Chapter 6

Disease Management for Organic Vegetable Farms

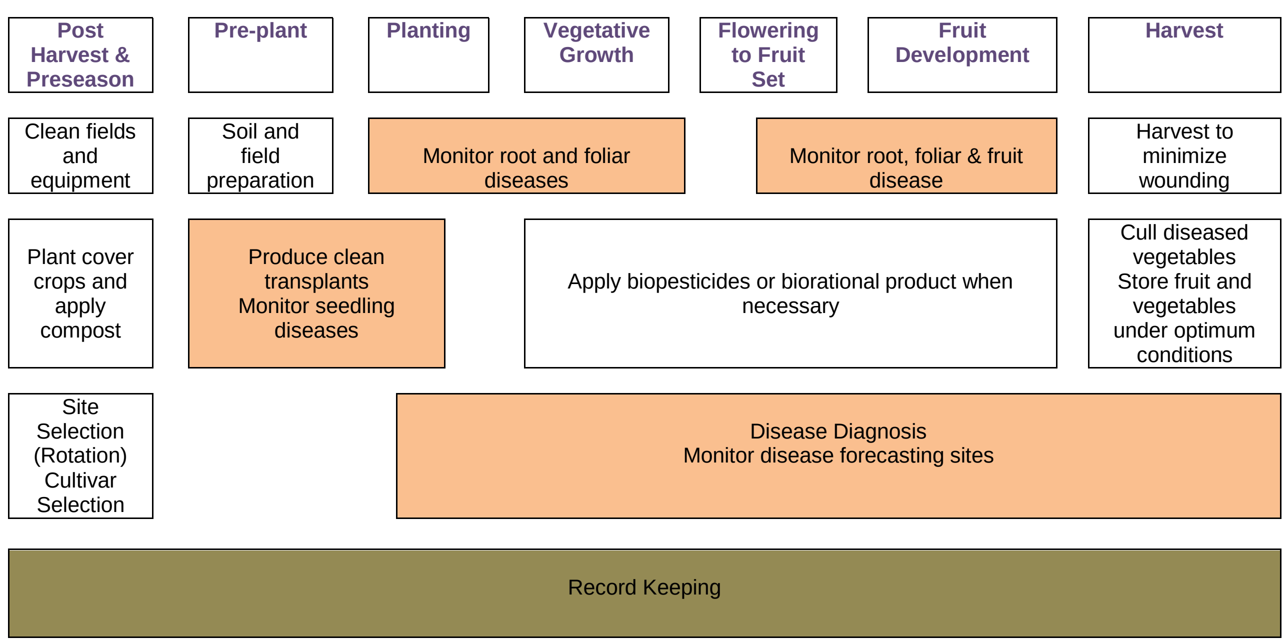
Kate Everts and Jennifer Himmelstein

Disease management in organic vegetable production in the mid-Atlantic region is arguably more difficult than in drier western regions. Due to our warm humid climate and intensive production practices, disease management is especially challenging. Successful organic farmers in the mid-Atlantic will use many different tools from their "disease-management" toolbox. This chapter focuses on practices (or 'tools') that are proven to work in the mid-Atlantic region.

Organic vegetable farming involves a comprehensive approach to soil health, crop health, and the maintenance of a biologically dynamic and diverse agro-ecosystem. Many organic farming practices favorably impact plant health. Examples of these practices are crop rotation and building soil organic matter, through cover crop amendments and inclusion of compost. In fact, organic growers often observe a reduction in some diseases following the transition from conventional to organic methods. The plant health benefits conferred by organic production practices can be further enhanced through additional cultural and biological practices that suppress disease.

Disease management of vegetable crops is a year-round endeavor for *all* production systems—organic, conventional, etc. (Figure 1). Typically, disease management for the

Figure 1. Vegetable Disease Timeline



upcoming growing season begins immediately after the previous years' harvest. At that time, diseased plant residue must be cleared, stakes removed, and winter crops planted. In the off-season, growers select seed of cultivars or varieties that are resistant to diseases. They also plan long-term cropping sequences several years in advance. Throughout the winter and spring, many practices may be used to reduce the amount of disease inoculum present at the beginning of the growing season. After crops have been transplanted or seeded, the plants must be checked periodically for disease to facilitate early detection and accurate diagnosis—essential steps for effective treatment. Some organic growers will use the timely applications of biofungicides or biorational products, which can slow the spread of an epidemic. These growers must carefully select only products permitted for organic production.

Soil Quality and Disease

Healthy soils are teaming with beneficial bacteria and fungi; these microorganisms are essential for promoting plant health and minimizing plant disease. The microbes in soil break down manure, compost, and other organic substances, which increases the available nutrients for plants. This process promotes healthier plants that are better equipped to survive and defend themselves against pathogen attack. Plants with nutrient imbalances are more susceptible to disease—particularly plants that are either too rich in nitrogen or deficient. The presence of adequate amounts of micronutrients such as calcium, boron and silicon will reduce plant disease. Obtaining the correct balance of macro and micro nutrients however, can be difficult in organic production systems because there is greater difficulty estimating plant nutrient amounts in organic fertilizers than for most conventional fertilizers. For more information, see the chapters on Soil Fertility and Soil Health and Cover Crops.

The high microbial activity in a healthy soil also may lead to general disease suppression. General suppression refers to a lessening of plant disease due to the high activity and dynamic interactions of many beneficial microorganisms within the soil community. Competition, parasitism and antibiosis between the plant pathogens and the beneficial soil microbes suppress disease. An effective method to encourage microbial activity and diversity is to increase the organic matter content of the soil.

Soil Building Methods to Reduce Disease

The primary method to maintain healthy soil is to increase organic matter content; this will improve soil structure and diversify the microbial community. Disease suppression may occur when soil-building tools such as mulches, cover crops, and compost are utilized.

Plant residue mulch (straw or no-till cover crop residue) improves soil structure and acts as a soil conditioner that prevents soil compaction. Reduced compaction provides better water infiltration during rain or irrigation, and reduces soil splash which can transport soil-borne pathogens to plants. In Maryland, for example, the prevalence of Septoria leaf spot of tomatoes was significantly reduced when crops were grown on a no-till hairy vetch cover crop (Mills et al. 2002). This cover crop reduced soil splash and pathogen transmission to the lower canopy. Some organic mulch, such as shredded bark, serves as physical barriers to foliar pathogens such as the foliar nematode. In addition, both cover crop mulch and plastic mulch suppresses weeds that potentially harbor pathogens of the cash crop. Some colored or reflective plastic mulches are used to repel insects, which are vectors of virus diseases. However, light colored mulch will not block enough light to inhibit weed growth. There are many benefits of mulch; however, incorrectly applied mulches may inhibit water penetration or block airflow which could decrease beneficial microbes and exacerbate disease. The proper selection and accurate application of mulch should eliminate or alleviate poor drainage reduce, soil splash and minimize weeds and insect virus vectors.

Compost application also increases the organic matter content of soil, improves drainage, soil texture, and provides nutrients and habitats for beneficial organisms. Compost may contain natural antibiotics produced by beneficial bacteria, which inhibit the growth of pathogens. In certain instances, compost induces systematic resistance in plants, triggering a plant's defense system prior to the onset of disease. When pathogens contact the plant, these “primed” plants are conditioned to resist the disease. Research conducted in Maryland, Ohio, New Jersey and elsewhere confirms that selected compost application leads to disease reductions in many crops.

Diseased plant material should not be composted because pathogens may not be eliminated if there is uneven heating of the compost pile. It is advisable to use compost that has been handled and cured in the appropriate manner to ensure that beneficial organisms, rather than harmful ones, are present. Compost is most effective as a disease suppressant if it (1) has been cured for at least four months, (2) is incorporated into the field a few months prior to planting, and (3) has been inoculated with biocontrol agents such as *Flavobacterium*. Adding biocontrol agents to compost is a form of specific suppression. Specific suppression occurs when one organism directly affects a pathogen. Various types of organisms, which have the ability to suppress disease, may be added to compost. For example, the beneficial fungus *Trichoderma hamatum*, which produces antifungal exudates that suppress the pathogen *Rhizoctonia solani*, can be added.

Green manure cover crops provide many of the same benefits as mulches and compost. Benefits include building soil structure, fertility, soil tilth, and favoring microbes that compete with potential pathogens. Some cover crops, particularly when incorporated as a green manure or soil amendment, can directly or indirectly suppress pathogens of the cash crop (Table 1). For example, *Brassica* cover crops successfully suppress the occurrence of *Rhizoctonia* on potatoes through the release of isothiocyanates into the soil. A green manure of *Vicia villosa* (hairy vetch) suppressed Fusarium wilt on watermelon in Maryland. Numerous cover crops have proved effective for suppressing disease in the mid-Atlantic and other regions. See Table 1 for selected research results from the mid-Atlantic.

Table 1. Selected Organic No-till Cover Crops and Green Manure Amendments which have Reduced Vegetable Diseases in mid-Atlantic Trials.

Cover Crop	Disease and Crop	Comments and Additional Research
Sorghum bicolor (Sudangrass) green manure	Nematodes on many crops and bean root rot	Suppression of nematodes is enhanced by the addition of poultry litter compost. (Sorghum green manure has also reduced fungal diseases of lettuce and potato.)
Brassicaceae spp.	Root knot nematode suppression	Also has reduced *Fusarium oxysporum, Rhizoctonia solani*, and *Verticillium dahlia.*
Vicia villosa (Hairy vetch) green manure	Fusarium wilt of watermelon and Anthracnose on watermelon	Response is location dependant. Hairy vetch is a host of Root Knot Nematode (RKN) and therefore, not suitable for RKN infested areas.
Mixed hay species	Damping off in tomatoes	Mix of tall fescue, orchard grass, timothy, red clover and alfalfa (Research conducted in Ohio)
Hairy vetch and Hairy vetch + *Secale cereal* (rye) No-till	Black rot, Anthracnose and Plectosporium blight on pumpkin	Provides a layer of plant material between soil and fruit which reduces soil splash. Edema of pumpkin also was reduced some years on a no till cover crop.
Hairy vetch no-till	Septoria leaf spot and early blight on tomato	Black plastic mulch also reduced disease in some years.
Sunnhemp (*Crotolaria juncea*)	Root knot nematode	Ongoing work by Dr. Cerutti Hooks in Maryland

Sudangrass and brassicaceae information for the mid-Atlantic (http://www.sare.org/publications/factsheet/pdf/06AGI2005.pdf)
Hairy vetch information for watermelons (http://www.plantmanagementnetwork.org/pub/php/research/2006/watermelon/)

Cultural Practices for Disease Management

Good cultural practices (such as rotation, sanitation, use of drip irrigation, etc.) create conditions that favor plant health. Good cultural practices fall into one of two categories. They will (1) reduce initial inoculum of the pathogen, or (2) make the environment less favorable for disease development and spread.

Initial inoculum refers to the pathogen propagules and structures that are present in the crop at the beginning of the production cycle. Maintaining the necessary host-free rotation period is important in reducing initial inoculum (Table 2). A two year host-free period will help manage gummy stem blight and black rot on cucurbits, bacterial speck and spot on tomatoes, Alternaria leaf blights and many other diseases.

Table 2. Host-Free Periods for Disease Management in Vegetable Production

Duration of Host-Free Period (Years)	Hosts	Diseases
1	Corn	Leaf blights
2	Bean	Anthracnose, bacterial blight
	Carrot	Leaf blight
	Cucumber, muskmelon, pumpkin, squash, and watermelon	Scab, leaf spots, gummy stem blight, black rot, anthracnose
	Onion	Leaf blights
	Parsnip	Leaf spot, root canker
	Tomato, pepper	Bacterial spot, bacterial speck, Anthracnose
	Tomato, potato	Early blight
	Spinach	Downy mildew, white rust
3	Beet	Cercospora leaf spot
	Cabbage, turnip	Black rot, Rhizoctonia wire stem, head rot
	Lettuce	Bottom rot, drop
	Parsley	Damping off
	Sweet potato	Scurf, pox
	Tomato	Bacterial canker
	Potato	Rhizoctonia canker
4	Bean	Root rots
	Cabbage, turnip	Black leg (Phoma)
	Potato, pepper, tomato, eggplant, strawberry and brambles	Verticillium wilt (early dying)
	Pea	Root rots
	Potato	Pink rot, Pythium leak
	Potato, carrot, beet, spinach, turnip, radish	Scab
5	Muskmelon	Fusarium wilt (not reliable)
	Pea	Fusarium wilt (not reliable)
6	Watermelon	Fusarium wilt (not reliable)
	Corn	Smut (not reliable)
8	Asparagus	Fusarium root and crown rot

However, rotation is not effective for all diseases. Some pathogens have resistant overwintering structures that can survive many years between hosts (e.g. pathogens that cause white mold or timber rot); other pathogens can live as saprophytes using the roots of non-host plants *(e.g. Fusarium oxysporum)*. In addition, some pathogens, such as the fungi that cause downy mildew or powdery mildew, do not overwinter in the mid-Atlantic region and are introduced each year via wind currents.

Because a host free period does not manage all diseases, rotation must be combined with other cultural practices (Table 3). For example, Phytophthora blight cannot be

Table 3. Cultural Practices and use of Host Resistance to Maintain Low Inoculum Level in Organic Vegetable Plantings.

Practice	Reason
Dispose of culls and plant refuse away from fields.	Cull piles harbor disease causing organisms that may infect the next crop.
Incorporate plant residue into soil as soon as possible after harvest.	Beneficial soil microbes will decompose plant residue and decrease the number of plant pathogen propagules.
Destroy weeds and volunteer plants that grow from previous year's seeds.	These plants can harbor pathogens, including viruses, which can infect the current crop. Volunteer plants allow the pathogen to survive during the host free rotation period.
Purchase plant cultivars (varieties) with resistance or tolerance to disease.	Resistant varieties will develop less disease than susceptible varieties. Tolerant varieties, which may develop high levels of disease, will compensate for damage and yield well.
Monitor and manage leafhoppers, aphids and other pests that spread virus and bacterial diseases.	Aphids and leafhoppers may introduce virus into a planting. Cucumber beetles vector bacterial wilt.

sufficiently reduced by long rotations. To reduce Phytopthora blight, a 2-year rotation away from tomato, eggplant, pepper, and cucurbit hosts is recommended. However, beans, spinach, and certain weeds also are alternate hosts of Phytophthora blight. Despite achieving a host-free period for two years, poor drainage in the fields will allow the pathogen to multiply so rapidly that excessive disease loss may occur. Phytopthora blight is one example that demonstrates the necessity of using more than one tactic for successful disease management.

Initial inoculum also may be reduced by methods that minimize the introduction of additional pathogenic propagules to the field. Seeds or transplants that have been certified as disease-free should be used whenever possible. Hot water treatment of seeds also is an effective method to reduce seedborne pathogens. Confirm with your seed company that your seed has been treated to reduce pathogens. Growers can heat treat their own seed; however, this process must be conducted carefully because seed germination can be affected. Directions can be found at eXtension.org (http://www.extension.org/article/18952).

Additional farm practices have the potential to hasten or reduce the spread of disease (Table 4). For example, infested transplant equipment can spread disease throughout

Table 4. Practices that Reduce Disease Spread in Vegetable Plantings.

Practice	Reason
Select field sites with good drainage.	Standing water will stress plants and predispose them to disease. Humidity will increase in water logged areas. Phytophthora crown rot will rapidly increase in wet areas.
Reduce soil compaction and eliminate hard pan layers.	Use of cover crops, especially deep rooted crops such as forage radish will improve drainage. Rip tillage and chisel plow will also reduce hard pans.
Improve soil structure and increase organic matter.	These practices promote healthy root systems and favor growth of beneficial soil microorganisms.
Plant on raised beds.	Raised beds improve drainage, and eliminate standing water around the plant stem.
Plant rows so prevailing winds flow between rows or stake and prune plants to improve air flow around foliage.	This will reduce humidity in the canopy and dry the soil surface, minimizing diseases such as white mold or Sclerotinia rot.

the field; therefore, growers should clean transplant equipment before and after use. Practices that promote drying of leaves will reduce infection. Use drip irrigation instead of overhead irrigation. If only overhead irrigation is available, water during the mid-afternoon, when plant leaves have time to dry before night fall. Harvest and pruning activities should be conducted when leaves are dry. Plan the work day so that fields with the most disease are worked last, so that disease is not spread by equipment from one field to another. Pruning, staking and tying plants can cause wounds and allow pathogens to enter the host; therefore, it is necessary to use extra care when conducting these procedures and to clean tools frequently.

Disease Diagnosis

Many resources are available through cooperative extension to alert farmers of impending disease problems. A website developed and run by cooperative extension faculty from North Carolina State University forecasts the initial outbreak of cucurbit downy mildew at locations throughout the east coast (http://cdm.ipmpipe.org/). Farmers who grow pumpkin, squash, watermelon, or other cucurbits can use it for an early warning of downy mildew outbreaks. In the mid-Atlantic region, watermelon and cantaloupe (muskmelon) growers should visit the cooperative extension site hosted at the University of Maryland, where MELCAST disease forecasting is provided. MELCAST http://mdvegdisease.umd.edu/forecasting/index.cfm provides information on how conducive the weather is for development of Alternaria leaf blight and gummy stem blight. The MELCAST model was developed to schedule conventional fungicide applications, but organic growers can learn if weather is favorable or unfavorable for these diseases and adjust their biofungicide sprays, or their harvest practices accordingly.

Accurate and timely diagnosis of vegetable diseases is the most important step for successful implementation of effective disease management practices. Although many disease symptoms can be difficult to distinguish, there are numerous resources available in print and online to aid the diagnosis process. When confronted with an unknown plant problem, the most reliable method to identify the cause is to contact an expert. Local county extension educators are your first line of defense; they often have seen similar problems and they may be able to provide a presumptive diagnosis. As soon as you see a problem that needs diagnosis, call your county extension educator. He or she will request a digital image, ask you to drop off a sample, or visit your field. If the extension educator isn't able to identify the problem, they will consult with a specialist. The extension educator or specialist will search for signs or symptoms of disease. Disease signs are the observed presence of a pathogen, such as sclerotia, spores, or spore producing bodies (Figure 2). Symptoms are the observable response of the plant to disease (e.g. wilt, leaf spot, or vascular browning). The extension educator or specialist will make a presumptive diagnosis if the symptoms are entirely consistent with the pathogen observed and if no other possible cause is present. If the cause still remains unknown, then a sample of the infected plant should be sent to the University of Maryland's Plant Diagnostic Laboratory for further evaluation (www.plantclinic.umd.edu).

Figure 2. Sclerotia and mycelia (here on pumpkin) or other visible pathogen structures are 'signs' of a disease.

Tips for submitting a plant sample for diagnosis:

- Include all plant parts necessary for a diagnosis. For example, to diagnose a wilt disease, roots, stems and leaves should be included.
- Send plants that have a range of symptom development.
- Send the sample as soon as possible after collection.
- Samples can be placed in plastic bags, but first wrap them in newspaper so that they are not overly wet.
- Communicate details about the pattern of the problem in the crop to the specialist or diagnostician by filling out the Specimen Submission Form located online at www.plantclinic.umd.edu.
- Photos of the affected field area are helpful for diagnosis, especially when coupled with information from the field such as:
  - Are all plants in one area affected?
  - Are diseased plants in a pattern in the field (such as adjacent to other diseased plants in a row)?
  - When did problems first appear?
  - Are other crops affected?
  - What crop was in the field last year?

Select Fungicides and Bactericides

Organic vegetable production is built upon a foundation of improving soil and crop health through the use of cultural practices. Despite these preventative efforts, it may be necessary to use fungicides and bactericides to combat certain disease epidemics. However, these off-farm materials should never be used to circumvent good cultural practices such as crop rotation, using cover crops, compost, and sanitation.

One product that is often applied to foliage is Compost Tea. There are many anecdotal claims about compost teas and their ability to reduce disease. However, there are few scientifically rigorous studies that confirm disease effects. A few research studies have found a reduction in disease where compost tea was used, but many more found no significant difference between plants treated with compost tea and not treated. Unfortunately many variables affect the composition of compost tea and make comparisons between treatments and among studies difficult. In addition, in some cases compost tea is phytotoxic. Of even greater concern is that it may harbor human pathogens. A good summary of compost tea pro's and con's can be found at http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5058470.

Selecting an appropriate product for organic production can be quite difficult because many materials available for use in organic production have not yet been properly evaluated. Farmers often rely on personal testimonials of other growers or manufacturer claims, which may be unreliable. Manufacturers do not need to prove that a product is effective in reducing disease in order to register it. This has led to the registration of some products that are ineffective. To select products for disease management, consult reputable sources such as ATTRA, www.attra.ncat.org/pest.html, eOrganic, www.extension.org/organic%20production, or the Resource Guide for Organic Insect and Disease Management at www.nysaes.cornell.edu/pp/resourceguide. One of the most challenging aspects of identifying appropriate products for organic production is determining which products are actually *allowable* for organic production.

The National Organic Program (NOP) allows some materials to be applied to organic crops, while prohibiting others. A list of active ingredients is in the NOP, not the actual brand names. Therefore, a product which contains an allowable ingredient could still be disallowed ***if*** it was formulated with materials that are not allowed (not on the NOP list). For guidance in what products are allowable, many organic certifiers use lists that contain brand names. These lists are published by organizations such as the Organic Materials Review Institute (OMRI) or the Washington State Department of Agriculture (WSDA). Farmers can accept the evaluation of a reputable organization such as OMRI or WSDA. Another alternative is to hire an Accredited Certifying Agent who will determine whether a product is in compliance with the NOP. Note that materials which have not been listed by OMRI, WSDA or another third party could be allowable. In order to determine if an unlisted product is allowable, it is necessary to evaluate all ingredients—including inert ingredients which may not be listed on the label. Farmers should be sure to document information used in their evaluation of a material.

Please note that a list of some selected OMRI approved fungicides and bactericides are included in Table 5. Although this list is not comprehensive, it provides a starting point for selecting a fungicide or bactericide. To remain compliant with organic production standards, it is important to *always* read labels for (1) the crops on which a product can be used, (2) the diseases that the product is effective on, (3) regulatory information on the product (e.g. re-entry intervals (REI)), and (4) usage instructions.

Vegetable Disease Management in Greenhouses and High Tunnels

Reducing diseases in protected environments such as greenhouses or high tunnels, is made easier because water on the foliage can be controlled (i.e. exposure to rainfall is eliminated). However, greenhouse environments without modification tend to be wind free and prone to high humidity. Dew frequently forms when clear nights follow warm humid days. Reducing humidity and dew is critical to reducing disease. This is most easily accomplished by ventilation in greenhouses. The sides of high tunnels can be raised to allow air flow. In enclosed greenhouses air flow can be increased by fans that move air around the structure, particularly around vegetable foliage and fruit. Improved air movement will also reduce temperature of the foliage as water is transpired. Removing unproductive leaves at the base of plants and trellising are two methods to alter the plant architecture resulting in improved air flow within the foliage (Figures 3).

Pathogen inoculum should be eliminated from potting media with sterile or disease free soil or soilless mixes. How and where the mixtures are prepared should be evaluated for cleanliness. If a disease free mix cannot be purchased, such as in the case of ground beds, soil should be sterilized.

Composts, while not sterile, may be suppressive to disease development. However, care must be taken with the source of the compost and be wary of unverified claims of suppression.

Elimination of all inoculum sources is difficult because pathogens survive in many places. Sclerotia of *S. sclerotiorum* or *S. rolfsii* are long-lived in soil. The nematode *Meloidogyne incognita* can survive deep in soil in ground beds and is difficult to eliminate. Bacteria survive on crop debris and on twine, stakes and wire. Weeds in or near the greenhouse can harbor viruses, and some plants serve a symptomless hosts of pathogens such as *Fusarium oxysporum* spp. and *Verticillium*.

Figure 3. Pruning lower, unproductive leaves off plants, as well as staking plants or growing them on trellises will reduce humidity around the plant, improve air flow and minimize disease.

Because all inoculum sources cannot be eliminated, measures should be taken to minimize the presence of disease. Use Greenshield or other disinfectant to clean tools, stakes, benches and walls. Avoid having ornamental plants in the vegetable production greenhouse. Also, launder work clothes frequently. Pathogens are easily spread through the activities of people, on hands, clothing and tools. Watering can also spread pathogens. Drip tape or the practice of watering at the base of plants, will minimize spread. Finally, pets and birds may bring pathogens inside a greenhouse structure or spread them from a diseased section of a greenhouse to a non-diseased area.

Additional techniques have been very useful in reducing disease in greenhouse environments. Grafting will reduce Fusarium wilt on tomato and watermelon crops (Figure 4). This approach is highly effective for reducing losses due to soilborne disease such as Fusarium wilt, but does add extra cost to production.

Figure 4. Grafted watermelon seedlings. Note the graft wound on the nearest plant and the plastic clamp over the graft on the adjacent plant.

Table 5. Selected Organic Material Research Institute (OMRI) Approved Fungicides and Bactericides

Fungicide (Trade name, Product Source) Re-entry Interval (REI)	**Target Diseases**	**Labeled Crops**	**Comments**
BACILLUS PUMILUS (Sonata, Ballad Plus; AgraQuest) 4 hr. REI	Early blight, late blight, downy mildew, powdery mildew	Many, including brassica, bulb vegetables, cucurbits, fruiting vegetables, leafy vegetables, and root and tuber crops	Thorough coverage is critical. Ballad is registered for sweet corn, sugar beets and some grain and oil seed crops.
BACILLIUS SUBTILLUS QST 713 (Cease, BioWorks, Inc.; Rhapsody, AgraQuest) 4 hr. REI	Suppression of foliar diseases, including leaf spots, powdery mildew, downy mildew, and *Botrytis* blight	Many greenhouse grown vegetables, including fruiting and leafy vegetables, cole crops, and cucurbits	Thorough coverage is critical.
BACILLIUS SUBTILLUS, QST, 713 Strain (Serenade ASO, Serenade MAX, AgraQuest) 4 hr. REI	Many, diseases including downy mildew, powdery mildew, bacterial spot, early blight, etc.	Many vegetables, including broccoli, leafy vegetables, cucurbits, pepper, tomato, and others	Applied as a protectant fungicide.
CONIOTHYRIUM MINITANS (Contans WG; SipcamAdvan) 4 hr. REI	*Sclerotinia sclerotiorum, Sclerotinia minor*	Many, including leafy vegetables, brassica, legume, fruiting vegetables, and bulb vegetables	Contains a beneficial fungus. Do not allow to stand overnight following mixture. Acts as a preventative. Highly effective if applied correctly.
COPPER HYDROXIDE (Badge X_2, Iasgro USA, Inc.; Champ WG, Nufarm Americas, Inc.) 48/24 hr. REI (see label)	Many bacterial and fungal diseases.	Many, including legumes, cole crops, solanaceous, cucurbit, and bulb vegetables.	See labels for specific usage instructions. Apply with caution, (copper is phytotoxic at high rates.)
HYDROGEN DIOXIDE (Oxidate; BioSafe Systems LLC) 0 hr. REI	Anthracnose, downy mildew, powdery mildew, *Pythium* root rot	Many, including cole crops, cucurbit, leafy vegetables, pepper, and tomato	Strong oxidizing agent. Contact fungicide, oxidizing sanitizer.
KAOLIN (Surround WP, Nova Source Tessenderlo Group) 4 hr. REI	Powdery mildew	Cucurbit vegetables	Product forms a white film on leaves and fruit. Also suppresses some insects.

PETROLEUM OIL (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 (Milstop, BioWorks, Inc.; Kaligreen, Otsuka Chemical Co. Ltd.) 4 hr. REI	Powdery mildew and others	Many vegetables, including cabbage, cucumber, eggplant, broccoli, cauliflower, lettuce, pepper, tomato, 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.
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, cucumber, melon, pepper, tomato, and others	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, herbs and others.	May be applied to soil or foliage through mist systems or sprayer.
SULFUR (Microthiol Disperss; United Phosphorus, Inc.) 24 hr. REI	Powdery mildew	Crucifers, cucurbits, pepper, and tomato	Crops grown in greenhouses may be more sensitive to sulfur injury. Do not use within 2 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 1 week before or after application. Acts as a preventative. Will not cure diseased plants.
TRICHODERMA VIRENS GL-21 (formerly known as Gliocladium virens) (SoilGard 12G, Certis USA L.L.C.) 0 hr. REI	Damping off and root rot, pathogens *Pythium* and *Rhizoctonia.*	Vegetable 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.
NEEM OIL (Trilogy, Certis USA, L.L.C.)	Foliar fungal diseases, especially powdery mildew	Many vegetables including cucurbit, bulb, cole crops and leafy vegetables.	Also labeled for mite and insect pests. Toxic to bees.
If any information in these tables is inconsistent with the label, follow the label. Some products may have labels approved by OMRI as well as non-approved labels. If in doubt, check with an Accredited Certifying Agent.			

Seedling Diseases in the Greenhouse

Fungal and bacterial diseases of vegetables can be introduced into the greenhouse on seed or through inoculum from a previous crop. To minimize the occurrence of these diseases:

- The greenhouse should be disinfected before planting (benches, walls, walkways, etc.).
- If possible, obtain seed from a source that has tested negative for the pathogen with a minimum assay number of 1,000 seeds.
- Hot water seed treatment is effective, but must be done carefully to minimize damage to the seed.
- Use clean transplant trays and disinfect trays if they will be reused.
- Destroy any volunteer seedlings and keep the area in and around the greenhouse weed-free.
- Avoid overhead watering if possible, or water in the middle of the day so that the plants dry thoroughly before evening.
- Keep relative humidity as low as possible through proper watering and good air circulation in the greenhouse.
- Always use new soil.
- Soil may be amended with an approved biocontrol agent that will minimize damping off.

As the seedlings develop, inspect them carefully for signs or symptoms of disease. Infected seedlings may have small lesions on the leaves, water-soaked lesions on the stem, or damping-off symptoms. Diseases that are transmitted on seed often are randomly located throughout the greenhouse. Initial infections will occur as “foci” or clusters of diseased plants.

If the seedlings appear diseased, destroy every tray that has symptomatic plants. Remove adjoining trays to a separate area for observation. Monitor these seedlings daily and destroy trays where symptoms develop. Do not transplant any trays containing plants with disease symptoms.

Figure 5. Many diseases in the greenhouse will appear in disease foci (clusters in an area around the initial infected seedling).

References and Resources

ATTRA National Sustainable Agriculture Information Service (http://attra.ncat.org/pest.html)

University of Maryland's Plant Diagnostic Laboratory (www.plantclinic.umd.edu)

National Organic Program (http://www.ams.usda.gov/AMSvl.O/nop)

Organic Materials Review Institute (OMRI) (http://omri.org/)

Washington State Department of Agriculture (WSDA) (http://agr.wa.gov/foodanimal/organic/)

Extension organic farming information from Cooperative Extension http://extension.org/organic%20production

National Organic Standards Board, Compost Tea Task Force Report www.ams.usda.gov/AMSvl.O/

Mills, D.J., Coffman, C.B., Teasdale, J.R., Everts, K.L., and Anderson, J.D. 2002. Factors associated with foliar disease of staked fresh market tomatoes grown under differing bed strategies. Plant Dis. 86:356-361.

Organic Seed Treatments and Coatings http://www.extension.org/article/18952

Cucurbit Downy mildew forecasting (http://cdm.ipmpipe.org/)

Watermelon and Muskmelon Alternaria leaf blight and gummy stem blight forecasting for Maryland and Delaware (http://mdvegdisease.umd.edu/forecasting/index.cfm)

University of Maryland's Vegetable and Fruit Headline News http://annearundel.umd.edu/AGNR/VegFruitNews.cfm

University of Delaware Weekly Crop Update http://agdev.anr.udel.edu/weeklycropupdate/