mildew, powdery mildew, *Pythium* root rot	Many including cole crops, cucurbit, leafy vegetables, peppers and tomatoes	Strong oxidizing agent. Contact, oxidizing sanitizer. (Active ingredient: hydrogen peroxide)
KAOLIN (Surround WP, Nova Source Tessenderlo Group) 4 hr. REI	Powdery Mildew	Cucurbit vegetables	Product forms a white clay film on leaves and fruit.
MANCOZEB (Dithane F-45, DF, Dow AgroSciences LLC) 24 hr. REI	Leaf spot diseases, seed treatment for damping off, seed rots and seedling blights	Tomatoes and others	Broad-spectrum protectant fungicide.

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Table E-14. Selected Fungicides and Bactericides Labeled for Greenhouse Use *(continued)*

Fungicide	Target Diseases	Labeled Crops	Comments
MANDIPROPAMID (Micora, Syngenta) 4 hr. REI	Downy mildews, blue mold, and late blight, and suppression of Phytophthora blight	Brassicas, peppers, eggplants, leafy vegetables, and tomatoes.	Registered for closed greenhouses with permanent flooring on transplants for re-sale to consumers.
PENTACHLORO-NITROBENZENE PCNB (Terraclor 75 WP, Terraclor Flowable, Terraclor 15G, Chemtura Corp.) 12 hr. REI	Root and stem rot, damping off (*Rhizoctonia solani, Pellicularia filamentosa*)	Vegetable bedding plants. Limited to container-grown beans, broccoli, Brussels sprouts, cabbage, cauliflower, peppers and tomatoes.	Flowable and 75WP: Apply as a soil drench. 15G: Used as growing media mix. See label additional information.
PENTHIOPYRAD (Fontelis, DuPont) 12 hr. REI	Many, including gummy stem blight, Sclerotinia stem rot, leaf spots, powdery mildew and anthracnose	Tomatoes, peppers and edible peel cucurbits	See label for specific usage instructions.
PETROLEUMOIL (Saf-T-Side spray oil, Brandt Consolidated) 12 hr. REI	Powdery Mildew	Cucurbit vegetables	Contact fungicide. Phytotoxicity may occur. See label for details
POTASSIUM BICARBONATE (Armicarb 100, Helena Chemical Company; Milstop, BioWorks, Inc.; Kaligreen, Taogossi Co., LTD) 4 hr. REI	Powdery mildew and others	Many vegetables including cabbage, cucumber, eggplant, broccoli, cauliflower, lettuce, peppers, tomatoes and squash	Works by contact. Potassium bicarbonate disrupts the potassium ion balance in the fungus cell, causing the cell walls to collapse.
POTASSIUM SALTS OF FATTY ACIDS (M-Pede, Dow Agro Sciences) 12 hr. REI	Powdery Mildew	Greenhouse cucumber	Contact fungicide. See label for details.
PROPAMOCARB HYDROCHLORIDE (Previcur Flex, Bayer Crop Science) 12 hr. REI	*Pythium* root rot and damping off	Tomatoes, leaf lettuce, cucurbits and peppers	See label for specific usage instructions.
PYRACLASTROBIN plus BOSCALID (Pageant Intrinsic, BASF Corp) 12 hr. REI	Botrytis grey mold	Tomatoes and tomato transplants	Pageant Intrinsic is also labeled for greenhouse use on transplants grown for the home consumer market
PYRIMETHANIL (Scala, Bayer Crop Science) 12 hr. REI	Early blight and gray mold	Tomatoes	Use in well-ventilated houses only and ventilate two hours after application.
STREPTOMYCES GRISEOVIRIDIS strain K 61 (Mycostop, Mycostop Mix, Vedera Oy, Finland) 4 hr. REI	*Fusarium, Alternaria, Phomopsis*, suppression of *Botrytis*, and root rots of *Pythium, Phytophthora*, and *Rhizoctonia*	Many including lettuce, cole crops, cucumbers, melons, peppers, tomatoes and vegetable transplants	Contains a beneficial bacterium. Repeat applications may be needed. Use as a soil spray or drench.
STREPTOMYCES LYDICUS (Actinovate, Natural Industries, Inc.) 1 hr. REI	Damping off and root rot, pathogens Pythium, Rhizoctonia, Phytophthora, Verticillium; and foliar diseases including downy and powdery mildew and Alternaria and Botrytis.	Greenhouse Vegetables and herbs and others.	May be applied to soil or foliage through mist systems or sprayer.
STREPTOMYCIN SULFATE (Agri-mycin 17, Nufarm Americas, Inc.) 12 hr. REI	Bacterial spot	Tomatoes and peppers	Repeated applications can result in resistant bacteria. Do not apply through any irrigation system.
SULFUR (Microthiol Disperss, United Phosphorus, Inc.) 24 hr. REI	Powdery mildew	Crucifers, cucurbits, peppers and tomatoes	Crops grown in greenhouses may be more sensitive to sulfur injury, so the lowest label rate should be tried initially. Do not use within two weeks of an oil spray treatment.
TRICHODERMA HARZIANUM (PlantShield, Rootshield, Bioworks, Inc.) 0 hr. REI	*Pythium, Rhizoctonia*, and *Fusarium.* When applied as a foliar spray, suppresses *Botrytis* and powdery mildew.	Greenhouse vegetables	Contains a beneficial fungus. Avoid applications of fungicides at least one week before or after application. Acts as a preventative. Will not cure diseased plants.

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Table E-14. Selected Fungicides and Bactericides Labeled for Greenhouse Use *(continued)*

Fungicide	Target Diseases	Labeled Crops	Comments
TRICHODERMA VIRENS GL-21 (formerly known as *Gliocladium virens*) (SoilGard 12G, Certis USA LLC) 0 hr. REI	Damping off and root rot, pathogens *Pythium* and *Rhizoctonia*	Food crop plants in greenhouse	Acts as a preventative and will protect noninfected plants. Will not cure already diseased plants. Allow treated soil to incubate for one day prior to planting for best results. Do not use other soil fungicides at time of incorporation
TRIFLUMIZOLE (Procure, Chemtura) 12 hr. REI	Powdery mildew	Cucurbint greenhouse transplants, Butterhead varieties of leafy greens	

If any information in these tables is inconsistent with the label, follow the label. Note that some states define pesticide applications in high tunnels as greenhouse applications and other states define them as field applications. Check with your extension educator or state department of agriculture for correct application.