Second Edition

RESOURCE GUIDE FOR ORGANIC INSECT AND DISEASE MANAGEMENT

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Funding for this guide was provided by:

Northeast Region SARE
Sustainable Agriculture Research and Education Program

USDA

NIFA

Maine Organic Farmers and Gardeners Association
MOFGA

Cornell University Founded A.D. 1865
Cornell University

COVER PHOTOS: Ann Rangarajan, Steve Reiners, Eric Sideman, Becky Sideman, and Chris Smart

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630 West North Street
Geneva, New York 14456
http://www.nysaes.cornell.edu

ISBN 0-9676507-8-X

Produced by CALS Communications, NYSAES, Geneva, NY
Cover and book design and composition: Elaine L. Gotham
Photography editor: Eric Sideman
Managing editors: Abby Seaman and Eric Sideman
Printed by: Arnold Printing Corp, Ithaca, New York

Unless otherwise noted, photos on pages 81-103 were taken by the authors: Brian Caldwell, Eric Sideman, Abby Seaman, Anthony Shelton and Christine Smart.

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Resource Guide to Organic Insect and Disease Management

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INTRODUCTION

WHY THIS GUIDE?

Organic farmers rely primarily on preventive, cultural, and integrated methods of pest and disease management. Additionally, there are a number of materials that can complement and support organic management. This guide was developed to provide a useful and scientifically accurate reference for organic farmers and agricultural professionals who are searching for information on best practices, available materials, and perhaps most importantly, the efficacy of materials that are allowed for use in organic systems. Many products available to organic farmers have not been extensively tested, and current research has not been summarized or made widely available to the practitioner. A major objective of this guide is to review literature for published trials on material efficacy in order to provide reliable information that can be used by farmers to effectively manage pests. An additional goal is to identify what materials have shown promise but require more research.

The second edition of the Guide includes new chapters on four additional crop families and four additional materials.

WHO SHOULD USE THIS GUIDE?

Organic farmers and those in transition to organic production, extension professionals, and farm advisors who want accurate information based on published research.

HOW TO USE THIS GUIDE:

The Guide is divided into three sections. The first section provides cultural information and management practices for a number of important vegetable crop groups. For each family, key pests and disease problems are described. Cultural methods and management practices that will help control each problem are listed, as well as materials that may be recommended for use.

The second section contains a set of generic fact sheets about specific materials that can be used in organic systems. The fact sheets provide background information about the type of material, how it is made, how it works, and the types of pests it will control. They also provide application guidelines for use and a description of the effects of each material on the environment and human health. Efficacy is summarized in text and with graphs based on data from trials reported in *Arthropod Management Tests* (Entomology Society of America), *Plant Disease Management Reports* (American Phytopathological Society), and other sources. Materials are rated and grouped into three categories of effectiveness: good, fair, and poor control. Replicated field trials on crops grown in the northeast are included. Results of studies in which a material was used in combination or alternating with another treatment could not be classified and are not included, even though in practice, such strategies may be effective. A complete bibliography of all efficacy data is available by contacting Brian Caldwell at bac11@cornell.edu or Abby Seaman at ajs32@cornell.edu.

The last section contains appendices with useful information about additional practices, such as plant resistance, trap cropping, habitats for beneficial insects, pesticide regulation, and additional resources.

WHAT ARE THE RULES ABOUT ORGANIC INSECT AND DISEASE MANAGEMENT?

Organic growers must use products that meet the requirements of USDA's National Organic Program (NOP) as established at 7CFR Part 205. Ingredients found in farm input products for crop or livestock production must be either a natural substance or a synthetic substance that is included on the National List (included in the regulations at 7CFR 205.600 - 205.607). A few natural substances are also specifically prohibited. Inert ingredients used in pesticides (substances other than the active ingredients) must be included on the U.S. EPA's former List 4A or 4B (available at http://www.epa.gov/opprd001/inerts/oldlists.html). The EPA no longer uses this List system, and NOP will be modifying this reference at some point in the future.

Certification agencies are charged with the responsibility of verifying that products used by farmers meet the requirements of the National List. They must review both active and inactive (inert) ingredients for compliance. Many certifiers use the services of the Organic Materials Review Institute (OMRI), a non-profit organization established to provide product review services. Those that use OMRI services often provide some in-house review of products as well, but in all cases, a certified farmer must be sure that any products used on the farm are approved by his or her certification agency. References to OMRI-listed products in this Guide are based on the June 2012 edition of the OMRI Brand Name List. Please consult later editions or www.omri.org for more up-to-date listings.

The US Environmental Protection Agency (EPA) also has a voluntary label review program for registered pesticides. A product that meets the USDA-NOP requirements may use the specific wording "For Organic Production." In general, if a product is not listed by OMRI, EPA, or directly by the certifier, the farmer must provide enough information to the certifier to assure that the product is in compliance with the NOP rules. Use of a prohibited material on an organic farm could result in loss of certification for 36 months.

Materials used for disease and insect control are subject to further restriction by NOP rules, which require that preventive, cultural, and physical methods must be the first choice for insect and disease control. If those methods are not effective, a botanical, biological, or synthetic substance on the National List may be used if the conditions for use are documented in the organic farm plan. This requirement reflects historic organic practice, which relies primarily on the use of biological and cultural practices, such as crop rotation, diversification, habitat management, beneficial organism releases, sanitation, and timing of cultural practices before resorting to limited use of permitted pest control substances.

Finally, all pesticides must be used according to their label as required by EPA and state regulations. Label instructions include directions for use, rates of application, permitted crops, and designated target species. Using products only on labeled crops is important, because off-label use may result in an illegal residue on food crops or action by regulatory agencies.

ACKNOWLEDGEMENTS

The authors would like to thank the following persons for their invaluable assistance in reviewing, correcting, and improving parts of this Guide: Jude Boucher (University of Connecticut), Brian Caldwell (Cornell University), Daniel Gilrein (Cornell University), Wendy Sue Harper (NOFA Vermont), Ruth Hazzard (University of Massachusetts), Margaret Tuttle McGrath (Cornell University), Elsa Sanchez (Pennsylvania State University), Michael Seagraves (North Central Agricultural Research Laboratory), Becky Sideman (University of New Hampshire), and Kim Stoner (Connecticut Agricultural Experiment Station).

SUPPORT

Funds for the first edition were provided by a grant from the USDA's Initiative for Future Agriculture and Food Systems and from the Sustainable Agriculture Research and Education program (USDA agreement #2002-47001-01329) and the EPA Region 2 under their FQPA/ Strategic Agricultural Initiative program. Institutional support was provided by Cornell University's New York Agricultural Experiment Station and Cornell Cooperative Extension, OMRI, and MOFGA.

The second edition was supported by the Northeast Sustainable Agriculture Research and Education (SARE) program. SARE is a program of the National Institute of Food and Agriculture, U.S. Department of Agriculture. The Maine Organic Farmers and Gardeners Association (MOFGA) and Cornell University provided institutional support.

HOW TO ORDER

A limited number of copies are available from the NYSAES online bookstore for $20 + shipping. A free pdf is available at http://web.pppmb.cals.cornell.edu/resourceguide/

The ISBN number is 0-9676507-8-X.
Publication date: January 2013

ORGANIC INSECT AND DISEASE CONTROL FOR Allium Crops

INTRODUCTION

Onions, garlic, leeks, shallots, scallions, and chives all belong to the genus *Allium,* as do about 20 other species of food crops used around the world. The edible portion of the plant is the leaf in some species (e.g., scallions, chives, leeks), the bulb in others (e.g., onion, garlic), or both. A bulb is a reproductive organ consisting of swollen leaf bases on a very shortened stem. Diseases and insects attack the root, leaf, or the bulb, reducing the yield and marketability of the crop or, if infested at the seedling stage, destroying it entirely. To a greater or lesser extent, all species in the genus generally suffer from the same pests and diseases.

I. INSECT CONTROL

ONION MAGGOT *(Delia antiqua)*

The onion maggot is the larva of a fly that is slightly smaller than the common house fly but with longer legs. Each female can lay several hundred eggs at the base of onion plants. The eggs hatch in 2-3 days, and the maggots crawl down into the soil and feed on the roots and basal plate of the onion **(Photo 1.1)**. Onion seedlings cannot tolerate the feeding and are usually killed. A maggot may kill several adjacent seedlings before it completes its development. The first sign of the problem is wilting seedlings. Larger onions that are attacked by the second or third generation of this pest may survive but may be misshapen, invaded by disease organisms at the wound site, or both, resulting in rotting onions. Yellow onions are much more attractive to the fly than red onions; leeks, garlic, and shallots are less attractive than onions.

In the Northeast, there are typically three generations per year. In the spring (May in the Northeast), adult flies emerge from overwintering pupae and search for onions. Flights can be predicted by following accumulated base 40° F degree days. Peak flight of the first generation is at 700 DD at a base of 40° F; peak for the second is 1960 DD at a base of 40° F, and peak for the third is 3240 DD at a base of 40° F. In some states, DD are calculated for specific locations; these should be used to help predict management strategies. In New York, Massachusetts, and New Jersey, for example, see: http://newa.cornell.edu/index.php?page=onion-maggot.

Another method of monitoring flights is to bait (with onions) an inverted screen cone trap mounted on wire legs. Its usefulness is greatest for detecting population levels in the early season. If flights are detected before onions are planted, then floating row covers or other management strategies are warranted. Observing the flies in the field is possible too. They are common in the morning, especially on damaged onions, which are more attractive to the flies. There is little an organic producer can do once the eggs are laid, which limits the usefulness of monitoring after egg-laying has occurred.

Cultural Control:

1. Encouraging natural enemies by diversifying habitat and food sources and refraining from the use of broad-spectrum pesticides will help lower onion maggot populations; however, these measures will not normally provide sufficient control and must be supplemented by other strategies. There is a parasitic wasp that attacks maggots and a fungal pathogen that infects adults but these are generally not useful in preventing early season injury. Important predators of eggs, larvae, and pupae include many species of rove beetles (Coleoptera: Staphylinidae) and ground beetles (Coleoptera Carabidae). Maintaining untilled refuge strips may help sustain predator populations.

2. The onion maggot fly is strongly attracted to rotting onions. To avoid adults laying eggs that will overwinter as pupae, fall clean up of onion debris is essential; sanitation is equally important in the spring to avoid attracting newly emerged flies to onion fields.
3. Proper landscape planning will also help to minimize problems with this pest. Rotate onions with unrelated crops to prevent onion crop residue near new onion fields. Although adults can fly between old and new fields, increasing the distance between fields decreases the likelihood that flies will find the new field.
4. Cull piles or compost piles containing onion residue should not be placed near new onion fields.
5. Deep fall plowing of onion crop residue reduces attractiveness to flies and buries potentially overwintering pupae, but shallow plowing is not effective.
6. Early removal of volunteer onions near new fields in the spring will also reduce the likelihood of infestation.
7. Delayed planting may help by avoiding the peak of the spring emergence but should be done with caution because onions must have good size by the long days of June in order for bulbs to reach proper size.
8. Row covers work well if they are installed in fields that did not have Allium crops the previous year, and they are only effective if placed as soon as seedlings are transplanted or emerge. Row covers should be supported by hoops to avoid damaging seedlings. Mulches or other barriers placed around the plant can also block the egg-laying fly as it walks down the stem to lay its eggs in the soil at the base of plant.

Materials Approved for Organic Production:

1. Entomopathogenic nematodes have shown variable results for controlling the onion maggot.

2. Recent research has indicated that, when used as a seed treatment, spinosad can greatly reduce infestation by the onion maggot. Advance planning is necessary, as seeds will need to be treated by seed companies. Commercial products are available as of 2011 but will probably not be widely marketed until 2013. At the time of this publication, there is not a formulation approved for organic production.

3. Certis recently labeled a spinosad bait product (Seduce). Although many vegetable and fruit crops are on the label, the only insects listed are cutworms and earwigs. As more trials are conducted with this product, other insects will be added, possibly including onion maggot.

SEEDCORN MAGGOT *(Delia platura)*

The seedcorn maggot is closely related to the onion maggot, and microscopic examination is needed to tell larvae apart when they are found feeding on onions **(Photo 8.11)**. The life histories of the two pests are very similar as well. The damage is very similar, except that the onion maggot may continue to feed on expanding bulbs, while the seedcorn maggot concentrates only on seedlings.

Cultural Control:

1. Avoid planting into actively decomposing organic matter. Because onions are typically planted while soil temperatures are low, overwintering cover crops that will be slow to decompose after incorporation should be avoided. Winter killed covers, such as oats or brassicas, are better options. Any compost applied before planting should be fully mature.
2. Manure applications immediately before planting should be avoided. Alternatively, manure applications to actively growing cover crops can be administered the previous season.
3. The seedcorn maggot is favored by early spring and cool soils, so if infestation has been a frequent problem, delaying planting until soils are warmer might be a good option to avoid peak spring emergence. Delayed planting should be done with cau-

tion because onions must have good size by the long days of June in order for bulbs to reach proper size.

Materials Approved for Organic Production:
Entrust seed treatment has shown good efficacy against seedcorn maggot (Nault, unpublished data), so the seed and bait treatments discussed in the onion maggot section may also be effective for this pest.

ONION THRIPS (*Thrips tabaci)* and WESTERN FLOWER THRIPS (*Frankliniella occidentalis*)

Thrips are small insects whose adults and larvae are similar in appearance except that adults have narrow wings that are fringed with hairs and have few or no veins when viewed with a hand lens or microscope **(Photo 2.9)**. Both adults and larvae are very small (1/16" long) and slender. Adults are light brown, while larvae are a creamy white. Onion thrips most often reproduce without mating, and many generations can be produced during a season. They prefer to feed on tender inner leaves, damaging cells with their unique mouthparts that lacerate the plant's epidermis rather than piercing it. They subsequently consume the leaked plant juices. Leaves develop silvery blotches or streaks often marked with black spots of fecal matter **(Photo 1.2)**. There are two species of thrips that attack onions: onion thrips and western flower thrips. Onion thrips are an important pest in most onion-producing areas. Western flower thrips can be a serious pest of onions in southern areas and an occasional pest of onions in the north. Both species feed on many kinds of field crops and vegetables. They overwinter as adults or larvae in plant debris or in soil.

Thrips are weak fliers, only able to fly from plant to plant; they can, however, be blown long distances by wind. Light thrips infestations tend to delay plant growth and retard maturity. Heavy infestations may destroy an entire planting. Leaves may become curled, crinkled, and twisted; growth may stop, and plants may die. Damage is more severe under hot conditions because more generations are produced in warm weather, and plants may be under stress and susceptible to infestation. Due to their small size, rainfall is a major mortality factor to thrips, so outbreaks are more likely under hot, dry conditions than under cool, wet conditions. Some varieties of onions have demonstrated some level of tolerance to thrips. Check seed catalogs for the latest developments.

Cultural Controls:
Refrain from using broad-spectrum pesticides, and encourage habitats for natural enemies. Natural enemies include predaceous mites, minute pirate bugs, and lacewings.

1. If thrips are a regular problem, identifying more tolerant varieties can alleviate losses.
2. Inspect transplants for thrips infestation, especially those brought from warmer climates.
3. Rotation away from crops that thrips will attack is difficult. Onion thrips can easily move from one crop to another, an important consideration when planning crop arrangement. Onion thrips feed on many crops including oats, wheat, barley and alfalfa. They also feed on flowering plants and many vegetable crops, such as cabbage and tomatoes.
4. Sanitation, including plowing under onion debris, is important.
5. Overhead irrigation and heavy rain provide some suppression of thrips populations by washing them off plants.

Straw mulch has been shown to reduce populations of thrips and may increase yield and onion size. Reflective silver mulches can also be useful (see: http://mysare.sare.org/mySARE/ProjectReport.aspx?do=search).

Materials Approved for Organic Production:
1. Because low numbers of thrips can be tolerated, IPM practices recommend various economic thresholds. A common one is an average of 3 thrips per green leaf. When scouting, sample about 50 plants from at least 10 different locations in the field, and

then calculate the average per leaf. If the number exceeds the threshold, consider treating, especially if the weather is predicted to be hot and dry.

2. In bulbing onions, foliar applications of spinosad (Entrust) have shown good reduction in onion thrips (Nault, 2004-2006 unpublished data), although the SpinTor (rather than the Entrust) formulation was tested.
3. Neem (azadirachtin-based) products (Aza-Direct) have shown variable results. One trial (Nault, 2009, unpublished data) showed fair results with a mixture of Neemix and Trilogy.
4. In a laboratory study, Kaolin clay (Surround) has been shown to significantly reduce the number of egg-laying and feeding adults. Kaolin clay requires reapplication during the season, especially after rains.
5. Insecticidal Soap (Safer's) and JMS Stylet oil have been mentioned in some fact sheets as materials used for thrips, but published efficacy studies were not found.

LEEK MOTH (*Acrolepiopsis assectella*)

The leek moth is a pest of onion, leek, and related *Allium* species. Though it was discovered in Canada in 1997, its presence was not confirmed in the US until it was reported in New York in 2009. A Cornell website has been developed that describes its biology, the damage it causes, and management strategies. See: http://web.entomology.cornell.edu/shelton/leek-moth/

In Ontario, Canada, there are three flight periods of leek moth per season. It overwinters as an adult moth or pupa in various sheltered areas, such as buildings, hedges, and plant debris. The first flight typically begins in late April and ends in mid-May. The third flight, which results in the overwintering stage, may start as late as the end of August.
Eggs are laid singly on lower leaf surfaces whenever night temperatures are above 50°F-53°F. Females lay up to 100 eggs over a three- to four-week period. After the eggs hatch, larvae **(Photo 1.3)** enter leaves to mine tissues (leaf miner stage). After a few days, larvae move toward the center of the plant where young leaves are forming. After several weeks of active feeding, larvae climb out onto foliage and spin their cocoons. Pupation lasts about 12 days, depending on weather conditions. Leek moth numbers and associated damage **(Photo 1.4)** typically increase as the season progresses.

On alliums with flat leaves, including leeks and garlic, larvae feed on top of and inside leaf material. They bore through folded leaves toward the center of the plant, causing a series of pinholes on the inner leaves. Larval mines in the central leaves become longitudinal grooves in the mature plant. On leeks, larvae prefer to feed on the youngest leaves but can consume leaves more than two months old. Leek moth larvae enter hollow leaves, such as those of onions and chives, to feed internally, creating translucent "windows" on the plant surface and making it more difficult to reach the larvae with insecticides. Occasionally, larvae attack reproductive parts of the host plant but usually avoid the flowers, which contain saponins that inhibit insect growth. Affected plants may appear distorted and are more susceptible to other plant pathogens. In general, damage is more prevalent near field perimeters.

Cultural Controls:
Cultural practices may be effective in reducing populations below damaging levels.

1. Crop rotation to fields distant from overwintering populations is recommended.
2. Delay planting until after the first flight.
3. Remove old and infested leaves from infested crops.
4. Destroy pupae and larvae.
5. Harvest early to avoid both damage by larvae of the last flight and population build-up for next season.
6. Plant susceptible crops away from infested areas.
7. Remove plant debris following harvest.
8. Till (i.e., bury) plant debris to help eliminate larvae and pupae that remain in the field following harvest.
9. Row covers may be effective treatments for leek moths. German literature suggests that damage to leeks may be reduced by both covering leeks with netting prior

to female activity and cutting off all outer leaves before the winter leaves appear in late season. Research in Ontario has shown that the use of lightweight floating row covers can protect developing plants from leek moth damage. In small plots or gardens, floating row covers work well. In the case of garlic, they should be placed early in the season. The cover can be kept in place with a variety of methods, e.g., trench and dirt, sandbags. The cover can be removed during the day for weeding and then reinstalled before the leek moth flight in the evening and early morning.

10. With garlic, remove and destroy the leaves and scapes of the garlic after harvest and before drying, reducing the population of pupae that can be found in the drying sheds afterwards.

Materials Approved for Organic Production:
Spinosad products have shown efficacy.

While many products are labeled for onions, in some states (like New York), the product label must also list the pest species. In New York, Cornell was able to obtain special labeling (2ee) for the use of Bt products and Entrust against leek moth. Field tests in Canada and greenhouse tests in New York have shown that Entrust has worked well. In a greenhouse test at Cornell, Bt products were largely ineffective. Because leek moth tends to be in sheltered parts of the plant, coverage is very important.

CUTWORMS (many species)

Cutworms are occasional pests of onions early in the season. In some years, they cause major losses, while in other years, there are no losses at all. Cutworms are the larvae of approximately a dozen different species of night-flying moths. Most species that attack onions overwinter as partially grown larvae that become active early in the spring when the onions are young and susceptible. Cutworms hide in the soil during the day and crawl on the surface at night. They feed and cut off young seedlings at the soil surface.

Cultural Control:

1. Since most species lay their eggs on vegetation in the late summer or fall, keeping fields clean of weeds and crops in the fall helps. Fall plowing exposes larvae to birds. Of course, this advice is counter to recommendations to keep soil covered.
2. Alternatively, delayed seeding in the spring can also be effective. Cultivating fields in the spring, after vegetation has appeared and grown a few inches, can starve cutworms before the onions are planted. A few shallow cultivations during this “starving period” can expose cutworms to birds and other predators. Take caution not to delay planting too long, as onions must be planted fairly early in order to be mature enough to produce large bulbs when the long day bulb initiation signal is received in June.

Materials Approved for Organic Production:

1. Entomopathogenic nematodes have shown good efficacy when environmental conditions are favorable (warm, moist, but not soggy soil). *Steinernema carpocapsae* has been shown to be very effective against cutworms, although reports are not specifically in onion production. Success with nematodes depends on proper application methods and good environmental conditions (moist soil). Irrigation may be necessary to keep the soil moist for at least two weeks after application. Be sure to carefully follow the instructions from the supplier.

2. Baits - Spinosad or Bt will kill the caterpillars, but getting the pest to consume the insecticide as a foliar application before significant damage is done is difficult. However, some farmers have reported good results using these materials in baits. In order to rid the area of pests, the bait is spread on the ground near the plants or prior to planting.

a. Spinosad - Seduce is a new commercial bait available from Certis. It is labeled for both onions and cutworms, so its use should be legal in all states. The product has not received much testing in university trials yet, but farmers are reporting good results.

b. Bt - a bait made from Bt is often recommended and has received good reports. The following method of using Bt is not described on the label. This off-label use is permitted by EPA under FIFRA 2ee, but growers should check with their state pesticide regulators about their specific state regulations. The bait is made by: determining the application area; mixing the highest concentration solution of Bt allowed on the label; and then mixing in a bit of molasses, alfalfa meal, or bran. Dampen the mix if necessary. Spread the bait along the planted or planned rows in the evening.

II. DISEASE CONTROL

DISEASES CAUSED BY BACTERIA

SLIPPERY SKIN *(Pseudomonas gladioli* pv. *allicola)*

Slippery skin occurs sporadically, depending on weather and soil conditions. Often, there are no external symptoms. The bulbs may become soft and watery, and, while still in the field, a few leaves in the middle of the leaf cluster may wilt and turn pale. The bulb may be sound at harvest and show no symptoms. The disease progresses after harvest. The inner portion of the bulb rots and becomes soft and watery. It is named "slippery skin" because squeezing the bulb can often result in the rotted portion popping out the top.

Slippery skin is more common when there is a lot of water from rain or irrigation on the surface of the soil. The pathogen is soil-borne and is transferred by splashing and accumulation of water at the neck of the onion. The bacteria move down the leaf to the corresponding bulb scale. High temperature favors the disease.

Cultural Control:

1. Avoid excessive overhead irrigation, especially late in the season.
2. Harvest bulbs when the weather is dry and bulbs are fully mature.
3. There is some varietal tolerance to slippery skin. The varieties Talon, Spanish Medallion, and Redwing ranked first, second, and third, respectively, for tolerance in a trial conducted in Washington State.

SOUR SKIN *(Burkholderia cepacia)*

Similar to slippery skin, squeezing an onion bulb infected with sour skin will cause the central portion to pop out, but with sour skin the central portion is not the rotten part. It will be firm and usable **(Photo 1.5)**. The disease gets its name from the pungent sour odor of infected bulbs. Sour skin causes scales of the bulb to become translucent and viscous. Scales adjacent to rotting ones may be fine.

The bacterium is soil-borne, may be present in irrigation water, and only enters plants through wounds. High rainfall and irrigation associated with warm temperatures promote the disease.

Cultural Control:

1. Avoid excessive overhead irrigation, especially late in the season.
2. Minimize wounding of leaves during fieldwork and harvest.
3. Harvest only when onions are fully mature and weather is dry.

4. There is some varietal tolerance to sour skin. The varieties Redwing, White Cloud, and Bello Blanco ranked first, second, and third, respectively, for tolerance in a trial conducted in Washington State.

Materials Approved for Organic Production:
None.

DISEASES CAUSED BY NEMATODES

STEM AND BULB NEMATODE (*Ditylenchus dipsaci*)

The stem and bulb nematode, also called the garlic bloat nematode, is a becoming an important garlic pest in the Northeast. Although first reported in the 1930s, it appeared as a major pest in New York in 2010 and is now found throughout the Northeast. The most common means of spread is by infested garlic bulbs used for seed. The microscopic worms feed by piercing root and leaf cells with their stylet. Leaves of severely infected plants turn yellow and dry prematurely. Plants may be stunted. The roots may be missing **(Photo 1.6)**, and the basal plate may appear to have a dry rot similar to Fusarium basal plate rot.

The pest is favored by wet, cool conditions. Although the pest is not active in hot, dry weather, such weather may exacerbate symptoms. The nematode survives freezing and hot weather in soil and plant debris.

Cultural Control:

1. The best way to avoid garlic bulb nematode is to use uninfested garlic for seed.
2. Monitor for symptoms of infestation during the growing season and submit suspect plants to a diagnostic lab for confirmation. Contact the lab to get instructions regarding how to take and where to send the sample.
3. DO NOT use garlic that is known to be infested for seed. Even bulbs that show no symptoms may have low levels of infestation. Do not sell any garlic for seed from a potentially infested lot. Do not replant garlic in an infested field for at least four years. Other hosts include all Alliums, celery, parsley, and salsify.
4. Mustards, sorghum-sudan grass, and other bio-fumigant cover crops have been shown to reduce nematode populations.
5. These nematodes can survive in dry debris, making sanitation of equipment and storage areas important.

Materials Approved for Organic Production:
None.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

BOTRYTIS LEAF BLIGHT *(Botrytis squamosa)*

Botrytis leaf blight (BLB) is one of the most common fungal diseases of onion. Severity depends on the abundance of overwintering inoculum, the number and duration of high humidity and leaf wetness periods, and moderate (50-70°F) temperatures. When conditions are favorable, it can devastate an entire field. The disease often causes smaller bulbs and lower yield. Symptoms begin as whitish, spindle-shaped lesions on the leaves, usually with a greenish halo, which later develops into a sunken yellowish spot with a characteristic slit oriented lengthwise to the stem **(Photo 1.7)**. Symptoms tend to appear first on older leaves. As the disease progresses, the lesions coalesce, and leaves yellow and die. Massive numbers of conidia (spores) are released from infected leaves and are wind-blown to new plants. Botrytis overwinters as sclerotia, which are formed on infected tissue and appear as tiny black specks. Dead leaves and culls left in the field or in cull piles over winter are the source of new infections. The sclerotia germinate in the spring and release spores, which infect young onion plants.

Cultural Control:

1. Rotating away from onions is the single most important cultural management practice. Crop rotation is most effective if the new field is well apart from the old field.
2. Minimizing the leaf and cull bulb tissue left on the soil surface after harvest is key to management. Culls should be destroyed, not piled. Volunteer onion plants in the spring should be rogued. Crop residue should be removed from the field at harvest or plowed deeply.

Minimizing periods of leaf wetness is key. Wide between- and within-row spacing allows more air movement. Double or triple rows will lead to a problem in wet years. Overhead irrigation should be done very early in the morning on sunny days to allow for quick drying and avoid extending the period of leaf wetness from dew.

Materials Approved for Organic Production:

1. Serenade (*Bacillus subtilis*) has been shown to be effective in at least one study.
2. In one trial, a copper based fungicide showed poor results.

BOTRYTIS NECK ROT (*Botrytis allii*)

Botrytis neck rot is primarily a problem with onion bulbs in storage but can also occur in garlic, leeks, and shallots. Although the infection takes place in the field, usually when the bulbs are harvested, the symptoms are expressed in storage. The onion bulb develops a wet decay, beginning in the neck and gradually spreading over the whole bulb **(Photo 1.8)**. The scales become dark gray to black, soft, and translucent.

The fungus overwinters primarily as sclerotia or sometimes as spores produced in the rotting onion. Seeds may also carry the pathogen. Infection only takes place in the field if the bulbs are moist, especially if there is any mechanical wounding. The fungus is unable to penetrate well-dried neck tissue.

Cultural Control:

1. The most important practice is to only store healthy bulbs with well-cured necks.
2. Use only disease-free seed.
3. Do not apply any additional nitrogen fertilizer to crop after mid July, so necks are dry at harvest.
4. Quick curing helps prevent infection, so it is best to harvest fully mature bulbs during dry weather. If the weather is not good for curing, onions should be cured artificially at 93° to 95°F for five days.
5. Do not allow harvested onions to sit in wet, humid conditions. Consistent cool, dry storage is important.
6. Eliminate cull piles, and rotation of at least two years helps if onion fields are well separated.

Materials Approved for Organic Production:

None.

BOTRYTIS ROT OF GARLIC (*Botrytis porri*)

The first symptoms may be seen in the field as stunted garlic plants with outer leaves dying back. The diseased garlic cloves are brown and necrotic. The key diagnostic symptom for growers is large clumps of black sclerotia around the neck **(Photo 1.9)**. A gray mold and water-soaked cloves may appear.

The pathogen persists in the soil as sclerotia or on diseased plant debris and seed. Moist, cool weather encourages the sclerotia to germinate and produce wind-blown spores that infect nearby garlic fields. When conditions are favorable, the disease spreads by masses of spores released by infected plants. Cool weather and excessive irrigation or rain favor the disease. Warm weather slows the progress of the disease.

Cultural Control:

1. Use clean garlic "seed."
2. Manage irrigation to minimize periods of leaf wetness.

Materials Approved for Organic Production:
None.

PURPLE BLOTCH *(Alternaria porri)*

Purple blotch is a very common and sometimes destructive disease that affects onions, garlic, shallots, and leeks. Lesions begin as whitish, sunken areas that elongate and develop purplish centers **(Photo 1.10)**. Under favorable conditions (i.e., warm with wet leaves), the lesions become large and oval with concentric rings of dark brown spores. The lesions may merge and kill entire leaves, which may become covered with brownish spores. Older leaves are more susceptible than younger leaves. This pathogen may also result in a watery rot at the neck of onions or garlic and lead to poor storage life.

Onion residue is the source of inoculum in the spring. The fungal mycelia and conidia (spores) persist as long as onion debris remains in the field or in cull piles. New conidia are produced on infected tissue in the spring and subsequently wind blown or carried in water to the new crop. The leaves must be wet for the spores to germinate, but germination is very quick, less than an hour. Symptoms may appear less than a week after germination, and new spores are produced quickly.

Cultural Control:

1. Sanitation is very important to limiting spread. Infected crop debris should be destroyed or buried after harvest. Cull piles should be eliminated.
2. Grow onions in rotation with non-host crops.

Materials Approved for Organic Production:

1. Serenade has been shown to be effective against purple blotch.
2. Copper has shown mixed results in trials, fair at best.

WHITE ROT (*Sclerotium cepivorum*)

White rot is a very serious problem because it may spread fast, and, once in a field, it can persist for many years. Luckily, it is a spotty disease that is currently present in only a small number of fields around the northeast. Those farms can no longer grow Allium crops in infested fields.

White rot is one of the most destructive fungal diseases affecting onion crops, and it is only damaging to plants in the onion family. It is not the same pathogen as white mold, which attacks many other crops such as beans, carrots, lettuce, tomato, pepper and others. Symptoms of white rot on the leaves include premature yellowing and dying of the older leaves, followed by death of the plant. In garlic, these symptoms are similar to those of some other diseases and are not particularly diagnostic, but the presence of white, fluffy fungal growth (mycelia) on the root end of the bulb is the defining characteristic. Eventually, the fungal growth moves around the bulb and inward between the storage leaves of onion and cloves of garlic **(Photo 1.11)**. Small, black sclerotia (tiny, hard, black bodies of dormant mycelia) form in the decaying tissue and throughout the white, fluffy mycelia **(Photo 1.12)**. Secondary infection by other fungi and bacteria may also occur.

The pathogen is not known to produce spores. This fungus reproduces only by the sclerotia, and it also spreads by direct contact, i.e., when the mycelium growing on one plant reaches the roots of the neighbor plant in the row. The sclerotia can lie dormant in the soil for many years until roots of a host plant grows nearby and the sclerotia are stimulated to germinate (see below). Transfer of the pathogen can happen on boots and tillage or other equipment. It can also move with soil during heavy rains. Additionally, animals feeding on diseased bulbs can defecate viable sclerotia.

Cultural Control:

1. The best control is good sanitation. Use clean seed cloves for garlic and clean onion sets and transplants. If only a small number of plants are infected, which is usually true of the first year it is found on a farm, pull and destroy the infected plants before sclerotia are formed.
2. An interesting idea for speeding up the eradication of white rot sclerotia from the soil is to stimulate them to germinate in the absence of an Allium crop. Sclerotia will sit dormant in the soil for 20 or more years until a chemical signal is received that onions or garlic are growing nearby. Over the past decade, researchers have been studying methods that stimulate the sclerotia to germinate without presence of an Allium crop on which the pathogen can complete its life cycle (Coventry et al 2006, also, see: http://oregonstate.edu/dept/coarc/sites/default/files/publication/00_sclerotium_garlic_powder.pdf). This "biostimulation" reduces the number of sclerotia in the soil. There is no specific recommendation yet; however a few practices that may reduce sclerotia in the soil include:
    a. Stimulate the sclerotia to germinate by growing scallions and harvesting before the disease completes its life cycle.
    b. For several years before trying to return to an Allium crop, spread compost made from onion or garlic waste in the spring or fall.
    c. For a few years before trying to return to an Allium crop, apply a sprayable concoction made from ground onion or garlic waste, or use garlic powder as a soil amendment.
3. If the disease is known to be present, or if onions from other farms are being stored and packed together, equipment, storage bins, etc. should be thoroughly pressure-washed and disinfected for ten minutes with a 0.5% solution of sodium or calcium hypochlorite (e.g., Commercial Solutions Ultra Clorox Germicidal Bleach, EPA Reg. No. 67619-8, from Clorox Professional Products Company). Then rinse with potable water.
4. Seed producers should execute extra diligence and may want to regularly disinfect any surface in contact with garlic.
5. Since chlorine materials will be inactivated by organic matter stuck on boots, quaternary ammonium compounds may be used as boot dips inside storage areas and packing sheds and before entering and after leaving fields. Quaternary ammonium compounds should not be used on any apparatus that is in direct contact with garlic, onions, or any other crop. Disposal of the dip solution must be in a manner that does not contaminate the soil, water, or crop. Note: not all quaternary ammonium products are labeled for boot washes, so read the label.

Materials Approved for Organic Production:
At this time, none have shown efficacy.

FUSARIUM ROT (*Fusarium oxysporum f.sp. cepae)*

Fusarium oxysporum is a ubiquitous soil-dwelling fungus that causes rots and wilts of many vegetables. The species comprises a number of strains called forma specialis (f. sp.), each of which causes disease on a particular crop or group of crops. The f. sp. *cepae* attacks onions, garlic, leeks, shallots, and chives. The pathogen invades the basal plate, and roots decay and die **(Photo 1.13)**. Diseased plants can be pulled easily from the soil. Roots injured by root maggots or machinery are more susceptible to infection. Affected plants turn yellow and wilt. A tan to pink rot forms at the base of the bulb and works toward the tip. Under moist conditions, white mycelium may grow around the rotting area, making it look a bit like white rot. *Fusarium* may also cause tan spots with white centers on the sides of garlic cloves.

Fusarium persists as resting spores in the soil or on crop residue for many years and can be spread by water, tools, equipment, and garlic seed or onion sets. Warm, moist soil favors development of the disease. If infection is late in the season, symptoms of the disease may not appear until bulbs are in storage.

Cultural Control:

1. A three-year rotation to crops other than Alliums is recommended.
2. For storage, dry bulbs quickly and store in a cool (32°-36° F), dry place (See: http://www.nysipm.cornell.edu/organic_guide/stored_fruit_veg.pdf).

Materials Approved for Organic Production:
At this time, none have shown efficacy.

PINK ROOT (*Phoma terrestris*)

Pink root affects onions but not other Allium crops. The fungus is a saprophyte and only a weak pathogen. It usually infects weak or stressed plants or follows injury or infection by another root pathogen. The hyphae of the fungus invade the roots, and the infected root turns pink and may shrivel and die. Sometimes infections are limited, and only a few roots show symptoms. In a severely infected plant, all of the roots are damaged, and leaves will either yellow and wilt or turn yellow with a red hue. Severe infections can reduce bulb size and yield.

Cultural Control:

1. Crop rotation will not eliminate the fungus from the soil, but repeated onion crops will lead to more severe pink root.
2. Optimum growing conditions to keep pink root in check include good soil tilth, fertility, and organic matter; adequate irrigation and management of other pests will also help.
3. There is some varietal tolerance to pink root. The named sweet onion cultivars Pegasus, Liberty, and Sweet Melody showed the highest levels of resistance in a trial conducted in Georgia in 2002. Five numbered varieties showed tolerance higher than Sweet Melody, so additional tolerant named varieties may be available.

Materials Approved for Organic Production:
At this time, none have shown efficacy.

PENICILLIUM DECAY (*Penicillium sp.*)

Penicillium decay is a common problem in garlic and onions; however, it rarely causes major crop loss. Occasionally, the disease reduces plant stand. More often, it is seen on a few bulbs in storage. In the field, clove decay will lead to wilted, yellowing, or stunted seedlings. Decaying bulbs in storage may be consumed by white mycelium, which turns blue as spores are produced **(Photo 1.14)**. Often, the blue mold is only seen on some of the cloves in the garlic head.

This fungus survives in soil and on all types of plant and animal debris, but these are not major sources of infection in garlic. Infections primarily come from planting infected cloves and from plant debris left in the field. Wounding non-infected cloves when cracking diseased heads apart for planting can lead to infection. In onions, *Penicillium* invades wounds, diseased tissue, and freeze-damaged tissue.

Cultural Control:

1. Careful handling of garlic seed pieces is important to reduce wounding at planting time. Keep the time between cracking heads apart and planting to a minimum.
2. Bulbs should be harvested with care and stored at 32-36°F.

Materials Approved for Organic Production:
At this time, none have shown efficacy.

DOWNY MILDEW (*Pernospora destructor)*

Downy mildew occurs only sporadically in the northeast, but disease development can be explosive, and epidemics can develop rapidly. This disease is caused by a fungus-like water mold (not a true fungus). The first symptom is pale green to brownish-yellow oval or circular shaped areas on the leaves, which may appear velvety. Symptoms often appear first on older leaves.

Spores are produced on nights with high humidity and temperatures between 39 and 77°F. The infected area appears violet in the morning, but most of the spores are dispersed by wind during the day, leaving a whitish mycelial growth. Leaves become girdled at the site of the lesion, fold over, and die from the affected point toward the tip. Dead leaves do not support further spore production. Downy mildew seldom kills the plant, but yields and storage quality are greatly reduced.

This pathogen overwinters as mycelia in diseased tissue, primarily on volunteer onion plants, bulbs left in fields for seed production, cull piles, or in perennial varieties of onions. In the spring, the mycelia produce spores that spread the pathogen to the new crop. The newly infected plants produce spores that are windblown and further spread the pathogen. Under favorable conditions (cool temperatures and high humidity), it takes only 10-16 days for a new lesion to produce spores, so an epidemic in a field can develop quickly. It can also overwinter as thick-walled oospores in the soil, which germinate and systemically infect seedling onions planted the following year.

Cultural Control:

1. Cull onions should be destroyed.
2. Perennial onions should not be grown if downy mildew has been a problem in the area.
3. Crop debris should be plowed deeply.
4. Onions should not be grown in the same field in consecutive years.

Materials Approved for Organic Production:
Sonata and Serenade have shown efficacy.

SMUT (*Urocystis magica*)

Onion smut occurs worldwide but is most common in areas that have cool summers. All Alliums can be infected, but garlic is much less susceptible than onions, leeks, and shallots. Only onions grown from seed are susceptible. Infection is only possible in young plants from the second day after germination until the seedling has its first true leaf, a period of about 10-15 days after seeding. Spores can remain viable in the soil for many years. Spores may be stimulated to germinate by root exudates from growing onions, at which time the fungus is able to penetrate the onion seedling between the root and the cotyledon. Once in the onion, it can invade each new leaf base and bulb scale as they grow; however, the germinating spore is unable to directly invade a true leaf. Thus, seedlings and sets are immune to new infection once they have true leaves above ground.

The first symptoms are dark lesions on the cotyledons soon after they emerge from the soil. The infection can then progress inward from leaf to leaf, forming lesions that eventually turn black with powdery spore masses. Plants become stunted and may die. This pathogen does not cause infected bulbs to rot, but they may become infected with secondary rotting organisms.

Cultural Control:

1. Grow onions from seedlings that have been raised in clean soil or from sets free of the disease.
2. Avoid contaminating smut-free fields with infested soil or infected crop residue.
3. There are some smut resistant varieties.

Materials Approved for Organic Production:
At this time, none have shown efficacy.

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ORGANIC INSECT AND DISEASE CONTROL FOR Brassica Crops

INTRODUCTION

Brassica vegetable plants belong to the mustard family, Brassicaceae (=Cruciferae). They are also called crucifers and cole crops. This diverse family, whose members have various edible plant parts, such as roots of radish and turnips, stems of kohlrabi, leaves of cabbage and other leafy brassicas, and seeds of mustard and rape, are consumed as fresh, cooked, or processed vegetables. Other members of this family include broccoli, Brussels sprouts, cauliflower, collards, kale, and rutabaga. Many weed species are also in this family and can harbor insect and disease pests.

I. INSECT CONTROL

CABBAGE APHID (*Brevicoryne brassica*)

The primary aphid pest is the cabbage aphid **(Photo 2.1)**, whose colonies resemble clumps of "white ashes." They suck plant sap, causing leaf distortion and poor growth. Cabbage aphids are particularly difficult to control once they enter sheltered parts of the plant, such as cabbage heads or Brussels sprouts. While cabbage aphids can damage crops in the summer, they tend to be more problematic in the fall. In recent years, late season aphid outbreaks have been increasing in fall brassica crops on organic farms, though the reasons are not clear. Green peach aphids are also an occasional problem on brassica crops early in the season or in the greenhouse. They are notorious for transmitting virus diseases, which render some brassica crops unmarketable. The presence of live aphids, or even dead aphids that have been parasitized, may make the product unmarketable.

Cultural Control:

1. Encourage natural enemies by diversifying the habitat and food sources, and refrain from use of broad-spectrum insecticides. The primary parasite of cabbage aphids in the Northeast is a very small, black wasp, *Diaeretiella rapae*, which lays its eggs inside the aphid. The parasite larva feeds inside the aphid, turning it a bronze color **(Photo 2.1)** and killing it. After about two to three weeks from the time the parasite lays eggs, an adult parasite emerges from the dead aphid. Generally, there is a lag period between the outbreak of aphids and control by the parasite, so some other control that does not harm the parasite is warranted.

   A diversified cropping system with several potential aphid hosts can allow *D. rapae* to maintain itself throughout the season, especially when aphid host abundance is low on one crop.
2. Many other insects, such as ladybird beetles and *Aphidoletes aphidimyza*, a naturally occurring midge that is also commercially available, can also be effective biological control agents against aphids (Shelton).

Materials Approved for Organic Production:

1. Soap: Scout brassica plantings once or twice per week, especially in the fall, and apply insecticidal soap sprays if aphids are found. Do not wait until aphids reach high numbers and dense colonies; apply when numbers are low. Repeat applications two or three times, and ensure coverage of the parts of the plant where aphids live, including undersides of leaves and in the buds, shoots, or heads of Brussels sprouts, broccoli, cabbage, etc. In recent studies, soaps have been ineffective against green peach aphid. Other recent studies indicated five good, one fair, and two poor results against other aphid species.

2. Rotenone is recommended in the older literature, BUT it is no longer a registered insecticide and may not be used.
3. Neem products can provide some control. Based on a limited number of studies, neem products gave good control on turnip aphid (two studies); fair (four) to poor (three) control of green peach aphid; and mostly good control of other aphids (two good, two fair, one poor). Please see the neem fact sheet for a discussion of the different types of neem products.
4. Summer oils may provide some control (two fair and three poor results).
5. Kaolin clay reduces aphid populations but leaves a white residue that may affect marketability.

CABBAGE LOOPER (*Trichoplusia ni*), DIAMONDBACK MOTH (*Plutella xylostella*), IMPORTED CABBAGEWORM (*Pieris rapae*)

The larvae of these Lepidoptera (moths and butterflies) eat the leaves of plants and may contaminate the marketable portion of brassica crops by either their presence or their fecal matter. The imported cabbageworm **(Photo 2.2)** is the most common of these three; it overwinters locally throughout the Northeast, so it is generally a pest every year. It overwinters as a pupa in crop debris, fence rows, and weedy fields. During the day, the large white butterflies of the cabbageworm **(Photo 2.3)** can easily be seen feeding on nectar from wild and cultivated crops or moving from plant to plant laying eggs. Adult flights are a good warning of later potential problems on cultivated crucifers.

In the Northeast, the cabbage looper **(Photo 2.4)** does not overwinter outdoors; the diamondback moth's **(Photo 2.5)** ability to overwinter in northern areas is also spotty. The diamondback moth and cabbage looper are commonly carried north on weather fronts from southern overwintering sites. Because this migration does not occur every year, populations are highly variable. Invasions of diamondback moth and cabbage looper may also arise from infested transplants, especially those from southern areas. All three pests may produce multiple generations each summer. To detect young caterpillars and early feeding damage, scout brassicas by searching the undersides of leaves. Scouting is especially important just before head formation begins, or when marketable leaves are small.

Cultural Control:

1. To avoid all three species, purchase only clean transplants, or raise seedlings in clean greenhouse settings. Infested transplants are most common from southern regions.
2. Cruciferous weed control near crop fields is important not only because weeds can act as an overwintering site for the imported cabbageworm, but also because they may support populations of all three pests during the crop season. In weedy fields, populations can build to epidemic levels from one generation to the next.
3. After harvesting early season brassica crops, the crop debris should be tilled into the soil to destroy larvae and pupae that could lead to higher populations on subsequent brassica crops.
4. Trap crops have had variable success. Trap crops are plants that are more attractive to moths for egg laying; however one has to be careful that populations that build up on the trap crop do not expand into the cash crop. See Appendix C for a more thorough discussion of trap cropping.
5. Encourage natural enemies. Several species of predatory and parasitoid wasps, as well as some generalist predators, prey on these caterpillars.

Materials Approved for Organic Production:

1. Spinosad can provide very good control (ten recent studies showed good control, three fair, and one poor).
2. Bt gives some control of all three species but is best on imported cabbageworm. Recent studies showed 21 good, 13 fair, and 9 poor results. For fall crops, spray on the morning of a warm day when caterpillars will be actively feeding.
3. Neem products (four good, three fair, and seven poor results from recent studies) may require several applications. Please see the neem fact sheet for a discussion of the different types of neem products.

4. Rotation of a Bt product (e.g. Bt *aizawi* or Bt *kurstaki*) with another insecticide with a different mode of action (e.g., spinosad or neem) will help to avoid resistance development in the pests. The best practice for delaying resistance is to apply only one class (based on mode of action) to each insect generation. Do not mix two insecticides.

CABBAGE MAGGOT (*Delia radicum*)

Adult cabbage maggots are flies that lay eggs at the base of plants. Damage is caused by larvae feeding on plant roots **(Photo 2.6)**, and the first symptom of infestation is wilting during the day. Infested plants are stunted and often die, especially during hot and dry conditions. Note that high soil organic matter seems to attract cabbage maggot flies.

Cultural Control:

1. Timing and avoidance - **(Photo 2.7)** illustrates the life cycle of the cabbage maggot. Insects overwinter as pupae, and adult flies emerge and become active about the same time that forsythia and yellow rocket are in bloom. More detailed emergence guidelines can be obtained by using degree-day models obtained from the local Cooperative Extension system. Although there are two to three generations each year, the first, arising from overwintering pupae, is the largest. Cabbage maggot eggs are very sensitive to high soil temperatures (above 95°F) and will die if exposed to these temperatures for several days in a row. If no mustard family crops are planted before about July 1 and early brassica weeds are well controlled, cabbage root maggot pressure on later plantings will be minimal. However, fall root crops, such as turnip, rutabaga, and daikon, can be damaged by later generations, which are active when soils are cooling down in late August and early September.
2. Exclusion methods can be very effective. Since flies lay their eggs on the soil around the base of the plant, placing a barrier at the plant base will prevent egg laying.
   a. In Europe, small-scale growers use 'circles' of a material (e.g., heavy cloth, felt, or a firmer substance) to block eggs from being laid in the soil. The circle should be 5 inches in diameter and slit to the center so that it fits tightly around the base of the plant.
   b. Adults can also be excluded by using spunbonded or netted row covers. Place the row covers on at the time of seeding, and seal the edges with soil. To avoid flies from emerging from overwintering sites under the row covers, do not plant where brassicas were grown during the previous year.
3. To minimize overwintering populations, plants should be tilled under as soon as possible after the last harvest.
4. Members of the Brassica family are the only hosts for cabbage maggots; therefore destroying wild relatives will help reduce cabbage maggot populations. This practice will also help with disease control; however, it may also reduce potential alternate host habitats for natural enemies.
5. Some growers have adopted their own methods, and there may be merit in trying such approaches. A grower in southeast PA claims success using sticky tape reels over early brassica rows and foliar sprays based on the microbial product, EM5. "Effective Microorganisms" (EM) are used in a Japanese system known as Nature Farming (Diver 1998).

Materials Approved for Organic Production:

1. Nematodes have shown some efficacy, but cultural controls (e.g., barriers and row covers) likely provide more cost effective control.
2. Recent research has indicated that, if used as a seed treatment, spinosad can greatly reduce infestation by the onion maggot, a closely related species. At the time of this publication, however, there is no formulation approved for organic production. Seeds must be treated by seed companies, so advanced planning is necessary.
3. Certis recently labeled a spinosad bait product (Seduce). Although many vegetable and fruit crops are on the label, the only insects currently listed are cutworms and earwigs. As more trials are conducted with this product, other insects may be added, possibly including cabbage maggot.

CRUCIFER (*Phyllotreta cruciferae*) and **STRIPED FLEA BEETLE** (*Phyllotreta striolata*)

These small black beetles **(Photo 2.8)** can hop or fly from plant to plant, where they feed on leaf margins or make small holes in leaves. Damage is most severe to seedlings; though plants can often outgrow the damage, the harvest will be delayed. With salad greens, kale, bunched turnips, or any harvest that includes leaves, the damage reduces marketable yield.
Most flea beetles do not overwinter in cultivated fields. They spend the winter as dormant adults in leaf litter in headlands, treelines, fencerows, etc. Adults emerge from overwintering sites in early spring and begin feeding on the first cruciferous weeds. Eggs are laid in soil at the base of plants and larvae feed on the roots. A summer generation of adults emerges in late July and August.

Cultural Control:

1. Crops mulched with straw or other organic materials appear to suffer less damage.
2. The most effective control of flea beetles, however, is often the use of spunbonded row covers to exclude the beetles. Place the row covers on at the time of transplanting or seeding, and seal the edges with soil. New netted, rather than spunbonded, row covers (e.g., Proteknet insect netting from Dubois Agrinovation) are gaining popularity.
3. Controlling brassica weeds can reduce flea beetle populations.
4. Perimeter trap cropping may work with flea beetles because they move into the field from the edges. Completely encircle the field with glossy leaf collards or Chinese giant mustard one to two weeks before establishing the main crop to allow the trap crop to reach an adequate size before the main crop does. Be careful that flea beetles do not move from these trap crops to the cash crops. It may be necessary to treat or destroy the trap crop in order to reduce the number of summer adults.
5. Time planting to include fall-harvested crops only. If uncovered brassica crops are only grown after early July and brassica weeds have been strictly controlled, flea beetle pressure may be minimal.
6. Crop rotation can provide some control. Avoid planting spring crops close to last fall's plantings, especially near woody or shrubby borders. Plant late brassicas (those planted after mid June) in a different field from spring brassicas, so summer adults emerging from spring crops do not attack new, late summer plantings.

Materials Approved for Organic Production:

1. Since flea beetles can recolonize rapidly, especially on sunny days, frequent treatment with any material may be required. Treat all brassicas in the field to reduce influx from untreated areas.
2. Research trials have indicated that spinosad can be effective, though results are variable (one good, three fair, and three poor results).
3. Even with high rates, Pyganic has shown variable results (one good, three fair, one poor).
4. Neem products are similarly effective (two fair, two poor results). Please see the neem fact sheet for a discussion of the different types of neem products.
5. Capsaicin gives some control (45% in one study). No products are currently OMRI listed.

ONION THRIPS (*Thrips tabaci*)

Onion thrips **(Photo 2.9)** can be a severe pest on many crops, including cabbage. On some cabbage varieties, their feeding causes bronze discolorations **(Photo 2.10)**. Many cabbage varieties have high levels of tolerance or resistance. The key to control of thrips on cabbage is to use tolerant varieties. A list of varieties and their tolerance levels can be found in the Cornell Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production (http://www.nysaes.cals.cornell.edu/recommends/) in the cabbage chapter. Also check seed catalogues since some companies list thrips susceptibility for each variety.

Cultural Control:

1. Avoid susceptible varieties.
2. Since onion thrips often migrate into cabbage from surrounding fields of wheat, oats, and alfalfa, separating cabbage fields from these crops will help reduce the potential for infestation.
3. Avoid planting onions close to brassicas, because the same species of thrips attacks both crops.

Materials Approved for Organic Production:
Spinosad – recent studies demonstrated one good, six fair, and two poor results.

SWEDE MIDGE (*Contarinia nasturtii)*

Swede midge is a serious insect pest of cruciferous plants, such as cabbage, cauliflower, and broccoli because the larvae feed on and disfigure or destroy the growing tips of the plant. The first discovery of swede midge in the US was in 2004 in western NY. The insect is native to Europe and southwestern Asia and has been known in North America only since 2000, when it was identified in Ontario, Canada. Swede midge has the potential to spread to most crucifers growing areas in the US and Canada. A Cornell website has been developed that describes its biology, the damage it causes, and management strategies. See http://web.entomology.cornell.edu/shelton/leek-moth/

Eggs are laid on the multiple growing tips of plants, but plant damage is caused by the larvae, which are small maggots. Larvae produce a secretion that breaks down the plant cell wall, allowing them to feed on the liquid contents. Larval feeding changes the physiology of the plant and results in the formation of swollen, distorted, and twisted tissue.

The swede midge spends the winter as pupae in the soil. Adult flies **(Photo 2.11)** emerge from overwintered pupae from May through June. Mating occurs soon after emergence, and the females lay eggs in the newest growing points of the plant. Subsequent overlapping generations are produced during the summer months, ensuring problems with this pest over the entire growing season.

Swede midge injury **(Photo 2.12)** is often difficult to distinguish from other factors that can damage the growing tip of a plant, such as mechanical injury from cultivation, insect and animal feeding, molybdenum deficiency, herbicide injury, genetic variation of the plant, and heat or cold stress. For confirmation of injury due to swede midge, the larvae can be found on or within the plant by putting suspected damaged plant tissue in black plastic bags and leaving them in the sun for an hour or less. The light colored larvae will leave the plant tissue and be visible on the black plastic.

Cultural Control:

1. Use clean transplants.
2. Implement a two- to three- year rotation to non-crucifer crops. Control cruciferous weed hosts during the rotation period. Adults are weak flyers but may be carried by wind to new fields, so rotate as far from an infested field as possible.
3. Destroy crop as soon after harvest as possible.

Materials Approved for Organic Production:
None have been shown to be effective.

II. **DISEASE CONTROL**

One of the most important measures in disease control is to start with healthy plants. This practice may seem obvious; however disease symptoms can be easily overlooked. Sources of pathogens include infested seed, debris from previously infected plantings, and infected weeds. Hot water treatment may be warranted in either saved seeds or seed lots with suspected disease. Many growers use transplants for brassica crops. If using transplants, ensuring that they are disease-free is extremely important. One way is to grow transplants rather than purchasing them, so they can be inspected weekly for disease symptoms. If plants are purchased commercially, be certain to carefully check transplants for disease symptoms before planting.

DISEASES CAUSED BY BACTERIA

BLACK ROT (*Xanthomonas campestris* pv. *campestris*)

The black rot pathogen frequently enters the plant through pores on the leaf margin and spreads systemically. Infected plants develop yellow to tan, V-shaped lesions at the leaf margins **(Photo 2.13)**. Within the yellow lesion, veins can become black. The bacterium can survive on seeds and in infected crop debris. Black rot is common in seedlings, but plants can be infected at any age. The pathogen can be spread by splashing water, workers moving from an infected field to a healthy field, insects or animals, and on transplants. Because the disease can be seed-borne, inspecting all greenhouse transplants for black rot is important. Systemically infected seedlings will become yellow, drop lower leaves, and may die. Any yellowing plants or plants with V-shaped lesions should not be planted in the field, as they will serve as a source of bacteria that may spread to other plants.

Cultural Control:

1. Plant varieties with some level of resistance or tolerance. A list of varieties and their tolerance can be found at the Cornell Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production (http://www.nysaes.cals.cornell.edu/recommends/) in the cabbage chapter.
2. Use hot water treated seed. For cabbage and Brussels sprouts, soak seed for 25 minutes in 122°F water; soak for 20 minutes for Chinese cabbage, broccoli, and cauliflower. Precise time and temperature control is essential to minimize damage to the seed.
3. Destroy crop debris after harvest.
4. Avoid overhead irrigation.
5. Use a three-year rotation away from crucifer crops.

Materials Approved for Organic Production:

Copper compounds can be used, but have not been effective in recent studies (two poor results). Copper can be effective if applied before the plant is infected.

HEAD ROT (several bacteria including *Psuedomonas* and *Erwinia* spp.)

This disease is most serious on broccoli, causing a rotting of the head that starts in the center. Warm, wet conditions favor the development of head rot.

Cultural Control:

1. Use well-domed varieties.
2. Harvest when heads are tight.

To avoid providing bacteria a place to become established, cut stalks at an angle, so water cannot collect on the cut stalk left in the field.

Materials Approved for Organic Production:

Copper is somewhat effective.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

ALTERNARIA LEAF SPOT (*Alternaria brassicae, A. brassicicola, A. raphani*)

The most common symptom of this disease is leaf spotting **(Photo 2.14)**, but damping-off and damage to the flowers and seed also occur. Leaf lesions begin as small black dots and enlarge to form target-like dark brown spots. Large numbers of spores are produced and can be spread by wind and rain. These spores rarely move farther than adjacent fields; infested seed is the primary means of spread to a farm. Greenhouse transplants should be inspected weekly for pinpoint black circular spots, as these are the first signs of the disease.

Cultural Control:

1. Use hot water treated seed. For cabbage and Brussels sprouts, soak seed for 25 minutes in 122°F water; soak for 20 minutes for Chinese cabbage, broccoli, and cauliflower. Precise time and temperature control is essential to minimize damage to the seed.
2. Use clean transplants.
3. Long rotations (three years) without crucifer crops or cruciferous weeds, such as wild mustard, are helpful.
4. Destroy cull crop and crop debris after harvest.
5. Plant later plantings upwind of earlier plantings.
6. Allow for good air movement (e.g., wide spacings, rows parallel to prevailing winds, not close to hedgerows).

Materials Approved for Organic Production:

Copper compounds are labeled, but have not been effective in recent studies (two poor results).

BLACKLEG (*Phoma lingam*)

Seedling infection may be first seen on the cotyledons or first true leaves. Bluish lesions may appear on stems that later elongate into light brown, sunken areas with black margins, and the stem will become girdled and blackened **(Photo 2.15)**. Inspect all greenhouse transplants for stem lesions.

Cultural Control:

1. Use hot water treated seed. For cabbage and Brussels sprouts, soak seed for 25 minutes in 122°F water, soak for 20 minutes for Chinese cabbage, broccoli, and cauliflower. Precise time and temperature control is essential to minimize damage to the seed.
2. Use a four-year crop rotation without crucifer crops.
3. Avoid manure from livestock that have been fed cruciferous crops.
4. Eliminate cruciferous weeds.
5. Destroy cull crop and crop debris after harvest.
6. Plant later plantings upwind of earlier plantings.
7. Allow for good air movement (e.g., wide spacings, rows parallel to prevailing winds, not close to hedgerows).

Materials Approved for Organic Production:

None known to be effective.

CLUBROOT (*Plasmodiophora brassicae*)

The symptoms of clubroot are seen belowground before any symptoms appear on the aboveground plant. Infected roots enlarge to form galls **(Photo 2.16)**. Severely distorted roots are unable to absorb water and minerals, and the top growth is later stunted with yellow lower leaves. The disease overwinters as resting spores in the soil. Transplants should be checked for clubroot symptoms and destroyed if found.

Cultural Control:

1. Maintain soil pH above 7.2 and high calcium and magnesium levels.
2. Rotate infested fields out of brassicas for a minimum of seven years.

Materials Approved for Organic Production:
None known to be effective.

DOWNY MILDEW (*Peronospora parasitica*)

Infection can occur during any stage of growth. First symptoms may be seen as discolored spots on the cotyledons, which can be a source of spores and later turn yellow and die. A systemic infection may occur that is capable of living in the plant without symptoms. Symptoms on the leaves are discrete, yellow areas on the upper surface, followed by white pathogen growth on the under surface. Under moist conditions, the affected areas enlarge and turn tan and papery **(Photo 2.17)**. Irregular black spots may develop on broccoli heads. Spores overwinter in the soil and on crop debris.

Cultural Control:

1. Use a three-year rotation without crucifer crops.
2. Avoid overhead irrigation.
3. Allow for good air movement (e.g., wide spacings, rows parallel to prevailing winds, not close to hedgerows).

Materials Approved for Organic Production:
Copper compounds.

WHITE MOLD (*Sclerotinia sclerotiorum*)

White mold is a fungal disease caused by *Sclerotinia sclerotiorum*, which has a very wide host range, including tomatoes, eggplants, peppers, beans, carrots, lettuce, cole crops, and many weeds. Early symptoms are water-soaked lesions, followed by rotting of stem tissue. In cabbage, the entire head may rot **(Photo 2.18)**. Later, a fluffy, white fungal growth appears, which often develops hard, black sclerotia (i.e., the overwintering structures of the fungus) **(Photo 2.19)**. These sclerotia can survive in the soil for several years. This disease is worse on heavy soils with poor drainage.

Cultural Control:

1. Use raised beds, and install drainage tiles to improve drainage if necessary.
2. Rotation is difficult because so many crops and weeds are hosts, and the sclerotia are very long-lived in the soil. If weed hosts are controlled, four years of cereal crops or sweet corn will likely help.
3. Avoid excessive irrigation.
4. Avoid overcrowding and weeds that prevent air circulation in the field.

Materials Approved for Organic Production:
Coniothyrium minitans (Contans) (see material fact sheet) is a fungus that, once applied and incorporated into the soil, attacks and destroys the white mold sclerotia. Contans is applied at or before planting time. It is mixed with water and sprayed directly onto the soil surface. To reduce survival of sclerotia, Contans should be applied after a crop with high levels of white mold infection.

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ORGANIC INSECT AND DISEASE CONTROL FOR
Chenopods: Spinach, Beets and Chard

INTRODUCTION

Spinach, beets, and chard belong to the plant family Chenopodiaceae. There are very few crop plants in this family, but many weeds, including common lambsquarters and oak leaf goosefoot. The flowers of plants in this family are inconspicuous, greenish, and often arranged in small clusters. Beets and chard are cool season crops that can tolerate frosts and light freezes. Spinach is even hardier and tolerates temperatures as low as 15º F. Beets and chard do well in both warm and cool weather, but spinach will bolt under the hot temperatures and long days of summer. There are some varieties of spinach that are somewhat bolt-resistant. While crops in this family are related, the most important diseases are very crop-specific.

I. INSECT CONTROL

APHIDS

The green peach aphid and black bean aphid are sometimes found on Chenopodiaceae crops; however, aphids are not usually a problem in organic systems where broad-spectrum insecticides are avoided. Aphid feeding can distort leaves, and aphids can transmit viruses from plant to plant. Although they may appear at any stage, they are more of a concern later in the season, when cucumber mosaic virus is more prevalent. Also, concern varies with market tolerance of contamination with aphids in harvested crops. The largest concern is with spinach production in high tunnels, where populations of aphids may explode quickly, and the infested crop may harbor populations that could infest subsequent crops.

Cultural Control:

1. Row covers can protect plants if installed before winged aphids arrive, and they can remain in place until harvest.
2. Aluminized reflective mulches may slow colonization of plants by winged aphids. Direct seeding or transplanting through the mulch is recommended for maximum protection

Materials Approved for Organic Production:

1. Soap provided poor control for green peach aphid, but studies with other species showed five good, one fair, and two poor results. Ensure coverage of the parts of the plant where aphids are located, especially the undersides of leaves and fruit.
2. Neem: Azadirachtin-based neem products may provide control.
3. Pyrethrin has not proven to be effective for aphids on spinach.
4. *Beauveria bassiana* may provide control.

FLEA BEETLES

There are several species of flea beetles that pose a risk to spinach, beets, and chard, including the spinach flea beetle (*Disonycha xanthomelas*) and the pale striped flea beetle (*Systena blanda*). Damage is most problematic in crops being marketed for greens; however, especially when small plants are attacked, yield reductions or complete losses may be observed. Most species overwinter as adult beetles and emerge in the spring. They feed on upper and lower leaf surfaces, making small holes and, when present in large numbers, creating a shot-hole appearance. These holes may become larger as the leaf grows.

Cultural Control:

1. Row covers are the most effective way to avoid flea beetles, but since they over winter as adults in soil or crop debris, be certain to combine the use of row covers with crop rotation.

2. Avoid growing Chenopods in fields where they, or other hosts to the pale striped flea beetle (bean, eggplant, lettuce, melon, pea, pepper, pumpkin, radish), were grown during the previous year.

Materials Approved for Organic Production:

1. In trials of organic materials, Entrust has shown the greatest efficacy in suppressing other species of flea beetles, but its effectiveness is still considered fair, at best.
2. Pyrethrin (Pyganic EC 5) showed poor to moderate efficacy in comparative trials; however, growers have reported it to cause at a least short-term, significant knockdown.

SEEDCORN MAGGOT *(Delia platura)*

The seedcorn maggot is closely related to the onion and cabbage maggot, and microscopic examination is necessary to tell the larvae from the three species apart. The life histories of the pests are very similar as well. There are up to three generations per year in the Northeast, depending on temperature, but the first tends to be most damaging because cool, wet conditions are more favorable for survival. The pest overwinters as pupae in the soil, and the adult fly emerges early in the spring. The seedcorn maggot fly is attracted to freshly turned soil, especially with fresh, decomposing organic matter or livestock manure. Eggs are laid on the soil and hatch in two to nine days, depending on the temperature. The resulting maggots feed on organic matter, including germinating seeds and young seedlings **(Photo 3.1)**. Seedcorn maggots are very damaging to large seeds, such as beans, peas, and corn **(Photo 8.11)**. They are also known to attack seedlings of asparagus, cabbage, onion, radish, and spinach.

Cultural Control:

1. Avoid using manures or unfinished composts without allowing time for them to break down and become incorporated into the soil before planting.
2. Avoid planting into soil that is high in fresh organic matter, such as newly turned sod or cover crops, and avoid planting into weedy fields.
3. The pest is favored by wet, cool soils, so if this pest has been a frequent problem, wait as long as possible for the soil to warm before planting.
4. Row covers will work if no pupae have overwintered in the soil or applied compost.

Materials Approved for Organic Production:

1. Spinosad seed treatment - Recent research has indicated that, when used as a seed treatment, spinosad can greatly reduce infestation by the onion maggot. This treatment may be effective for seedcorn maggot as well. Advanced planning is necessary, however, as seeds must be treated by seed companies. At the time of this publication, there was not a formulation approved for organic production.

2. Spinosad bait - Certis recently labeled a spinosad bait product (Seduce). Although many vegetable and fruit crops are on the label, the only insects listed are cutworms and earwigs. As more trials are conducted, other insects will be added, possibly including onion maggot and seedcorn maggot.

LEAFMINERS (beet leafminer, *Pegomya betae* and spinach leafminer, *Pegomya hyoscyami*)

Both of these pests attack spinach, beet, chard, and some weeds, such as lambsquarters. The spinach leafminer is more common in the east. The adult is a fly that lays its eggs on the undersides of leaves. The eggs hatch in as few as three days, depending on temperature. The tiny, pale maggots tunnel into the interior of the leaf to feed on cells, leaving pale mines that, when numerous, run together to form necrotic, blister-like areas **(Photo 3.2)**. The damage is usually cosmetic, ruining the marketability of greens but not impacting yield. When fully grown, the larvae drop out of the leaf to the ground and pupate in the soil. Leafminers overwinter in the soil as pupae and emerge in the mid spring.

Cultural Control:

1. Destroying crops at the end of harvest and controlling weeds, especially lambsquarters, chickweed, and plantain, is important for reducing the number of overwintering pupae.
2. Deep plowing can bury pupae and reduce the number of emerging flies the following spring.

Materials Approved for Organic Production:
Since spinosad (Entrust) penetrates leaves to some extent, some farmers claim that it is effective against leafminers; however, at the time of this publication, reports of efficacy studies have not been found.

WEBWORMS

Webworms are more of a problem in the south and west than they are in the Northeast, but occasionally, the garden webworm (*Achyra rantalis)* or the alfalfa webworm (*Loxostege sticticalis*) reaches levels of concern in New York and New England. Webworms begin feeding on the undersides of leaves. As they grow larger, they eat through the leaves, creating large notches or holes. As the name implies, webworms spin webs among the leaves **(Photo 3.3)**. Damage from either young webworms or small infestations may go unnoticed, but as the larvae mature, they can consume leaves rapidly and destroy a whole crop. Webworms overwinter in soil as either pupae or larvae. In the spring, the moths emerge and lay eggs on the undersides of leaves, either singly or in short rows. There can be two or more generations per year, but the first is the most damaging because it occurs when plants are small.

Cultural Control:
To keep local populations small, management of weed hosts is important.

Materials Approved for Organic Production:
Bt and spinosad give good control. Early detection is important for preventing significant damage.

II. DISEASE CONTROL

DISEASES CAUSED BY BACTERIA

SCAB (*Streptomyces scabies*)

Streptomyces scabies is a common soil inhabitant that can persist indefinitely with or without a host. When host crops are grown, the Scab pathogen populations increase, resulting in an increase in disease severity in subsequent years. It causes rough, tan to brown, raised, corky lesions on the root surface of beets, radishes, turnip, parsnip, carrot, and potato tubers. Spinach and chard are not affected. This pathogen belongs to a group of organisms called actinomycetes, which are filamentous bacteria and include many beneficial species commonly present in soil. *Streptomyces scabies* produces asexual spores in chains. Because of the filamentous growth ability of actinomycetes, this pathogen can spread to reach new nutritional sources by growing between soil particles. Scab is a common problem in high pH soils, but it is usually not severe or of economic importance on Chenopod crops.

Cultural Control:
There are no cultural practices other than lowering soil pH.

Materials Approved for Organic Production:
None.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

ANTHRACNOSE (*Colletotrichum dematium*)

Anthracnose is a disease of spinach that is favored by persistent cool, wet conditions. It is primarily a problem in fall plantings and winter production in low or high tunnels. Disease symptoms begin with small, round, water-soaked spots that later coalesce into gray-tan areas, becoming brown, thin, dry and paper-like. Tiny black fruiting bodies develop that produce spores, which can be dispersed by wind, splashed rain, or overhead irrigation. This fungus overwinters in a vegetative state in plant debris and may be seed borne.

Cultural Control:

1. Use clean seed.
2. Use practices that maximize air movement and minimize hours of leaf wetness (e.g., good weed control, wide spacing, etc.).
3. After harvest, destroy remaining crop, and bury infected debris deeply. A three-year crop rotation is recommended.

Materials Approved for Organic Production:
None with known efficacy.

APHANOMYCES (BLACK) ROOT ROT (*Aphanomyces cochlioides*)

Black root rot is not common, but it is serious when it occurs. It is a problem in beets, where it may affect young seedlings and cause poor stands. When it attacks seedlings, it causes damping-off, in which the stems and hypocotyls constrict and become threadlike and black. During mid-season, it attacks the root tip of the beet, causing a black rot that spreads up the root. It is more common in warm, wet soils. This fungus can survive for several years as spores in soil, on weeds, and on crop debris.

Cultural Control:

1. Crop rotation with non-hosts, such as corn or small grain cover crops, helps by reducing the amount of the pathogen in the soil.
2. Improving soil drainage and aeration helps.
3. Managing weeds that are alternate hosts, including lambsquarter and prostrate pigweed, will help prevent the pathogen from persisting in the soil.

Materials Approved for Organic Production:
None with demonstrated efficacy.

DAMPING OFF AND SEED ROT (*Pythium spp*. and *Rhizoctonia solani*)

Spinach and beets are particularly susceptible to *Pythium* and other pathogens that cause seedling diseases. Germination in cool soils is often less than 50%, especially when soils are wet. *Pythium* is most likely the culprit in cool soil, but it can cause problems over a wide range of temperatures. *Pythium* more commonly causes pre-emergence damping off, while *Rhizoctonia* is frequently responsible for post-emergence damping off; both species can attack seedlings at any time as they germinate, emerge, and mature in wet soil, causing root rot. The stems of the seedlings may also be affected below or just above the soil line, showing lesions and constriction **(Photo 3.4)**. Seedlings are stunted and weak, and in serious infections, the seedlings wilt and die.

Both species of fungi are saprophytes and can survive in the soil without a host. The amount of pathogen in the soil increases following host crops and after the addition of organic matter from crop debris, livestock manure, unfinished compost, or plowed down green manures.

Cultural Control:

1. Crop rotation is of limited value because these pathogens can survive without a host; however, rotations with corn, small grain crops, or grass family green manures will reduce the pathogen population.

2. Legume cover crops are good hosts for these pathogens and will maintain or increase populations.
3. Allow three weeks after plowing crop debris or adding fresh organic matter.
4. Where these pathogens are a persistent problem, winter-killed cover crops are the best choice to allow thorough decomposition before planting.
5. Most important are practices that promote rapid germination and seedling growth, such as reducing excessive soil moisture, using raised beds, and following recommended fertility levels.

Materials Approved for Organic Production:
One trial testing a *Trichoderma harzianum* seed treatment showed fair results, and trials testing *Trichoderma virens* soil drench showed one good, one fair, and one poor result.

CERCOSPORA LEAF SPOT (*Cercospora beticola*)
This disease is a common problem of spinach, beets, chard, and many weeds, such as lambsquarters, red root pigweed, and plantain. The disease usually begins with a few spots on the older leaves. As it progresses, younger leaves become covered with many circular spots that are light tan to brown in the center, with a distinct dark brown to purple rim that grows wider as the disease progresses **(Photo 3.5)**. The spots eventually coalesce, and the leaves then become chlorotic and die. It may start as a cosmetic problem, which may later reduce yield as more leaves become affected. Warm, humid weather with nighttime leaf wetting favors the disease. Each lesion produces large numbers of spores, and the disease can spread quickly from even a few infected plants. The disease overwinters in crop and weed debris and on seed.

Cultural Control:
1. Crop rotation of two to three years is recommended with new fields being 300 feet from fields with a disease history.
2. Destroy any infected crop and manage weeds within 300 feet of new planting.

Materials Approved for Organic Production:
None with demonstrated efficacy.

DOWNY MILDEW *(Peronospora farinosa f. sp. betae)*
Downy mildew is not a widespread problem but is sometimes troublesome in cool, wet weather, especially if overwintered inoculum is present or in winter high tunnel production. The disease affects spinach and beets as well as Chenopod weeds, such as lambsquarters. This water mold attacks leaves, causing light yellow, irregularly shaped spots on the upper surface, with corresponding gray mycelial mats on the lower surface **(Photo 3.6)**. Spores are commonly produced on the lower surface, and under especially humid conditions, they are produced on the upper surface as well. If conditions remain favorable, the disease progresses, and the plants yellow, become stunted, and die. The pathogen overwinters as either mycelium in seed or spores in crop debris and soil.

Cultural Control:
1. A two- to three-year rotation with non-host crops is recommended, along with good management of Chenopod weeds.
2. Avoid poorly drained soils.
3. Avoid growing susceptible crops in fields adjacent to those where infected crops were grown during the previous season.
4. While resistant varieties exist, they are not always successful because there are ten races of this pathogen, and resistance to one race does not mean resistance to another. If downy mildew has been a problem, plant varieties with resistance to as many races as possible, and keep records of success.

Materials Approved for Organic Production:
None with demonstrated efficacy. One fixed copper trial showed poor results.

FUSARIUM WILT (*Fusarium oxysporum* f. sp. *spinaciae*)

Fusarium is a very common, persistent soil borne fungus with multiple strains that target different crops. The f. sp. *spinaciae* strain infects spinach. Plants can become infected at any age. Infected seedlings may die very quickly. When older plants are infected, the first sign is wilting of the older, outer leaves. Later, the plants appear stunted, and the younger leaves roll. Plants are easy to pull from the ground because roots are weak with dark lesions. These symptoms are not diagnostic because similar symptoms arise from poorly drained soil, poor fertility, or persistent wet weather. If such problems occur without an obvious cause, a laboratory diagnosis may be warranted.

The pathogen is seed borne, but it can also be spread by wind-blown soil, surface drainage, and soil transferred on production equipment. Once introduced to an area, it can survive for many years in the soil without a host. Moist, moderately warm soil is required for infection to occur.

Cultural Control:

1. Purchase clean seed grown in areas where no wilt occurs.
2. If wilt is found, rotate to non-susceptible crops for three years.
3. Destroy the crop after harvest.
4. Maintaining pH at an upper range (6.8-7.0) may decrease disease severity.

Materials Approved for Organic Production:
None with demonstrated efficacy.

WHITE RUST (*Albugo occidentalis*)

White rust is a sporadic disease, but when it occurs, it is of economic significance because the spots that develop on spinach leaves reduce marketability. Chlorotic areas appear on the upper surface of leaves, and shiny blisters form on the lower surface. As the disease progresses, the upper surface and other plant parts may also develop blisters. The blisters contain large numbers of sporangia (asexual spores). When the sporangia mature, the blisters rupture, and the sporangia are dispersed by wind. The dispersed sporangia release zoospores (swimming spores) that germinate to start new infections. The disease is favored by warm days and wet nights. Water is needed for zoospore development and infection of new plants. This water mold can also produce a sexual spore (an oospore) that can overwinter in the soil. The pathogen may also survive as a surface contaminant on seed.

Cultural Control:

1. Destroy diseased plants, and bury crop residue.
2. A three-year rotation will reduce the amount of inoculum, but some oospores (thick walled, persistent, sexual spore) may still survive in the soil. Once the disease has occurred, careful monitoring of subsequent spinach crops is recommended.

Materials Approved for Organic Production:
None with demonstrated efficacy.

NUTRITIONAL DISORDERS

HEART ROT

This disorder affects beets and begins as black spots that develop into a dark rot that is sometimes mistaken for a disease. Heart rot is the result of a boron deficiency. An early symptom of boron deficiency is a white netting appearance on the upper surface of the leaves. Wilting of young leaves may also occur. In plants, boron deficiency most commonly results from high soil pH coupled with very dry conditions for extensive periods. This induced deficiency is the most common cause of heart rot on organic farms, where organic soil amendments generally maintain adequate levels of boron in the soil, but the combination of high pH and low soil moisture cause the boron to be unavailable to plants.

Cultural Control:
Maintain recommended boron levels in the soil, an optimum pH, and adequate irrigation during dry spells.

Materials Approved for Organic Production:
Soluble boron products are permitted if a soil deficiency is documented by testing. Check with the local certifier for approved materials.

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ORGANIC INSECT AND DISEASE CONTROL FOR Cucurbit Crops

INTRODUCTION

Cucurbitaceae is a large family composed of several major vegetable crops, including cucumber, muskmelon, watermelon, summer squash, winter squash, pumpkin, gourd, and bitter melon. A similar pest and disease complex affects these crops, though individual varieties differ in susceptibility to various pests.

I. INSECT CONTROL

APHIDS (*primarily Aphis gossypii*)

Aphids do not cause serious, direct injury to cucurbits, but various species of aphids can transmit viruses to plants in this family. The use of resistant varieties is the only reliable control for diseases caused by viruses. Aphid feeding may cause the leaves to become distorted. Honeydew (a special name for fecal matter of aphids) may also serve as a growing medium for sooty mold, a fungus that can disfigure the fruit with black blotches.

Cultural Control:

1. Reflective mulches may help to repel aphids while also providing horticultural benefits.
2. Separate later planted fields from early fields.
3. Natural enemies will help keep aphid populations in check but will be less effective in very hot weather when aphids reproduce rapidly. Refrain from using broad-spectrum insecticides.
4. Eliminate virus host plants, such as burdock, pokeweed, and other perennial broadleaf weeds.

Materials Approved for Organic Production:
Unless virus diseases are a problem, such as in late crops, aphid control is generally not needed. The best control is to eliminate virus host crops, rather than treat for aphids.

SQUASH BUG (*Anasa tristis*)

The squash bug **(Photo 4.1)** sucks sap from the leaves and stems of squash and pumpkins, causing leaves to wilt and eventually turn black and crisp. This insect can also cause severe damage by feeding directly on the fruit. Adults are dark gray and about 5/8 inches in length. They overwinter in protected areas (e.g., under debris in fields, in buildings) and lay eggs on the undersides of leaves in the spring and summer. The eggs hatch into light green or gray nymphs that congregate on leaves or fruit **(Photo 4.2)**.

Cultural Control:

1. Crop rotation and sanitation are very important. Avoid leaving cucurbit crop debris available for over wintering sites. Till debris under in the fall, and plant a cover crop. Keep headlands mowed. Next year, plant cucurbits in a new field.
2. During the summer, adults tend to congregate under shelter at night. In the evening, place boards on the soil surface near the squash, and use them to collect (and destroy) the pest in the following morning.
3. Destroy egg masses on the undersides of leaves.
4. Provide habitat for natural predators in or near the field. A parasitic fly, *Trichopoda pennipes*, affects adult squash bugs, and several wasps parastize the eggs.
5. Avoid heavy mulch or no-till in susceptible crops such as zucchini. Squash bugs like shelter and appear more numerous in reduced tillage or mulched crop systems.

Materials Approved for Organic Production:

1. Pyrethrum on young nymphs.
2. Neem (two of three recent studies show good control).
3. Mixtures of pyrethrum and neem have shown good control in some trials.

SQUASH VINE BORER (*Melittia cucurbitae*)

The squash vine borer **(Photo 4.3)** is a pest only on squash and pumpkins. The vine borer is the larva of a moth that lays its eggs at the base of the plant. It resembles a white "worm" and causes squash and pumpkin plants to wilt by burrowing into their vines. It overwinters as a larva in the soil. For reasons that are unclear, squash vine borer tends to be less of a problem in large plantings than in smaller ones. Winter squash, pumpkins, and zucchini are particularly susceptible. Butternut squash (*C. moschata*) is resistant.

Cultural Control:

1. Plant resistant varieties.
2. Soon after crop harvest, plow the vine debris deeply to bury larvae.
3. Rotate fields.
4. In small plantings, it may be possible to manually remove the larvae. Find the sawdust-like frass on the affected plant stem, and then locate the larva by slicing lengthwise along the stem until you reach it. Destroy the larva, and then cover the slit in the stem with soil.
5. Keep floating row covers in place (after transplanting or direct seeding) until flowering.

Materials Approved for Organic Production:

1. Bt and spinosad have been shown to be effective in two trials in which three weekly applications were used, starting soon after the first moths were caught in pheromone traps.
2. *Bt aizaiwi* has been somewhat more effective than spinosad and *Bt kurstaki*.

Spray timing is very important for targeting newly hatched larvae before they bore into the stem. The adult flight can be monitored using pheromone traps, predicted using base 50°F degree-days (DD_{50}), or correlated with the first appearance of flowers on chicory, a common roadside weed. The following information is from the University of Wisconsin: Pumpkin and squash crops should be monitored once 900 DD_{50} have accumulated. During the three-week egg-laying period (around 1000 DD_{50}), two to three insecticide treatments, five to seven days apart, will control most of the larval borers before they become protected by the vines.

STRIPED CUCUMBER BEETLE (*Acalymma vittatum*)

Striped cucumber beetles (SCB) are 1/4 inch long beetles with black and yellow longitudinal stripes, a black head, and a black abdomen **(Photo 4.4)**. In the Northeast, they overwinter as adults, sheltered under plant debris, and become active in the spring as soon as cucurbits appear. The overwintered generation lives until August and feeds on all plant parts. Small seedlings are very susceptible and often killed. Once the plants attain 4-5 true leaves, they are more tolerant of striped cucumber beetle feeding; however, disease transmission is still important (see below). The beetles lay their eggs at the base of cucurbit plants. Larvae feed below ground on roots and crowns of the plants. The new generation of adults emerges in July and can cause feeding damage to pumpkins and other cucurbit fruit. They overwinter and then feed on next year's crop.

The cucumber beetle also carries the organism that causes bacterial wilt, which can be more damaging than the insect. Cucumbers, summer squash, zucchini, and melons are the most susceptible. Reducing the numbers of beetles is the primary way to reduce the risk of wilt.

A related species, causing similar damage, is the spotted cucumber beetle, which is yellow-green with 12 black spots.

Cultural Control:

1. Crop rotation and sanitation are important. Avoid leaving cucurbit crop debris available for overwintering sites. Plow debris under after harvest, and plant a cover crop to reduce the overwintering population. Keep headlands mowed. Rotate cucurbits to distant fields to help delay infestations.

2. Floating row covers and netting, such as Proteknet, are very effective for avoiding beetle damage while plants are getting established. Remember to periodically (and temporarily) remove the covers to weed, and to allow pollination, remove permanently when the flowers appear. Parthenocarpic (not needing pollination) varieties of cucumber may be grown season-long under row cover or netting.
3. Use of trap crops is possible when the main crop is a less-attractive cultivar, like summer squash, melon, or cucumber. Cultivars vary dramatically in their attractiveness to beetles. The inexpensive variety Dark Green Zucchini is very attractive and takes up little space. Blue Hubbard squash is also an effective trap crop that is not susceptible to wilt. A trap crop can be planted around the perimeter of the cash crop and allowed to attract beetles. To gain the most benefit and discourage entry to the main crop, be sure the trap crop plants are larger than and completely encircle the cash crop. Placing yellow sticky cards in the trap crop may increase its attractiveness. Applying kaolin clay to the main crop will help protect it by decreasing its attractiveness relative to the trap crop.

   Because insecticides allowed for organic production are relatively ineffective against striped cucumber beetle, controlling adult beetles on the trap crop is not a reliable option. Trials have suggested that beetles lay more eggs on the trap crop than on the main crop (Seaman et al. 2011); therefore, destroying the trap crop after the overwintering generation of adults begins to disappear may reduce the number of larvae surviving to produce a summer generation, and local populations may be reduced over time. The trap crop should be mowed and disked to destroy the roots. Mowing alone is not enough to kill larvae feeding on the roots. For more information on perimeter trap cropping see: http://www.hort.uconn.edu/ipm/veg/htms/sumsqshptc.htm
4. Yellow sticky cups or tape can trap many SCB adults. They should be replaced regularly, as they become saturated with beetles and field debris.
5. Use transplants instead of direct seeding. They are more tolerant of both feeding damage and bacterial wilt when beetles arrive.
6. If planting from seed, plant later, after peak overwintered beetle activity is over.

Materials Approved for Organic Production:

1. Kaolin clay (Surround). Growers report repellency if it is applied frequently—twice a week during rapid early season growth.
2. Pyrethrum is reported to give some control by growers, but has not been shown to be effective in University trials.
3. Application of beneficial nematodes to the root systems of plants with early season SCB populations will reduce, but not fully control, the following generation and may be an option for controlling larvae on the roots of a trap crop.

II. DISEASE CONTROL

The table below summarizes disease susceptibility of Cucurbits and is adapted from the Cornell Pest Management Guidelines for Vegetables (Cornell 2012).

Table 1. Disease Susceptibility of Cucurbits

Disease	Cucumber	Musk Melon	Pumpkin	Summer Squash	Winter Squash	Water Melon
Bacterial wilt	H	M	M,V	M	L	-
Angular leaf spot	L,R	L	M	L	M	L
Powdery mildew	M,R	M,R	H,R	H,R	M,R	M
Black rot (gummy stem blight)	L	M	M	L	M	M
Fusarium wilt	-	H,R	-	-	-	-
Fusaruim crown rot	L	L	H	M	M	L
Phytophthora blight	H	H	H	H	H	H
Downy mildew	H,R	H,R	H	H	H	L
Viruses	L,R	H	M	H.R	M	L

R=resistant varieties exist; L=low (occurs, but rarely in damaging levels); M=moderate; H=high level of susceptibility to pest; V=variable susceptibility among varieties; - = pest tolerance for a particular crop is unknown.

DISEASES CAUSED BY BACTERIA

ANGULAR LEAF SPOT (*Pseudomonas syringae* pv. *lachrymans)*

The bacterium can attack leaves, stems, and fruit. Leaf symptoms begin as small, water-soaked lesions, which expand to fill the area between large secondary veins, giving them an angular appearance **(Photo 4.5)**. Lesions may become dry and fall out, giving the leaves a "tattered" appearance **(Photo 4.6)**. Lesions on stems and fruit are generally circular, water-soaked spots with a light tan center.

Cultural Control:

Plant resistant varieties. (Cornell Guidelines). See http://www.nysaes.cals.cornell.edu/recommends/

1. Rotate away from cucurbits for 2-4 years.

Materials Approved for Organic Production:

Copper compounds.

BACTERIAL WILT (*Erwinia tracheiphila)*

This disease is spread by the striped cucumber beetle and the spotted cucumber beetle (SCB). Bacterial wilt is commonly seen on cucumbers and muskmelons. Some varieties of gourd, pumpkin, and squash are also very susceptible to the disease. Information on cucurbit varieties and susceptibility to wilt and other diseases can be found on the Cornell Vegetable MD Online website (McGrath 2001). See http://vegetablemdonline.ppath.cornell.edu/NewsArticles/CucBW.htm10

Symptoms of the disease on young plants can include wilting of the entire plant and rapid death **(Photo 4.7)**. Symptoms on older plants include wilting of leaf tissue between veins and wilting of one or more runners. Watermelon is quite resistant to both SCB and bacterial wilt. Muskmelons are susceptible to feeding injury and disease transmission, especially around the time of runner formation. Some summer and winter squash varieties are not as affected by bacterial wilt as melons and cucumbers.

Recent studies suggest that asymptomatic weed hosts may play a major role in survival of the bacterium over the winter.

Cultural Control:

1. Control of bacterial wilt depends on control of the cucumber beetle; therefore, all measures described above for control of SCB will aid in the control of bacterial wilt as well.
2. Resistant cucumber varieties, such as County Fair pickling cucumber, are becoming available.

Materials Approved for Organic Production:
See cucumber beetle controls.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

BLACK ROT AND GUMMY STEM BLIGHT (*Didymella bryonia)*

Black rot is the fruit-infecting phase of the disease and is most common on butternut squash and pumpkins **(Photo 4.8)**. The black rot fungus penetrates the rind, allowing entry to other organisms that cause the whole fruit to rot.
Gummy stem blight refers to the foliar and stem-infecting phase of the disease **(Photo 4.9),** which is commonly seen on muskmelons and watermelons. On foliage, symptoms begin as water-soaked areas or pale brown spots. Brown cankers develop on stems, and a brown to black exudate may appear (gummy stem). The fungus can be seed-borne and may also overwinter in the soil. Infection by powdery mildew increases the opportunity for gummy stem blight infections.

Cultural Control:

1. Crop rotation to a non-cucurbit crop for two years is helpful.
2. Plant disease-free seed. Do not save seed from an infected fruit.
3. Moisture is necessary for the pathogen to infect. Optimal conditions for the pathogen are: relative humidity of 85% or higher, and one to ten hours of free moisture on leaves (due to rainfall, dew, or irrigation). Thus, it is important to minimize free moisture on the leaf surfaces by using drip, rather than overhead, irrigation.
4. Avoid injuring fruit when harvesting, as wounds allow the pathogen to enter, and the fruit could rot in storage. Cutting stems short can help reduce injury.
5. As soon as a cucurbit crop is harvested, crop debris should be plowed under to reduce overwintering inoculum.

Materials Approved for Organic Production:
Application of approved products is not currently an effective management option.

DOWNY MILDEW (*Pseudoperonospora cubensis)*

Downy mildew can be particularly severe during wet and humid weather. Symptoms on the upper leaf surface are angular, pale green to yellow areas, similar to symptoms of angular leaf spot **(Photo 4.10)**. On the lower leaf surface, fuzzy gray sporulation occurs. As the disease progresses, lesions dry out and become brown. The inoculum for downy mildew blows north from southern states, and disease may first appear after storm fronts pass through the area. The downy mildew IPM PIPE (http://cdm.ipmpipe.org) maps the locations of reported infections and provides forecasts of inoculum movement.

Cultural Control:

1. Plant resistant varieties.
2. Select planting sites with good air movement. Decreasing humidity in the crop canopy will help prevent downy mildew infections.
3. Avoid overhead irrigation.

Materials Approved for Organic Production:
Copper compounds (one poor result in recent studies; four good and three poor results against different species of downy mildew on other crops). Tracking inoculum movement on the IPM

PIPE and beginning applications before the disease is present will result in better control than starting after symptoms are found.

FUSARIUM WILT AND CROWN ROT

These diseases can be caused by several different members of the genus *Fusarium*, which has many subspecies that are host-specific. *Fusarium* species can be seed-borne but also persist in the soil as spores, with some subspecies surviving for many years without a host. Spread of the pathogen most commonly occurs through movement of infested soil and plant debris.

Fusarium wilt is a serious disease of cantaloupe and muskmelon. Mature plants are most commonly affected by this pathogen, with symptoms including yellowing of older leaves and wilting of runners. Vascular discoloration is apparent if the stem is cut along its length near the crown.

Fusarium crown rot can attack all cucurbits. Symptoms include wilting of leaves followed by plant death, which can occur within several days **(Photo 4.11).** Necrotic rot of the crown and upper root area can be seen. Fruit can also be attacked at the fruit-soil interface.

Cultural Control:

1. Crop rotation is ineffective for the Fusarium wilt of melons and cucumbers, but the crown rot organism persists for only two years, making a three- to four-year rotation effective.
2. Liming the soil to a pH 6.5-7.0 can reduce wilt.
3. Resistant varieties are the best defense. The muskmelon variety Athena is resistant.

Materials Approved for Organic Production:

No materials are currently available.

PHYTOPHTHORA BLIGHT (*Phytophthora capsici)*

The disease is not present on all farms; however, the range of the pathogen appears to be increasing each year. Prevention is the most important management practice for farms that do not yet have the pathogen. The pathogen can be introduced on produce purchased from other farms, in soil on shared equipment, and in irrigation or floodwater. There is no treatment once plants are infected. Symptoms include a sudden wilt of infected plants and white yeast-like growth on affected fruit **(Photo 4.12).**

Cultural Control:

1. Select well-drained sites, or improve the drainage. Use raised beds for non-vining crops. Manage drainage and irrigation to avoid puddling of water. Subsoil plow before planting or between beds for better drainage. Remove any soil dams that might hold water at the end of rows. Avoid leaks in irrigation systems. Do not plant low areas of the field; infections generally start in low areas where water sits.
2. Use a four- to five-year crop rotation.
3. Do not save seed from an infected fruit.
4. The pathogen survives in the soil and can easily be transferred from an infected field to a healthy field by farm equipment or shoes. Thoroughly clean equipment after working in affected fields or when sharing or purchasing equipment from another farm.
5. Note that peppers, tomatoes, eggplants, lima beans, and snap beans are also hosts for this pathogen.
6. Never return crop culls that may be infected with *Phytophthora* to the field.
7. Compost may contain organisms that are antagonistic to the pathogen.

Materials Approved for Organic Production:

No materials are currently available for control of *Phytophthora* blight.

POWDERY MILDEW (*Podosphaera xanthii)*

Powdery mildew appears later in the growing season than bacterial wilt and can reduce yields by decreasing the size or number of fruit. Fruit quality can also be reduced because of sunscald, lower sugar content, or incomplete ripening. The disease is easily recognized by a white, powdery growth on both upper and lower leaf surfaces **(Photo 4.13)**. As the disease advances, the leaves yellow, turn brown, and die **(Photo 4.14)**. All cucurbit species are susceptible, although resistant varieties of cucumber, melon, summer squash, winter squash, and pumpkin are available.

The fungus is thought to blow into the Northeast from southern states each year and, with the exception of greenhouses, probably does not overwinter in this region.

Cultural Control:

1. Growing the crop in smaller parcels may slow disease spread.
2. Unless stressed (e.g., by heavy weed competition), field-grown plants are resistant until fruit starts to enlarge.
3. Vigorous indeterminate varieties may maintain sufficient numbers of healthy leaves to tolerate powdery mildew longer in the season.
4. Grow resistant or tolerant varieties.
5. If powdery mildew develops late in the season when fruit is close to maturity, it may simply be tolerated.

Materials Approved for Organic Production:

1. Sulfur.
2. Copper (studies revealed one good, one fair, and five poor results).
3. Mineral oil (two fair and one poor result).
4. Several plant oils are reported to reduce powdery mildew.
5. Potassium bicarbonate (some trials have shown good control).
6. *Bacillus subtilis* (Serenade) (Studies showed one fair control and six poor).
7. Combinations of oil and potassium bicarbonate are more effective than either one is alone.

LESS COMMON DISEASES

There are many diseases of cucurbits that can be present at low levels or are important only in certain regions. Generally, these respond to cultural techniques such as a good four-year rotation; pathogen-free seed; raised beds; good soil drainage; careful watering, preferably with trickle irrigation; and vigorous plants.

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ORGANIC INSECT AND DISEASE CONTROL FOR
Legume crops

INTRODUCTION

Legume crops belong to the family of flowering plants known as Fabaceae. Sometimes the family is referred to as the Leguminosae, or legumes. The unifying characteristic of the family is that the fruit, often called a pod, has a single chamber and opens along two edges. Pods typically contain more than one seed. This family is very diverse and includes both trees and herbs. Worldwide, it is among the most important plant families for food crops. In the northeast region, the two most commonly grown legume food crops are peas and beans.

I. INSECT CONTROL

APHIDS

The pea aphid has traditionally been the only significant aphid that attacks peas. Fava beans, alfalfa, vetch, and clover are also hosts. Populations are usually small, and there is little damage during vegetative growth of peas; however, aphid populations may increase at flowering. Especially during pod-fill, feeding can result in smaller seed size and fewer peas per pod. Additionally, the pea aphid can transmit viruses.

Populations of pea aphids may build rapidly in late June and early July. Later in the pea season, aphids may either leave the planting for perennial hosts or die when the peas are harvested or senesce. Sexual forms appear on perennial hosts in August and September and lay overwintering eggs on the plant stems. Alfalfa, vetch, and clovers are common sites for overwintering eggs.

Additionally, the recently invasive soybean aphid can be a pest on snap bean. While feeding rarely causes direct damage, colonizing aphids are a serious vector for viruses, especially cucumber mosaic virus. If plants are small at the time of colonization, feeding by adults can cause leaves to curl downward and may temporarily stunt plant growth. Infested plants will outgrow these symptoms, and because snap bean is not a suitable host for reproduction, the colonizing aphids will eventually disappear. Treatment is rarely, if ever, warranted.

Cultural Control:

1. In the fall, harvest or mow alfalfa, vetch, and clovers that are near fields that will be planted with peas or snap beans during the following spring. This practice reduces overwintering aphid populations.
2. Since soybeans are attractive to aphids, avoid planting late-season snap bean fields near soybeans.
3. Maintain habitat for natural aphid enemies including lady beetles, lacewings, predatory midges, and parasitic wasps.

Materials Approved for Organic Production:

Aphid populations should be monitored when peas begin to flower. Action thresholds recommended for conventional production are one to two aphids per leaf or two to three aphids per stem tip and one per small pod. In organic production, a better approach may be to monitor populations over a two to three week period before flowering, and treat if populations continue to increase with no natural enemies present. If aphid populations are above threshold, control may be warranted.

1. Soap: Ensure coverage of the parts of the plant where aphids live, especially the undersides of leaves and fruit.
2. Neem: Azadirachtin-based neem products can provide some control.

CUTWORMS (many species)

Cutworms are occasional early-season pests of peas and beans. In some years, they cause major losses, while in other years, there are no losses at all. Cutworms are the larvae of approximately a dozen different species of night-flying moths. They are greasy-looking caterpillars that have a habit of curling into a "C" shape when disturbed. Most species that attack peas overwinter as partially grown larvae, so they become active very early in the spring when the peas first germinate and are very susceptible to damage. Cutworms hide in the soil during the day and feed at night. Some species feed and cut off young seedlings at the soil surface, while others may climb and feed on leaves.

Cultural Control:

1. Since most species lay their eggs on vegetation in late summer or fall, keeping fields clean of weeds and crops in the fall helps. This advice is counter to recommendations to keep soil cropped in the fall, so management decisions should be based on how severe the problem is. Fall plowing exposes larvae to birds and other predators.
2. Alternatively, cultivating fields in the spring, after vegetation has appeared and grown a few inches, can starve cutworms before peas are planted. In warm areas, spring cultivation and delayed planting are not practical because peas must be planted very early in the season to avoid hot weather in which they do not grow well. In cool regions that allow for late-planted peas, a few shallow cultivations during this "starving period" can starve cutworms and expose them to birds and other predators.

Materials Approved for Organic Production:

1. Entomopathogenic nematodes have shown good efficacy when environmental conditions are favorable (warm, moist, but not soggy soil). *Steinernema carpocapsae* has been shown to be very effective against cutworms, although reports are not specifically in pea production. Success with nematodes depends on proper application methods. Irrigation may be necessary to keep the soil moist for at least two weeks after application. Be sure to carefully follow the instructions from the supplier.
2. Baits - Spinosad or Bt will kill the caterpillars, but getting the pest to consume the insecticide as a foliar application before significant damage is done is difficult. However, some farmers have reported good results using these materials in baits. In order to rid the area of pests, the bait is spread on the ground near the plants or prior to planting.
    a. Spinosad - Seduce (OMRI Listed) is a new commercial bait that has shown promising results against black cutworm.
    b. Bt - A bait made from Bt is often recommended and has received good reports from some farmers. The following method of using Bt is not described on the label. This off-label use is permitted by EPA under FIFRA 2ee, but growers should check with their state pesticide regulators about specific local regulations. The bait is made by: determining the application area; mixing the highest concentration solution of Bt allowed on the label; and then mixing in a bit of molasses, alfalfa meal, or bran. Dampen the mix if necessary. Spread the bait along the planted or planned rows in the evening.

SEEDCORN MAGGOT (*Delia platura*)

The seedcorn maggot is the larval stage of a fly. The maggot feeds mostly on decaying vegetable matter in the soil, but if seeds are slow to germinate, they fall prey as well. The fly lays its eggs in moist soil and is attracted to soil high in fresh organic matter. The eggs can hatch at very low temperatures, so this pest is often a problem early in the spring, especially in cold, wet springs when seeds are slow to germinate. The larvae feed on the seed, especially the embryo **(Photo 8.11)**. Seeds may be killed before they sprout or may sprout but have missing parts such as a cotyledon or growing tip **(Photo 5.1)**.

Cultural Control:

1. Encouraging rapid seed germination is important for minimizing seedcorn maggot damage. For example, waiting for warm soil, waiting for a favorable short-term weather forecast, and shallow planting can all help. Seeds that are slow to germinate are likely targets for the seedcorn maggot.
2. Avoid adding organic matter that is not fully decomposed to fields of early spring planted crops (e.g., unfinished compost, livestock manure, recently incorporated cover crops). Clean cultivation is recommended for early plantings.

Materials Approved for Organic Production:
None.

PEA WEEVIL (*Bruchus pisorum*)

Pea weevil is a sporadic problem for peas and can cause poor germination. While there are many factors that may contribute to poor germination, investigating the seed lot for signs of hollowed-out seeds is a worthwhile undertaking in the absence of other, reasonable causes.

Adult pea weevils are short, chunky beetles with brown, white, black, and gray flecks. They are not true weevils, as they lack the typical snout. Adults hibernate from late summer through winter under bark, crevices of fence posts, sides of buildings, crop debris, etc. In the late spring, when the peas are flowering, the adults begin flying and move into fields. After feeding on pollen for a short period, females lay eggs on the newly forming pea pods. Eggs resemble little cigars, and females may lay one or more eggs on each pod. In two to four weeks, white grubs with small brown heads emerge from the eggs and burrow through the pod into the young peas. They feed and grow inside the pea for about five to six weeks, at which time they chew an escape hole and pupate. In as little as one to three weeks after pupation, the new adult may emerge through the escape hole and fly off to hibernate. Many adults, however, will stay in the pea for longer periods and may be found in purchased seeds. There is no tolerance in the market for peas infested with pea weevil, and customers selling and buying seeds are not happy when many of them are truly shells of what they should be.

Cultural Control:

1. Cultural practices are the most important means of reducing pea weevils for organic growers. The most important practice is to avoid planting hollow or infested seed. When growing peas for seed, harvest as soon as they are ready, and do not leave crops in the field after harvesting season. Crop left in the field allows adults to leave the peas and move to hibernating sites, perpetuating the infestation by building the population for next season.
2. For the same reason, clean up spilled peas, and destroy crop debris immediately after harvest.

Materials Approved for Organic Production:
There are no silver bullets for organic pea growers. Management practices are aimed at reducing the population. Conventional growers scout for pea weevil and, if adults are above threshold, they will spray when the flowers begin to wilt but before pods are sizing. Once flowering begins, scouting is done with a sweep net around the edge of the crop. The pea weevil is only active when daytime temperatures are above about 65°F. Sprays must target the adult because, once the eggs are laid and larvae bore into the pod, they are protected from the insecticide.

An exhaustive literature search did not reveal efficacy data for approved organic materials against this pest.

MEXICAN BEAN BEETLE (*Epilachna varivestis*)

The Mexican bean beetle (MBB) is one of the few members of the lady beetle family that has evolved to feed on plants rather than other insects. It is a somewhat spotty pest in the North-east, with many farmers never seeing them and others having crops devoured year after year.

This pest feeds primarily on snap and dry beans, but they are occasionally seen feeding on soybean or cowpea. Larvae and adults feed on the undersides of leaves and remove tissue between the leaf veins, resulting in skeletonized leaves. The adults also feed on pods. The adult resembles a lady beetle, with 8 black spots arranged in rows across the body, which may range in color from rust to yellow **(Photo 5.2)**. The sluggish, bright yellow larvae have distinctive branched spines **(Photo 5.3)**.

The Mexican bean beetle overwinters as an adult, hiding in trashy and weedy areas along the edges of fields. They move into fields in the late spring to early summer and feed for one to two weeks before the females lay groups of orange eggs on the undersides of leaves. The eggs hatch into larvae in one to two weeks. The larvae then feed for about three weeks before they pupate, and a new generation of adults emerges in about 10 days. The worst damage from this pest occurs in late July and August, as populations build on sequential plantings. There may be two to three generations per season, with fewer in cooler, northern locations.

Cultural Control:

1. Discourage hibernating beetles by cleaning up all plant debris after harvest.
2. Maintain wide, clean headlands and brushless wood edges.
3. Avoid sequential plantings in close proximity.
4. Locate late season plantings at a distance from early season plantings.
5. Plow under crop debris shortly after harvest.

Materials Approved for Organic Production:

1. Moderate control can be achieved with Entrust as well as mixtures of pyrethrin (PyGanic EC5.0) and Neemix.
2. Biological control can be very effective. *Pediobius foveolatus* is a wasp that deposits its eggs in larvae. The wasp larvae feed inside the MBB larva and eventually kill it. About 25 new wasps emerge from each killed MBB larva, so control actually gets better as the season progresses. Release timing is very important; plan ahead so releases occur as soon as the pest is present. Releases occurring before MBB presence or after the infestation has reached damaging numbers will not be effective. Scouting for egg masses and ordering wasps as soon as the first egg mass is found is recommended in Massachusetts. Detailed information, including release rates, can be found at: (http://extension.umass.edu/vegetable/insects/mexican-bean-beetle)

   Pediobius is available from the following suppliers: New Jersey Department of Agriculture (http://nj.gov/agriculture/divisions/pi/prog/beneficialinsect.html or call 609-530-4192), Green Spot Ltd., NH, (http://www.greenmethods.com 603-942-8925), IPM Laboratories, NY (http://www.ipmlabs.com/ 315-497-2063), ARBICO (http://www.arbico.com/ 800-827-2847).

POTATO LEAFHOPPER *(Empoasca fabae)*

The potato leafhopper (PLH) is a migratory pest in the north. Some years, it is present only in low numbers, while in others, high numbers devastate beans and other popular crops including potatoes, eggplants, strawberries, and alfalfa. The PLH only overwinters in the southern region of the US, reaching the northeast in May, June, or July. There are one to six generations per season, depending on the time of arrival, host availability, and weather conditions.

The adult is a very mobile, light green, wedge-shaped insect that is about 1/8 inch long **(Photo 5.4)**. The nymphs are smaller and bright yellow-green in color **(Photo 5.5)**. They are found on the underside of the leaves and have the characteristic habit of moving sideways like a crab when disturbed. This pest is a sucking insect, removing sap from the vascular cells of the plant. Feeding causes a complex of damage known as "hopperburn" **(Photo 5.6)**. The first sign of injury is a whitening of the veins of the leaves. Soon after, the leaves become yellow and flaccid, then brown and crisp, starting at the edges. Because there is no chewing or other typical signs of insect feeding, hopperburn is often mistaken for a disease symptom.

By the time injury to the plant is noticed, yield loss cannot be prevented. The injury is not reversible, and the plants are stunted at best; young plants may die. Monitoring the pest is essential. Sweep nets are typically used to sample adults, while nymphs are sampled directly on the underside of a leaf. A common threshold for determining if treatment would be cost effective is an average of one nymph per trifoliate leaf or 50 adults in 10 sweeps with a net.

Cultural Control:
Since the PLH does not overwinter in the Northeast, crop rotation is of no value. Row covers may be used to protect young beans until they flower, after which the crop is less susceptible.

Materials Approved for Organic Production:
Pyrethrin (e.g. PyGanic EC5.0) has been shown to be the most effective material available to organic growers. Spray in the evening and be sure to get good coverage, especially on the undersides of the leaves. Multiple sprays may be required because this material does not persist.

CORN EARWORM, EUROPEAN CORN BORER, AND CABBAGE LOOPER
These occasional pests of beans can, in some cases, cause serious injury. The larvae feed on the foliage, making holes in the leaves. When pods are present, they feed on the outside of the pod and may burrow inside to feed on the seed. Avoid planting beans near corn, which is a much better host for these insects. For serious, recurring infestations, mass release of *Trichogramma ostriniae* may be worthwhile for controlling European corn borer. Release must be timed to occur when eggs are present. This egg parasitoid will not affect corn earworm or cabbage looper. Bt (e.g. DiPel 2X) and spinosad (Entrust) may be effective if applied before caterpillars bore into the pods.

II. DISEASE CONTROL

DISEASES CAUSED BY BACTERIA

BACTERIAL BLIGHT- Peas (*Psudomonas syringae pv. pisi*)
Bacterial blight of pea is a common problem that may reduce yields and scar pods during wet years but is not a significant problem under dry conditions. It is not the same pathogen that causes the bacterial diseases of beans, though it does have a wide host range including sweet peas, hairy vetch, cow peas, and soybeans. Lesions may be found on any of the aboveground parts of the plant. They begin as small, water-soaked spots that later develop brown margins, become necrotic, and may grow together, causing the leaves to turn brown and die. The whole crop may be lost if bacterial blight infection occurs during the seedling stage.

The pathogen does not persist in soil. The principal source of infection is infested seed. If conditions are wet at planting time, the disease is more likely to be transmitted from the seed to the developing plant. Subsequent spread within and between fields is possible by moving water, machinery, insects, people, etc.

Cultural Control:
1. Planting clean seed is key to management.
2. Resistant varieties are available.
3. Seed raised in arid regions are less likely to be infected.
4. Avoid walking or working in pea fields when the plants are wet.
5. Promote good airflow and fast leaf drying by providing adequate row and in-row spacing.

Materials Approved for Organic Production:
Copper fungicides can be effective in limiting secondary spread. See the copper fact sheet (page 123) for a discussion of efficacy and minimizing accumulation in the soil.

COMMON BACTERIAL BLIGHT- Beans (*Xanthomonas phaseoli*)

Common bacterial blight can affect leaves, pods, and seeds. On leaves, the first symptom is water-soaked spots that enlarge and become light brown and irregular in shape, with narrow, bright yellow margins **(Photo 5.7)**. With time, the lesions may coalesce and kill the leaflet. On pods, the lesions are circular, slightly sunken, and become reddish brown. On white beans, seed symptoms are most evident as yellow to brown spots, and the seeds may become shriveled.

From year to year, bacterial blight's most common means of survival is contaminated seed. Bacteria from pod infections invade the seed and become dormant until germination. Once the disease progresses for as little as two weeks, bacteria can exit the stomata of infected leaves or ooze from pods and serve as an inoculum source for secondary spread. While seeds of tolerant varieties may carry the bacteria without showing any symptoms in the field, they can be a source of initial inoculum for non-resistant varieties. These bacteria can overwinter in crop debris and are spread within and between fields by people, animals, equipment, insects, wind blown rain, etc.

Cultural Control:

1. The use of pathogen-free seed is key to management.
2. Buying seeds produced in dry climates is recommended.
3. A two-year rotation is recommended. Scouting for and removing volunteer beans is also important.
4. Tolerant varieties are available.
5. Avoid walking, working, or harvesting in wet fields.
6. Promote good airflow and fast leaf drying by providing adequate row and in-row spacing.

Materials Approved for Organic Production:

Copper fungicides can be effective in limiting secondary spread. See the copper fact sheet (page 123) for a discussion of efficacy and minimizing accumulation in the soil.

HALO BLIGHT and BACTERIAL BROWN SPOT-Beans (*Pseudomonas syringae pv. phaseolicola*) and (*Pseudomonas syringae pv syringae)*

The first symptoms of these diseases are tiny spots forming on the underside of the leaves. In the case of halo blight, the spots are water-soaked and turn reddish brown. Starting with a halo around the spots, the leaves eventually turn yellow. With bacterial brown spot, the halo is bright yellow. Halo blight also affects pods, beginning with tiny red-brown spots that enlarge slowly and may form a crusty ooze in the center. Cool, moist weather favors quick spread of these diseases. The bacteria are carried within and between fields by splashing rain, wind-carried particles, animals, workers, and equipment.

From year to year, the most typical means of halo blight survival is in contaminated seed and crop debris. Similar to common blight, seedlings emerge from infected seeds carrying large numbers of bacteria that spread rapidly if conditions are favorable.

Cultural Control:

1. The use of pathogen-free seed is key to management.
2. Buying seeds produced in dry climates is recommended.
3. A two-year rotation is recommended. Scouting for and removing volunteer beans is also important.
4. Tolerant varieties are available.
5. Avoid walking, working, or harvesting in wet fields.
6. Promote good airflow and fast leaf drying by providing adequate row and in-row spacing.

Materials Approved for Organic Production:
Copper fungicides can be effective in limiting secondary spread. See the copper fact sheet (page 123) for a discussion of efficacy and minimizing accumulation in the soil.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

ROOT ROTS

There are a few soil borne pathogens that cause root rots and have very similar aboveground symptoms because they result from lack of root function. Leaves yellow, and the plants are stunted and slowly die. These species may attack young peas or beans and cause damping-off, seed decay, and wilts.

FUSARIUM WILTS (*Fusarium oxysporum f. sp. pisi* on peas, and *F. oxysporum f. sp. solani* on beans)

Fusarium is a root-rotting fungus that survives in the soil as very resistant spores that can persist without a host for more than 10 years. Both peas and beans are susceptible. The fungus penetrates the roots and invades the vascular tissue of the plant. Early symptoms are downward turning leaves, followed by yellowing of the plant from the base to the tip. The root system superficially looks normal, but slicing the roots or base of the stem longitudinally will reveal a reddish brown discoloration of the vascular tissue. Warm, dry conditions cause the disease to progress, rapidly killing the plants. Planting peas in the earliest workable fields is recommended, so the crop develops during the cool part of the season. Optimum growth of the *Fusarium* fungus occurs when the soil warms to 68^{o} F – 72^{o} F.

PYTHIUM DISEASES (*Pythium spp.*)

There are several species of *Pythium* that cause pre- and post-emergent diseases that effect the seeds (seed rots), seedlings (damping off), and roots (root rots) of peas and beans. Once the plant emerges and develops mature cells with thicker cell walls, *Pythium* is less likely to be a problem. It may still attack young cells at the root tips and lead to "root pruning" and stunted, chlorotic plants that yellow from the bottom up and may eventually die. At advanced stages, determining if the plant has died from a wilt or a root rot is difficult. Plants dying from root rot tend to be easily pulled from the ground. *Pythium* diseases of seeds and seedlings result in either gaps in plantings where seeds have simply rotted away or stunted seedlings that died shortly after emerging.

Pythium spp. are common soil inhabitants with a wide host range, which makes crop rotation less effective. The pathogen can survive for many years with no host at all or in root debris. *Pythium* is a fungus-like water mold (not a true fungus), and high soil moisture is necessary for it to become a problem for peas or beans.

RHIZOCTONIA ROOT ROT *(Rhizoctonia solani)*

Rhizoctonia root rot is often lumped together with problems caused by *Fusarium* and *Pythium* because telling them apart in the field is difficult. Seeds, seedlings, and older plants may be affected, although the pathogen is less likely to attack mature plants. The most distinguishing symptoms are elongate, sunken, reddish lesions on the hypocotyl, the part of the stem between the root and seed leaves. The hypocotyl may be girdled. Damping-off of seedlings and stunting of older plants may occur.

Rhizoctonia overwinters as sclerotia or as mycelium in plant residues. It may be carried on seed but is more commonly maintained and spread with infected soil. *Rhizoctonia* produces no asexual spores and, in fact, rarely produces any kind of spore. Living on decomposing organic matter, it can remain in the soil for long periods as sclerotia or as mycelium on a wide range of hosts.

Cultural Control of Root Rots:

1. Avoid using old seed with low vigor.
2. Deep plowing to bury root debris has been shown to reduce the disease in some studies.
3. Avoid wet soils.
4. Depending on which species is present, temperature may be a factor. There are some species that do well in cool soil and some that do well in warm soil. Personal experience may help to determine if one or the other is more prevalent in a given area.
5. Resistant varieties have been developed for some root diseases, especially *Fusarium* wilt. A complicating factor is that there are many races of each *Fusarium* species, and resistance to one race does not mean the crop will have resistance to another. Most modern varieties of peas are resistant to race 1 of *Fusarium oxysporum f. sp. pisi*. Race 2 causes a disease called "near wilt," which may be the most common problem in the northeast at this time. Diagnostic labs may be able to determine which race is present in the soil. Work with seed companies to find varieties resistant to that race.
6. Crop rotation to grass green manures, cereal crops, pasture, or grass hay crops may reduce soil infestation, increase soil organic matter, and improve soil structure to reduce disease. However, to avoid problems with seed corn maggot, do not incorporate organic matter immediately before planting. Plant seeds shallowly in warm, moist (but not wet) soils to speed germination.

Materials Approved for Organic Production:
Biological control agents may be useful as seed treatments. For example, Actinovate AG (*Streptomyces lydicus*), Mycostop (*Streptomyces griseoviridis*), and T-22 HC (*Trichoderma harzianum*) are labeled for *Pythium* (see Material Fact Sheets for details and efficacy reports).

POWDERY MILDEW *(Erysiphe pisi)*

Powdery mildew is a very common disease, but in most years, it arrives late enough to not severely reduce yields in peas (except for late production) and is not a significant problem in beans. This genus has a wide host range, but there are different species that are specific to certain crops (e.g., only the *E. pisi* causes powdery mildew on peas). In years when powdery mildew is severe, it will reduce yield in both weight and number of peas per pod.

Erysiphe is an unusual fungus because it thrives in warm, dry weather, needing only moderate dew in the evening to germinate and grow. In fact, rain and heavy dew wash spores off plants and are deleterious to spore survival.

The first symptoms occur on the upper surfaces of older leaves, where light-colored spots appear and eventually turn white and powdery **(Photo 5.8)**. Small, black structures called cleistothecia form in mature lesions. The fungus overwinters as sexual spores in cleistothecia on infected plant debris and may survive in seed. Spread of the disease during the growing season is by conidia spores blown in the wind.

Cultural Control:

1. Cleaning up crop debris and using clean seed is the first line of defense.
2. Resistant varieties are available.
3. Early production helps to avoid the problem.
4. Overhead irrigation can help to slow disease progression.

Materials Approved for Organic Production:
Sulfur is effective if used early in disease development. See Fact Sheet.

GRAY MOLD *(Botrytis cinerea)*

Gray mold affects most vegetable and fruit crops, including peas and beans. The fungus is ubiquitous, and cool, moist conditions favor disease development. *Botrytis* usually infects senescent tissue first and spreads if conditions remain favorable. During periods of leaf wetness, dying petals, cotyledons, sepals, and older, lower leaves may become infected by blowing spores. If in contact with diseased tissues, any part of the plant may become infected. Lower leaves that are deep in the foliage are prime target areas. In shipment or on the shelf, pods may be affected if they are in contact with diseased petals, and the crop could be a mass of fungus by the time it reaches market.

The first symptoms on leaves are grayish lesions that may become brownish and dry. In damp conditions, the diseased areas become fuzzy, with gray spores produced in masses **(Photo 5.9)**. Infected fruit develops water-soaked, yellowish to greenish brown, irregular lesions, which can become somewhat soft. When conditions are favorable, the fungus grows very quickly, and the crop becomes a gray, fuzzy mass of rotting tissue and spores.

Botrytis overwinters as mycelium on plant debris or as sclerotia either in the soil or on plant debris. In the spring, conidia are produced and spread by moving air, plant debris, or soil. Spores need a wet surface on which to germinate and are produced in large numbers when conditions are cool and damp. Infection rarely occurs in warm temperatures, but once infection occurs, the fungus grows well even when it is warm. The germinating spore cannot penetrate healthy tissue; however, senescing or wounded tissue is easily colonized (e.g., flower petals, dying foliage, etc.), which can lead to growth into the living tissue. Too much nitrogen or too little potassium have been reported to make pods more susceptible to gray mold.

Cultural Control:

1. Cultural management is the key. Since it has such a wide host range and is ubiquitous, avoiding this disease is difficult. Crop rotation and sanitation may help (corn and grasses are not hosts) but will rarely prevent the problem if the weather favors the disease.
2. Close plant spacing and a dense canopy favor disease development. Plant in well-drained fields with good air movement. Avoid overcrowding, overwatering, weedy sites, and wet mulches.
3. When possible, use drip irrigation instead of overhead irrigation. If using overhead irrigation, water at times that do not extend the period of leaf wetness, e.g., very early in the morning on a sunny day.

Materials Approved for Organic Production:

Products containing *Bacillus subitlis* (Serenade) and potassium bicarbonate (Kaligreen, MilStop) have been shown to be effective.

WHITE MOLD *(Sclerotinia sclerotiorum)*

White mold has a very wide host range of vegetables, including beans. Other common hosts are carrots, tomatoes, peppers, and lettuce. It is not common in peas. If a field has a history of white mold problems, beans are in a crowded or weedy situation, or the weather is damp, white mold is more likely to be a problem. The disease starts on the stems, leaves, or pods as dark green, water-soaked lesions that rapidly increase in size and later develop a mass of very white, cottony mycelium **(Photo 5.10)**. Black sclerotia, which look like small black pebbles, develop in the white mass **(Photo 5.11)**. Whole branches of the plant may be consumed, and eventually the whole planting can be lost if conditions favor the fungus.

Sclerotia can remain viable in the soil for more than five years. Exposure to moist, cool conditions for several weeks preconditions the sclerotia to produce apothecia, tiny, cup-shaped fruiting bodies from which spores are released. After preconditioning, moderate soil temperature and near field capacity soil moisture stimulate apothecia and spore production. The spores are primarily carried by the wind, and in order to complete successful germination, they require senescing tissue (e.g., flower petals) as a food source. For this reason, white mold does not usually take hold until the beans flower. Spores can remain viable on a plant surface for up to two weeks. Once germinated, mycelia in the senescent tissue can survive for up to a month, waiting for sustained moist conditions during which it can invade healthy plant tissue. Spread from one plant to another is common by contact with the mycelia.

Cultural Control:

1. Practices that promote good airflow and quick drying are the most important management, e.g., wide rows oriented in the direction of prevailing wind, wide spacing in rows, good weed management, irrigation timed not to increase the hours of leaf wetness.
2. Rotation with non-host plants like corn helps. Since the sclerotia are very long lived without a host in the soil, rotation must be long to be of value.

Materials Approved for Organic Production:
*Coniothyrium minitans (*Contans). Contans is a fungus that, once applied and incorporated into the soil, attacks and destroys the white mold sclerotia. Follow the directions on the label carefully because success is dependent on eliminating near-surface sclerotia that are likely to germinate and produce apothecia and spores. Using enough of the material to reach all of the sclerotia in the soil profile would be cost prohibitive. Contans requires 3 to 10 weeks to effectively colonize and destroy sclerotia. Apply Contans to a *Sclerotinia*-infected crop immediately following harvest at 1 lb/A, and incorporate the debris into the soil. Alternatively, apply at 2 lb/acre to a crop right after planting, followed by shallow incorporation (or irrigate) to about a 1 to 2 inch depth. After application, do not till deeply, or sclerotia that are deeper than the Contans treated zone will be brought to the surface. To reduce survival of the sclerotia, Contans should be applied after a crop with high levels of white mold infection.

PHYTOPHTHORA BLIGHT (*Phytophthora capsici)*

Beans are a host of this pathogen that has, over recent years, become an increasing problem in peppers and many cucurbits. Phytophthora is not common in beans, but has been reported over the past few years. Moreover, *Phytophthora* blight in cucurbits has been reported to be worse when following a bean crop.

Initial infection comes from overwintering oospores that, when the soil is wet, germinate to produce sporangia. Swimming zoospores are released from the sporangia, so plants in the wettest areas of the field are generally infected first. In beans, large, water-soaked lesions can occur on the leaves, stems, or pods. Pods shrivel and become leathery, later developing a characteristic white, yeast-like growth typical of *Phytophthora*. Large numbers of sporangia are produced, causing the disease to spread rapidly by water movement under wet conditions. *Phytophthora* blight is most common in beans after severe rainstorms.

Cultural Control:

1. Avoid fields with a history of *Phytophthora* blight.
2. Crop rotation to non-host crops (such as sweet corn or crucifer crops) is recommended.
3. Arrange plantings so water movement does not potentially bring the pathogen from an infested to a clean field.
4. Manage soil tilth to promote rapid drainage.
5. Subsoiling, chisel plowing, cover cropping, and any other practice that helps avoid wet areas is recommended.
6. The pathogen can easily move from field to field with infested soil or runoff. Irrigation water can be a source of inoculum.
7. Clean equipment and boots if used in an infected field, and always work in uninfested fields before infested fields.

ANTHRACNOSE *(Colletotrichum lindemuthianum)*

Anthracnose is primarily a problem on dry beans. The pathogen overwinters in the seed and in plant residue and, under damp conditions, can germinate and produce spores quickly. The spores are windblown, and when there is incessant wet and windy weather, the disease can become widespread and devastating. Lesions begin as tiny brown specks that develop into dark brown spots with purplish rims and light centers **(Photo 5.12)**. Lesions can develop on any part of the plant, but they are most damaging when on the pod in snap beans or on the seeds in lima and other dry beans because they reduce marketability. Although there are some resistant varieties, there are still many susceptible cultivars, and when conditions are favorable for the disease, it can be very destructive.

Cultural Control:

1. Planting certified seed grown in dry climates is recommended.
2. Crop rotation (two to three years) is important.
3. Infected crop residue should be buried shortly after harvest.
4. Use resistant cultivars when possible, which may be difficult because resistance must be to the particular race of the pathogen in a given area.
5. Promote good airflow and fast leaf drying by providing adequate row and in-row spacing.

Materials Approved for Organic Production:
None.

ASCOCHYTA BLIGHT, LEAF AND POD SPOT *(Ascochyta pisi, A. pinodella, Mycosphaerella pinodes)*

These three species of fungi cause similar diseases in peas, and all three can be present at the same time. The symptoms are similar in the field, and these closely related species can be distinguished only with microscopic examination. Management for all three species is similar. All parts of the plant can be attacked. Infected leaves develop tan spots that are slightly sunken and have a distinct dark border. Under favorable conditions, the spots may develop concentric tan and dark brown rings. Infected pods have similar spots but do not develop the concentric rings.

These pathogens are seed-borne and can persist on plant debris. *M. pinodes* can form sclerotia and resistant spores that can persist in the soil for years. Spores are carried by wind and rain.

Cultural Control:

1. Use seed that is pathogen free.
2. Seed grown in dry climates is recommended.
3. Crop rotation (four to five years) is important.
4. Infected crop residue should be buried shortly after harvest.
5. Promote good airflow and fast leaf drying by providing adequate row and in-row spacing.

Materials Approved for Organic Production:
None.

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ORGANIC INSECT AND DISEASE CONTROL FOR Lettuce

INTRODUCTION

Lettuce belongs to the Composite family, a large group that includes sunflowers, artichokes, endive, and chicory, as well as noxious weeds, such as thistles and ragweed. It is commonly grown as a salad crop for its edible leaves. It may be the most widely grown crop on organic farms because its value as "locally produced" is unsurpassed. There are three commonly grown types of lettuce: leaf, head, and romaine. All three are popular as baby greens and are used in salad mixes. Cultivated lettuce is closely related to wild lettuce, and both share the same insect pests and diseases.

I. INSECT CONTROL

ASTER LEAFHOPPER (*Macrosteles quadrilineatus*)

The aster leafhopper **(Photo 6.1)** is found throughout the Northeast. Since it does not overwinter well in cold climates, its population size varies from year to year, depending on migration northward from milder regions. It feeds on over 100 species of plants, although cereal and grasses seem to be its preferred host. It is a major pest of lettuce, not because of direct damage, but rather because it transmits the pathogen that causes aster yellows (see below for details on this disease).

Cultural Control

While direct feeding by the aster leafhopper can injure the crop and may require a rescue treatment to limit injury, a more important factor in the spread of the disease is the proportion of the population that is carrying the pathogen. Consequently, management is focused on reducing the sources of disease inoculum.

1. Lettuce fields should be plowed immediately after harvest to remove the source of infection for later crops.
2. Perennial broadleaf weeds near lettuce plantings should be controlled.
3. The use of reflective mulches can be effective for repelling adult leafhoppers.

Materials Approved for Organic Production:

None are currently available.

SLUG SPECIES (GRAY GARDEN SLUG: *Derocerus reticulatum*)

Slugs **(Photo 6.2)** cause some cosmetic damage to lettuce leaves and when very abundant, can damage young seedlings. The biggest cause for concern, however, is their presence within harvested lettuce heads. They thrive wherever conditions are moist and living or decomposing plant material is present. Slugs are generally worse in wet years.

Cultural Control:

1. Mulch and permanent ground covers encourage slugs.
2. Tillage lowers slug populations, so for slug-sensitive crops, best practice may be to utilize intensive tillage and cultivation.

Materials Approved for Organic Production:

1. In lab trials, Surround WP (Kaolin clay) caused 100% mortality of garden slugs within 48 hours (Shelton & Plate 2003). More study is needed, but Surround may play a role in slug control in field-grown crops. Use of Surround on near-mature lettuce causes residue problems on the crop.

2. Sluggo is a bait formulation with iron phosphate, which has recently received OMRI listing for organic production. This product has received good grower reports.

TARNISHED PLANT BUG (*Lygus lineolaris*)

The tarnished plant bug (TPB) is a sucking insect **(Photo 6.3)** that feeds on lettuce and dozens of other crops and wild plants, including most legumes, buckwheat (when flowering), pigweed, members of the brassica family, and many plants in the Rose family, such as strawberries. A plant toxin released during the feeding process in lettuce causes brown lesions along the midrib, which reduce marketability. TPBs overwinter as adults under debris and in protected areas. They become active in early spring and deposit eggs on stems, midribs, and blossoms of host plants. The eggs hatch in about a week, and nymphs feed and cause much of the crop damage; they reach the adult stage in about 30 days. There are usually at least three generations in the Northeast, with peak populations in mid-June and mid-July.

Cultural Control:

1. There are a number of natural enemies of the TPB, including the big-eyed bug (*Geocoris punctipes*) and the wasps *Peristenus digoneutis, Leiophron uniformis, Anaphes ovijentatus,* and *Peristenus pallipes. P. digoneutis* is a non-native beneficial that was released in the Northeast in the 1990's. It has become established as a biological control agent and is spreading in the region. However, vegetable and small fruit growers have not yet reported a significant reduction in damage.
2. Row covers are not very useful for protecting lettuce, since TPB attacks lettuce in the hottest part of the season. Lettuce quality will suffer under row covers during that time.
3. Crop rotation has no effect on the TPB population because it is very mobile and feeds on many different kinds of plants.
4. Managing the whole farm with respect to hosts will have a significant impact. Avoid mowing or harvesting host plants in the area of other host crops that are in a susceptible stage. For example, mowing a field of alfalfa may drive the TPB into a neighboring field of lettuce. On the other hand, maintaining a field of hairy vetch in pre-bloom stage may attract the TPB and entice them away from a nearby lettuce field. To limit overwintering TPB populations, controlling weeds and keeping headlands mowed prior to crop growth are important practices.

Materials Approved for Organic Production:

Pesticides have only limited effect on TPB because of the rapid re-infestation that occurs from non-treated areas.

1. Pyrethrum gives limited control (40-60% control in the older literature; one poor result in recent studies).
2. Neem has shown some promise, but more studies are needed (two fair results against Lygus bugs in recent studies).

II. DISEASE CONTROL

DISEASES CAUSED BY BACTERIA

ASTER YELLOWS

Aster yellows is caused by a unicellular organism belonging to a group of organisms called phytoplasmas. They differ from bacteria because they lack a cell wall and are smaller. The organism that causes aster yellows infects the phloem sieve cells in lettuce (the food conducting cells). Symptoms include blanching and chlorosis of the young center leaves of lettuce plants **(Photo 6.4).** These leaves appear as short, thick stubs in the middle of the head. Outer leaves also become yellow. The disease also causes sterile or aborted flowers in seed crops. The organism overwinters in the bodies of adult aster leafhoppers and in perennial or biennial host plants, e.g., Russian thistle, wild lettuce, dandelion, plantain, and many others. It is transmitted to lettuce during leafhopper feeding; aster yellows is not a seed borne disease.

Cultural Control:
Control is based upon removal of reservoirs of the overwintering organism near lettuce fields, i.e., weed control in the headlands and nearby fields.

1. Lettuce fields should be plowed down soon after harvest.

Materials Approved for Organic Production:
None currently known to be effective.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

BOTTOM ROT AND WIRESTEM (*Rhizoctonia solani*)

Rhizoctonia causes two different diseases in lettuce. Wirestem, which is a late damping off disease, occurs in seedling production. Symptoms include a shrinking of the stem just above the soil line, causing the stem to collapse and the plant to fall over. Bottom rot occurs late in field plantings, usually when the lettuce is approaching maturity, and the bottom leaves are in direct contact with the soil. Rust-colored lesions appear on the midrib of these leaves and may expand and eventually cause the leaf to collapse. There is no fluffy, white mycelium like there is with lettuce drop, and there is no gray mass of spores like there is with gray mold. The fungus can overwinter as either mycelia or sclerotia in the soil and on plant residue. Plants are most commonly infected by direct contact with mycelium. In addition to being a pathogen, *Rhizoctonia* is a good saprophyte and can persist on decomposing organic matter in the soil.

Cultural Control:

1. Rotation with grass family crops and green manures helps by reducing the population of the pathogen in the soil.
2. Bury the sclerotia before planting by plowing, rather than disking. Plant lettuce in well-drained soil and control weeds to allow good air flow.
3. In fields with a history of bottom rot, growing on raised beds helps.
4. Romaine and other upright lettuce varieties are likely to escape infection because the leaves do not touch the soil.
5. As new additions of organic matter may temporarily increase *Rhizoctonia* populations in the soil, avoid incorporating organic matter immediately before planting crops where Rhizoctonia diseases have been a problem.

Materials Approved for Organic Production:
None are currently available.

DOWNY MILDEW (*Bremia lactucae*)

Downy mildew is caused by a water mold. It is particularly common where temperatures are low and leaves are wet for long periods. These conditions are common in cool season hoophouse and greenhouse production. Downy mildew lesions first appear light green, and the leaf then develops a yellow, chlorotic appearance. Older lesions turn tan and papery **(Photo 6.5)**. Under optimal conditions for pathogen growth, sporangiophores (structures bearing sporangia) and sporangia (structures containing spores) emerge from the leaf stomata **(Photo 6.6)**. These appear as discrete, white projections, usually on the underside of the leaf. Diseased leaves often become infected by soft rot bacteria and fungi. Between crops, the organism survives as mycelia and oospores in the residue of infected plants. Wild lettuce can carry the disease.

Cultural Control:

1. Crop rotation is the first line of defense. Plow deeply to bury diseased crop residue.
2. Reduce the duration of leaf wetness by avoiding overhead irrigation, orienting the rows parallel with prevailing wind, using wide spacing within rows, controlling weeds, and minimizing crop debris in the field at time of planting.
3. Do not use poorly drained fields for early or late plantings.

4. Manage greenhouse ventilation to avoid long periods of leaf wetness.
5. The most effective means of controlling downy mildew is to grow resistant varieties. However, resistance is strain-specific, so best results are realized by noting which resistant varieties do well in a given area.

Materials Approved for Organic Production:
None currently known to be effective.

GRAY MOLD (*Botrytis cinerea*)

In addition to being a plant pathogen, the fungus that causes gray mold is a widespread saprophyte that feeds on dead and dying plant material. Consequently, spores are present at all times, and management depends on cultural practices that minimize favorable conditions for spore germination and fungal growth. Under cool, humid conditions, the fungus invades wounds and dying tissue on many plant species. On field-grown lettuce, gray mold is a common problem in the spring and fall, when weather conditions are often favorable. In the greenhouse, persistent high humidity and plant surface moisture are the usual causes of an outbreak. Gray mold can spread from an infected plant to other plants after harvest and is a common, marketplace disease of lettuce, chicory, and endive. Initial symptoms show the infected area to look water soaked. As the infection progresses, the lesion changes color from brown to gray **(Photo 6.7)**. The disease can spread from the leaves to the stem. Affected areas rapidly turn soft and rot. The characteristic gray, fuzzy mycelium that is usually seen on plants infected by gray mold may not always be present on lettuce.

Cultural Control:
1. Avoid wounding plants during cultivation.
2. Reduce the duration of leaf wetness by avoiding overhead irrigation, orienting the rows parallel with prevailing wind, using wide spacing within rows, controlling weeds, and minimizing crop debris in the field at time of planting.
3. Use raised beds.
4. Manage greenhouse ventilation to avoid long periods of leaf wetness.
5. While crop rotation may occasionally be effective, most often it is not an effective control because gray mold spores are ubiquitous.

Materials Approved for Organic Production:
None currently known to be effective.

LETTUCE DROP (*Sclerotinia minor or S. sclerotiorum*)

Drop is also referred to as white mold or watery soft rot. The causal organisms have many different hosts, including weeds and vegetables, such as carrots, cabbage, beans, tomatoes, and celery. It is also a major disease of chicory and endive. On lettuce, the name describes the symptoms; infected plants appear wilted, and the outer leaves drop to the ground while remaining attached to the plant **(Photo 6.8; Photo 6.9)**. The fungus attacks the petioles and spreads to the center of the plant. Upon uprooting, infected plants often show characteristic, pure white, cottony mycelia and black sclerotia (i.e., tiny, hard, black, oblong capsules) in various stages of development. Sclerotia drop to the soil when the host tissue disintegrates. If the conditions are favorable, sclerotia will produce new mycelia that spread through the soil, infecting new plants. The sclerotia can also survive in the soil for at least five years and, with adequate soil moisture, will form spore-producing fruiting bodies called apothecia. Ascospores are released from the apothecia and carried by wind to host plants, where they germinate if conditions are favorable.

Cultural Control:
1. Growers who experience only occasional outbreaks during seasons of prolonged wet weather, can achieve satisfactory control with practices that promote quick leaf drying. Control of weeds is important. Crop rows should be oriented parallel to the prevailing wind, and plants should be spaced widely within rows. Drip irrigation is recommended. Avoid overhead irrigation.

2. If the disease has been severe, a minimum five-year rotation with non-host crops, such as corn, cereal, or forage grass, is recommended. Shorter rotations with onions and potato can be used where the disease is less severe.
3. Flooding of the field between crops can promote spore release when no host is present and helps to reduce inocula.
4. There are no resistant varieties.

Materials Approved for Organic Production:
Contans (a biological control product) is a formulation of a beneficial fungus, *Coniothyrium minitans* that parasitizes and kills sclerotia in the soil. It may be most beneficial in reducing the survival of sclerotia when applied after a year of heavy disease pressure. Refer to the *Coniothyrium minitans* fact sheet for more information.

REFERENCE
Shelton, A. M. & Plate, J. D. (2003). Report on Insecticide Evaluations on Selected Pests of Vegetable Crops in New York. Cornell University/NYSAES (internal document).

ORGANIC INSECT AND DISEASE CONTROL FOR Solanaceous Crops

INTRODUCTION

The botanical family Solanaceae includes several important vegetable crops, such as tomatoes, potatoes, eggplants, and peppers. These crops share a number of insect and disease pests, so any crop rotation plan should consider all crops grown from this family.

I. INSECT CONTROL

APHIDS (Primarily the GREEN PEACH APHID, *Myzus persicae*, and the POTATO APHID, *Macrosiphum euphorbiae*)

Aphids are small, soft-bodied insects **(Photo 7.1)** that suck nutrients from plant tissues and form colonies on the undersides of leaves and often in or around flowers. Several different species of aphids attack potato, tomato, eggplant, and pepper. In hot, dry weather, populations can increase rapidly, causing leaves to wilt and twist. In most organic systems, aphids are rarely a lasting problem because predator and parasite populations keep the aphid population in check. However, there is often a lag period between when aphid populations first arrive and when their natural enemies build up, so plants should be scouted regularly, and treatment may be necessary in some situations, such as tomatoes or peppers in a high tunnel. Some aphids transmit viruses, which are particularly devastating in seed potato production.

Cultural Control:

1. Encourage beneficial insects. Limit use of broad-spectrum insecticides, such as pyrethrum, because they kill predators and parasites and may cause the aphid populations to flare up. Leaving or creating beneficial insect habitat and food sources will help.
2. Use virus resistant cultivars, if available.
3. Control overwintering weeds and inspect overwintered and imported plants in greenhouses because they are often the source of initial infestation of spring transplants.

Materials Approved for Organic Production:

1. Soap: If aphid populations are high, control may be necessary. Ensure coverage of the parts of the plant where aphids live, especially the undersides of leaves. In recent studies, soaps have been ineffective against green peach aphid. Other studies we examined indicated five good, one fair, and two poor results against other aphid species.
2. Rotenone is recommended in the older literature, BUT it is no longer a registered insecticide and may not be used.
3. Neem products can provide some control. Based on a limited number of studies, neem products gave good control of turnip aphid (two studies); fair (four) to poor (three) control of green peach aphid; and mostly good control of other aphids (two good, two fair, one poor). Please see the neem material fact sheet for a discussion of the different types of neem products.
4. Summer oils (two fair and three poor results) provide some control.
5. Kaolin clay (currently not labeled for aphids on these crops) and plant and mineral oils may be effective.

ASIATIC GARDEN BEETLE (*Maladera castanea*)

The Asiatic Garden Beetle is a native of Japan and China, where it is not an important pest; however, it is becoming an important pest in the Northeast. The pest spends much of its life in the soil as a grub (similar to a Japanese beetle grub), feeding on the roots in sod and weedy gardens. The grubs (larvae) pupate early in the spring, and adults emerge in June-July and start feeding on about a hundred species of flowers and garden vegetables. Peppers and eggplants are favorites. The adults are round, cinnamon-to reddish-brown beetles **(Photo 7.2)**. They eat big, irregular holes in leaves and blossoms. They are often difficult to find because they feed at night and burrow into the soil during the day. Evidence of Asiatic garden beetle includes chewed leaves but no visible pests; checking plants at night often reveals cutworms, but more and more growers are discovering Asiatic garden beetle as well.

Cultural Control:

1. Maintain good weed control in fields.
2. Fall clean up and tilling under crop debris will help.
3. If the beetle is not already hiding in the soil, row covers will protect crops from adult feeding.

Materials Approved for Organic Production:

Growers report good control of adults with spinosad (Entrust).

COLORADO POTATO BEETLE *(Leptinotarsa decemlineata)*

Colorado potato beetles (CPB) overwinter as adults **(Photo 7.3)**, hibernating in the soil near previous host crop fields. They emerge in the spring and crawl to new hosts, where they feed and lay eggs **(Photo 7.4)**. The resulting larvae **(Photo 7.5)** and successive generations can quickly defoliate a crop. The CPB prefers potatoes and eggplants but can also be a problem on tomatoes and peppers.

Cultural Control:

1. Crop rotation to non-susceptible crops is the first line of defense, since CPB only feeds on solanaceous plants. Greater distance between fields means that adults take longer to find the current year's crop. Rotating solanaceous crops as a group will concentrate the population in one area of the farm, making distance rotation easier. Control of solanaceous weeds (e.g., horse nettle) that can serve as hosts is important.
2. A plastic-lined barrier trench between the old field and new field of host crops will catch and trap many crawling adults. This practice will reduce the overall population, though supplemental control may still be required.
3. If young potato plants are infested, rapidly moving a flame from a propane torch over the top of the plant has been shown to kill overwintered, adult CPBs, which tend to feed at the top of the plant. Although this measure may singe plant tissue, there will be no long-term damage to the plant if done carefully. Suction devices can also be used.
4. Mulching crops with straw or hay before adults arrive has been shown to significantly reduce and delay CPB pressure.
5. For plantings less than two acres, hand-picking may be practical if the CPB pressure is low.
6. Trap cropping with a potato variety that grows well in cool weather, such as "Superior," has been shown to be effective. Plant the trap crop between the previous and current year's fields (i.e., near CPB overwintering sites), and destroy beetles by flaming or with insecticides when adult CPB numbers on the trap crop are high.

Materials Approved for Organic Production:

1. Spinosad: Recent studies showed 12 good and 2 fair results.
2. Neem products: Recent studies showed one good and two fair results. Generally, neem is slow-acting, but it reduces overall damage and numbers of large larvae. Please see the neem material fact sheet for a discussion of the different types of neem products.
3. *Beauveria bassiana*: Recent studies showed one good, one fair, and five poor results. See the material fact sheet on *Beauveria bassiana*.
4. *Bt tenebrionis* (also called *Bt san diego*) - currently there are no approved formulations.

EUROPEAN CORN BORER (*Ostrinia nubilalis*)

The European corn borer has over 200 host plants and is primarily a pest of corn. Pepper and eggplant are also relatively common hosts, and tomato and potato are less frequently affected. In the spring, adults lay their eggs on plants, and the emerging larvae bore into stalks **(Photo 7.6)** or fruits. Larvae usually enter the fruit under the calyx or sometimes directly through the side and feed inside. Secondary rotting of infested fruit is common.

Cultural Control:

1. Crop rotation is of only limited value because adults can easily fly between fields.
2. Some pepper varieties differ in their susceptibility, but there are no truly resistant varieties.
3. The effectiveness of spray materials can be increased by using pheromone traps to determine peak activity periods and treating accordingly. Check with county extension for any available IPM forecasting services.

1. Release of *Trichogamma* wasps has been shown to be effective. *Trichogramma ostriniae* is a tiny wasp that is smaller than a pinhead. The female wasp lays her eggs inside the European corn borer eggs. Usually, all of the eggs in the mass are destroyed, and the whole egg mass turns black. For details on using this beneficial insect, see: http://nysipm.cornell.edu/factsheets/vegetables/swcorn/trich_ost.pdf.

Materials Approved for Organic Production:

1. *Bt kurstaki*: There have been no recent studies on peppers. Bt may be effective, though it has a very short residual protection. Timing the spray to catch the borer during its short time outside, before it bores into the pepper, is difficult.
2. Spinosad: Recent studies: three good, one poor result on this crop.

FLEA BEETLES (POTATO FLEA BEETLE – *Epitrix cucumeris*, TOBACCO FLEA BEETLE - *Epitrix hirtipennis*, PALESTRIPED FLEA BEETLE - *Systena blanda*, and EGGPLANT FLEA BEETLE - *Epitrix fuscula*)

Flea beetles **(Photo 7.7)** are common pests of potatoes, tomatoes, and eggplants when the crops are young. Their feeding causes small holes in the leaves. Under light insect pressure and good growing conditions, seedlings and transplants will grow out of the damage. Eggplant is especially attractive to flea beetles, and small transplants may need protection. The species that attack the Solanaceae are not the same as those that attack brassica crops or sweet corn, which is important when considering crop rotation.

Cultural Control:

Row covers work well but can be expensive. Crops under row covers usually produce earlier yields.

Materials Approved for Organic Production:

The studies below were conducted primarily on flea beetle pests of other crops, particularly brassicas. Results may be different on flea beetle pests of solanaceous crops.

1. Rotenone is recommended in the older literature, BUT it is no longer a registered insecticide and may not be used.
2. Spinosad: Research trials have indicated that spinosad can be moderately effective, though results are variable (three fair and two poor results).
3. Neem products are similarly effective (two fair, two poor results). Please see the neem material fact sheet for a discussion of the different types of neem products.
4. Pyrethrum: Pyganic has shown variable results (four fair, two poor) even with high rates.
5. Kaolin clay (Surround): Recent trials have shown three poor results.

Note: Since flea beetles can re-colonize rapidly, especially on sunny days, frequent treatment with any material may be required. Treatment of all susceptible plants in the field is advisable in order to reduce influx from untreated areas.

HORNWORM (TOBACCO *Manduca sexta*, and TOMATO, *Manduca quinquemaculata*)

Hornworms are large green caterpillars **(Photo 7.8)** that are common in warmer climates. They are, however, becoming more and more common in the Northeast, especially in high tunnels and greenhouses. They can consume considerable leaf tissue.

Cultural Control:
Scouting and hand picking the larvae works well because they are usually present in small numbers. The caterpillars are well camouflaged; look for the large droppings beneath plants.

Materials Approved for Organic Production:

1. *Bt kurstaki:* There is a lack of research data, however growers report successful use.
2. Spinosad: One recent study showed good control.

POTATO LEAFHOPPER (*Empoasca fabae*)

Potato leafhoppers **(Photo 7.9)** do not overwinter in the Northeast but "leap frog" their way up from southern areas each summer, arriving in very large numbers in some years and smaller numbers in others.
The potato leafhopper favors alfalfa, beans, strawberries, and potatoes. It is a serious pest of potatoes, as both adults and larvae suck plant juices. Their feeding causes curling, stunting, and dwarfing, accompanied by a yellowing, browning, or blighting of the foliage, known as "hopperburn" or tipburn (because the damage is first seen at the leaf tips) **(Photo 7.9)**. Once significant "hopperburn" is evident, the crop has already lost yield, so early scouting is important.

Cultural Control:

1. Crop rotation is not effective, as leafhoppers do not overwinter in the Northeast, and they can move large distances.
2. Some varieties are more tolerant. These include "Elba," "Green Mountain," some russets, "Snowden," "Ontario," and "Katahdin." "Red Norland" is very susceptible. More information may be found in seed catalogues or through the local extension office.
3. Scouting and early detection are important because population levels vary greatly from year to year, and successful control must start early.

Materials Approved for Organic Production:

1. Pyrethrum (recent trials have shown one good result).
2. Neem products: One recent study showed fair control. Please see the neem material data sheet for a discussion of the different types of neem products.
3. Spinosad: Entrust is not effective against this pest.

TARNISHED PLANT BUG (*Lygus lineolaris*)

The tarnished plant bug (TPB) is a sucking insect **(Photo 7.10)** that feeds on flowers and buds of eggplant, pepper, and tomato and causes flower drop, which greatly reduces yield in some years. When there are large numbers of tarnished plant bug, feeding on leaves will cause browning of the tips and edges, especially on potato and eggplant. This damage may be mistaken for a disease or hopperburn (see above discussion of leafhopper).

Cultural Control:

1. Avoid mowing legume hay fields surrounding crops just prior to or during flowering of solanaceous crops because such a disturbance will drive the TPB into the crops.
2. Floating row covers work well to protect buds and flowers on young plants and can greatly increase early yield. They may not be practical for mid-summer use.
3. Practice good weed control; TPB seems to be more of a problem in weedy areas.

Materials Approved for Organic Production:
There are no proven, effective organic insecticides for TPB, although pyrethrums will reduce the overall populations. Neem products are recommended for trial.

II. DISEASE CONTROL

DISEASES CAUSED BY BACTERIA

BACTERIAL CANKER (*Clavibacter michiganensis subsp. michiganensis*), **BACTERIAL SPECK** (*Pseudomonas syringae pv.* tomato) and **BACTERIAL SPOT** (*Xanthomonas campestris pv. vesicatoria*) are all quite common and are all managed in the same way.

Canker is most common on tomato. The first symptoms may include wilting, browning at the ently crack open and spots on the fruit. The fruit lesions have a dark brown center surrounded by a white ring, with a characteristic "birds-eye" appearance **(Photo 7.11)**.
Speck is found only on tomato. Small black lesions (1/8 inch) with a yellow halo appear on leaves, and black, raised lesions or dots appear on fruit **(Photo 7.12)**.
Spot occurs on both tomato and pepper. Symptoms can appear on leaves, stems, and fruit **(Photo 7.13)**. Lesions begin as water-soaked spots that become brown and may have an irregular shape **(Photo 7.14)**. Infected leaves eventually turn yellow and drop off the plant.

Cultural Control:

1. Plant disease-free seed. Hot water seed treatment at 122°F for 25 minutes is recommended for tomato seed. For pepper seed, hot water treatment at 125°F for 30 minutes is recommended. Strictly follow time and temperature recommendations to minimize damage to seed germination and vigor. Hot water treatment can also eliminate fungal pathogens on the seed. Chlorine treatment of seed is also effective. Clorox® Commercial Solutions Ultra Clorox Germicidal Bleach is labeled for pepper (bacterial spot pathogen) and tomato (bacterial canker pathogen) seed treatment (EPA Reg. No 67619-8). There is less chance of seed being damaged with bleach than hot water; however, chemical controls such as Clorox are effective for pathogens on the seed surface only; hot-water treatment can kill bacteria inside as well as on the outside of seed. To Clorox treat seed, mix 24 oz product with 1 gallon of water to obtain a solution with 10,000 ppm available chlorine. Use 1 gallon of this solution per pound of seed. Put up to 1 pound of seed in a cheesecloth bag, submerge in this solution and provide continuous agitation for 40 minutes, rinse seed under running tap water for 5 minutes, then dry seed thoroughly on a paper towel in a location free of mice. Prepare a fresh batch of the dilute Clorox solution for each 1-pound batch of seed. The soak can stimulate germination, so if the seed is dried and held too long, germination will be reduced. To legally make this treatment, a label with this use must first be obtained from the Clorox company (800-446-4686) or by going to the following web site. http://www.thecloroxcompany.com/downloads/msds/bleach/cloroxcommercialsolutionscloroxgermicidalbleach1stainremover02-10.pdf
2. Pepper varieties that are resistant to bacterial spot are available (see the Cornell Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production http://www.nysaes.cals.cornell.edu/recommends/.)
3. If growing and using transplants, all greenhouse materials should be cleaned and sterilized prior to use. The spread of bacterial diseases in the greenhouse is common.
4. If trellising or caging tomatoes, stakes and cages should be either new or cleaned and disinfected. Sodium hypochlorite at 0.5% is effective and must be followed by rinsing and proper disposal of solution. Hydrogen peroxide is also permitted.
5. If pruning tomatoes, disinfect tools or gloves regularly to minimize spread of bacteria from infected plants.
6. Use a three-year crop rotation away from tomato and pepper.
7. Avoid overhead irrigation, as bacterial diseases can spread by splashing water.
8. Avoid working in the crop when it is wet.
9. Compost may contain organisms that are antagonistic to the pathogens.

Materials Approved for Organic Production:
Copper compounds. Recent studies showed two fair and one poor result.

COMMON SCAB (potato) *Streptomyces scabies*

Common scab is a disease of potatoes that results in corky lesions on the surface of the tuber **(Photo 7.15)**. It is caused by the filamentous bacterium, *Streptomyces scabies*. The pathogen can survive in the soil for many years.

Cultural Control:

2. Plant scab-free potato seed.
3. Rotate with crops that are not hosts. Hosts include beets, carrots, turnip, radish and parsnip. Good rotation crops are sweet corn and grass family green manures, such as rye, millet, and oats. Avoid plow down crops of legumes, especially red clover, immediately before potatoes.
4. Use resistant cultivars (see Reiners, 2004 Potatoes). http://www.nysaes.cornell.edu/recommends/
5. Maintain pH below 5.5. This practice is usually not suited for diversified vegetable growers because it is detrimental to the other crops in the rotation.
6. Maintain good soil moisture, especially at tuber initiation.

Materials Approved for Organic Production:

1. Applying sulfur in the row when planting is suggested, but unproven.
2. Biologicals, such as Trichoderma, are recommended for grower testing.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

ANTHRACNOSE (tomato) *Colletotrichum coccodes*
Anthracnose is a common disease that appears on ripening tomato fruit. Symptoms begin as small, sunken, water-saturated lesions. Black fungal structures develop and are visible within the lesion **(Photo 7.16)**. While symptoms appear only on ripe fruit, infection can occur on both green and ripe fruit.

Cultural Control:

1. Use a three-year crop rotation away from potato, tomato, and pepper.
2. Mulching can reduce the severity of infection.
3. Avoid overhead irrigation, or use it such that fruit wetness is minimized.
4. Plant disease-free seed. Hot water seed treatment at 122°F for 25 minutes is recommended for tomato seed.
5. Stake or cage plants, so fruit is not in contact with the soil.
6. Compost may contain organisms that are antagonistic to the pathogen.

Materials Approved for Organic Production:
Copper products showed one poor result in recent studies.

BLACK SCURF (potato) *Rhizoctonia solani*

Black scurf is a fungal disease of potato that can delay emergence and reduce yield. More commonly, however, the disease results in a high percentage of tubers with rough, black structures on the surface, reducing marketability **(Photo 7.17)**. These surface markings are reproductive structures called sclerotia; they can survive for years in the soil and infect susceptible crops in future seasons. While *R. solani* is uncommon as a damping off and root rot pathogen on tomato, pepper, and eggplant, *Rhizoctonia* has a very broad host range including many vegetables.

Cultural Control:

1. Use seed tubers free of sclerotia.
2. Use a three-year or longer crop rotation including a grass or cereal green manure, such as sudex (sorghum-sudan grass hybrid) or Japanese millet, the year before potatoes.
3. Promote quick emergence by planting in warm soil, covering seed pieces with no more than two inches of soil, and hilling up later. Also, avoid wet soil at planting time.
4. Plow down Brassica green manures that contain high levels of glucosinolates, which have a fumigant effect when decomposing e.g., 'Pacific gold' oriental mustard and 'Idagold' mustard.

Materials Approved for Organic Production:
Trichoderma (RootShield and SoilGard 12 G) have has shown variable results.

EARLY BLIGHT (potato, tomato) *Alternaria solani and Alternaria tomatophila*
Early blight is caused by two fungi that are serious problems in tomatoes and potatoes, but rarely affect peppers and eggplants. All aboveground portions of the plant can be affected throughout the growing season. The disease starts on the lower leaves with small, circular spots that resemble a target with their concentric rings **(Photo 7.18)**. Leaves develop yellow blighted areas, and later the tomato fruit may rot on the stem end. Though rare, potato tubers can also become infected. The pathogen can overwinter on diseased plant residues

Cultural Control:

1. Use crop rotations of at least three years to non-hosts (i.e., away from tomato, potato, and eggplant).
2. Provide optimum growing conditions and fertility. Stressed plants (including drought) are more susceptible to early blight.
3. Stake or cage plants to keep fruit and foliage away from soil.
4. Drip irrigation is preferred. If using overhead irrigation, start before dawn, so plants are dry early in the day. The key is to keep the period of leaf wetness to a minimum.
5. Mulching helps to prevent splashing of spores from soil up to lower leaves.
6. Indeterminate tomato and late-maturing potato varieties are usually more resistant or tolerant to early blight.
7. Early blight can be seed-borne, so buy from a reliable supplier. Hot water seed treatment at 122°F for 25 minutes is recommended to control early blight on tomato seed. See chlorine treatment procedures under bacterial diseases.
8. Each season, disinfect stakes or cages with an approved product before use. Sodium hypochlorite at 0.5% is effective and must be followed by rinsing and proper disposal of solution. Hydrogen peroxide is also permitted.

Materials Approved for Organic Production:

1. Copper products showed one good and one poor result in recent studies.
2. When used as a drench at planting, a *Trichoderma harzanium* product (PlantShield HC) showed fair to good results on tomatoes in NYS.

GRAY MOLD (greenhouse tomato) *Botrytis cinerea*

Gray mold can occur wherever tomatoes are grown but is primarily a problem in greenhouse or high tunnel production. The disease can affect all aboveground parts of the tomato. Lesions can form on leaves, stem, petiole, and senescent petals, frequently causing blossom drop or fruit infections **(Photo 7.19)**. Lesions on leaflets progressively expand to include the petiole, and eventually the whole leaf is killed. Stem infections can cause girdling and death of the stem. Infected tissue develops a fuzzy, gray mold growth, which can give off clouds of spores when shaken.

Cultural Control:
Since gray mold has a very wide range of hosts, the spores are difficult to avoid. Controlling the disease involves managing the environment in the greenhouse or high tunnel to make it less favorable for disease spread.

1. Minimize leaf wetness, and maximize ventilation.
2. High calcium levels in the soil that result in a calcium to phosphorus ratio of two or higher in the leaf petiole aids in reducing susceptibility of tomato plants.

Materials Approved for Organic Production:
Copper may be effective. Begin application before the canopy becomes dense.

LATE BLIGHT (potato, tomato) *Phytophthora infestans*

Late blight **(Photo 7.20)** is caused by a water mold pathogen and is a serious disease of both potato and tomato. It is infamous as the cause of the Irish potato famine. It can quickly defoliate plants and cause fruit rot in tomato and tuber rot in potato. Spores can be carried long distances in the wind, and the disease can spread rapidly. In the Northeast, the pathogen overwinters only in living plant debris, most commonly on seed potatoes or unharvested and cull potatoes. As greenhouse and high tunnel tomato production becomes more common, overwintering may occur on infected tomato tissue that survives the winter. Imported solanaceous transplants, including tomato and petunia, may harbor late blight.

Cultural Control:
1. Destroy cull potatoes and control potato volunteers in all fields.
2. Do not allow infected greenhouse or high tunnel tomatoes to survive the winter.
3. Use drip, rather than overhead, irrigation in order to keep the foliage dry. Alternatively, overhead irrigate early in the morning (i.e., before dawn), so the plants are dry early in the day. The key factor is to keep the period of leaf wetness to a minimum.

Materials Approved for Organic Production:
Copper products give fair to good control but must be applied often and thoroughly.

LEAF MOLD (greenhouse tomato) *Fulvia fulva*

In the Northeast, leaf mold has historically been a disease of high tunnel and greenhouse production; however, it is now becoming common in field production as well. It is a disease that is usually a problem only under highly humid conditions. The initial symptoms are light green to yellowish spots on the upper surface of the leaf **(Photo 7.21)**, with a dark green mold on the undersurface of each spot **(Photo 7.22)**. Later, the spots coalesce, and leaves wither and drop from the plant. Usually, only the foliage is affected. Older leaves are affected first, so if the disease arrives late in the season, it does not affect yield. If it strikes early, the loss of foliage will reduce yield. Blossoms, petioles, and fruit may be affected during severe outbreaks.

Cultural Control:
1. Sanitation is important. After harvest, remove all crop residue, and steam the production area for at least six hours.
2. Minimizing periods of leaf wetness reduces the severity of leaf mold. Avoid wetting leaves by overhead irrigation or dripping condensation. Maintain good ventilation.
3. There are many resistant varieties of tomatoes suitable for high tunnel and greenhouse production.

Materials Approved for Organic Production:
None known.

PHYTOPHTHORA BLIGHT (pepper, tomato, eggplant) *Phytophthora capsici*

Phytophthora blight is a serious problem of peppers in warmer parts of the Northeast and will attack tomato, eggplant, cucurbits, and beans. Plants collapse as the pathogen attacks the roots and crown and girdles the stem. Fruit will rot where they touch the ground or from spores carried in splashing water **(Photo 7.23)**. Fruit lesions develop as dark, water-soaked areas that spread and become coated with the white spores. *P. capsici* overwinters in the soil.

Cultural Control:

1. Tolerant pepper varieties are available and should be used if Phytophthora blight has been observed on the farm in previous years.
2. Crop rotation away from a host plant for four to five years. Note that peppers, tomatoes, eggplants, cucurbits, lima beans, and snap beans are all hosts for this pathogen.
3. Use raised beds and ensure good soil drainage.
4. Maintain good soil structure to avoid poor drainage and standing water in the field.

Materials Approved for Organic Production:
No control materials are effective against Phytophthora blight.

SEPTORIA LEAF SPOT (tomato) *Septoria lycopersici*

Septoria leaf spot is a fungal disease of tomato and has a biology similar to early blight. Initial symptoms include peppering of lower leaves with small circular spots with dark brown margins **(Photo 7.24)**. Rapid defoliation can occur under optimal (i.e., wet) conditions **(Photo 7.25)**. The fungus is spread by splashing water, insects, equipment, or field workers.

Cultural Control:

1. Since septoria leaf spot is often seed-borne, be sure to buy seed and/or transplants from reputable sources.
2. Keep leaves dry and to promote air circulation by properly spacing plants.
3. Stake and mulch plants to help keep leaves dry and prevent soil and inoculum splashing onto leaves.

Materials Approved for Organic Production:
Copper products showed one good and one poor result in recent trials.

VERTICILLIUM WILT (eggplant, tomato) *Verticillium albo-atrum* or *V. dahliae*

Verticillium wilt can be a serious problem in eggplant and some tomato varieties. This disease can be caused by either of two fungal pathogens, *Verticillium albo-atrum* or *Verticillium dahliae*. Infected plants exhibit leaves that turn yellowish, and portions of the plant collapse **(Photo 7.26)**. Most modern tomato varieties are resistant, but many heirlooms are not. On potatoes, the disease is called "early dying."

Cultural Control:

1. Avoid other host crops in the rotation before eggplant or tomatoes, including potatoes, peppers, and strawberries.
2. Plant resistant varieties.
3. Compost may contain organisms that are antagonistic to the pathogen.

Materials Approved for Organic Production:
No control materials are effective against Verticillium wilt.

WHITE MOLD (tomato, pepper, eggplant) *Sclerotina sclerotiorum*

White mold is a fungal disease that has a very wide host range, including tomatoes, eggplants, peppers, beans, carrots, lettuce, cole crops, and many weeds. Early symptoms are water-soaked lesions and firm, rotting of stem tissue. Later, lesions become covered with a white, fluffy fungal growth **(Photo 7.27)**, and black sclerotia can be found on and in the diseased tissue **(Photo 7.28)**.

Cultural Control:

1. Use raised beds and tiles to improve drainage if necessary.
2. Rotation is difficult because many crops and weeds are hosts, and the sclerotia are very long-lived in the soil. Four years of sweet corn or other cereal is recommended for infested fields.

3. Avoid excessive irrigation.
4. Avoid overcrowding and weeds that maintain moisture in the crop canopy. Good airflow is essential to control white mold.

Materials Approved for Organic Production:

Coniothyrium minitans (Contans) is a beneficial fungus that can be applied to the soil to reduce survival of sclerotia. It should be applied after a crop is infected with white mold or before a susceptible crop is planted in an infested field.

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ORGANIC INSECT AND DISEASE CONTROL FOR Sweet Corn

INTRODUCTION

Sweet corn is in the grass family (Graminaceae) with other cereal crops. It shares few diseases with other common vegetable crops, so it may be useful in crop rotations. Sweet corn shares pests with field and silage corn, so proximity to these crops is often a problem for sweet corn producers.

I. INSECT CONTROL

CORN EARWORM (*Helicoverpa zea*)
The corn earworm (CEW), also known as the tomato fruitworm, is a major pest of sweet corn. The adult moth lays eggs in the silk **(Photo 8.1)**, and the larva crawls down the silk channel and eats kernels from the tip of the ear downward **(Photo 8.2)**. The pest is not known to overwinter in the Northeast US; it is commonly carried into the region each year on weather fronts from southern regions, so crop rotation is not effective. Pheromone traps are useful for detecting CEW flights and helping to time control practices.

Cultural Control:

1. Corn varieties with long, tight husks impede the entrance of the worm somewhat, but provide only partial control. Varieties reported to be less susceptible to damage include: Silver Queen, Stowell's Evergreen, Viking RB, Supersweet JRB, Golden Bantam, Jubilee, Texas Honey June, and Bodacious.
2. Since the pest is usually not a problem until mid to late summer, try to avoid injury by planting early and harvesting before expected arrival of CEW. Using short season varieties also helps.
3. Naturally occurring predators and parasites provide some control but are often not sufficient to avoid economic losses. Plantings that increase habitat diversity may help to promote establishment of natural enemies, but supplemental control is often needed.

Materials Approved for Organic Production:

1. *Bacillus thuringiensis* var. *kurstaki* (e.g. Dipel) is a well-known microbial insecticide that targets some caterpillars. Bt has to be ingested in order to be effective. Placement of the material where it will be eaten is difficult because the CEW does not feed outside the ear. A manual applicator ("Zea-Later") has been developed to apply 0.5 ml of a Bt and oil mixture (or other treatment) directly into the silk channel. The Zea-Later has a "gun" that squirts the mixture. The worker moves up and down the rows of corn, inserting the tip of the applicator into the silk near the tip of each ear. The estimated time needed to treat one acre is eight hours. Treatment is only necessary when corn is silking and moths are present. Many local Extension programs can provide information about moth activity, or farmers can place monitoring traps in their own fields.
   Ears need to be treated only once, but timing is critical. For optimal effectiveness, the mixture should be applied when silks have reached full length and just begun to wilt and turn a bit brown, approximately five to six days after 50% of the corn has begun to show silk. Earlier treatment may result in "cone tips," where the kernels near the tip do not develop due to the oil interfering with pollen tube development. Later treatment allows the worm to escape and feed (Hazzard & Westgate 2004).
2. Spinosad also has been shown to work in the Zea-Later and when used as a spray applied to silks (two good, two fair, and one poor result in recent studies).

CORN FLEA BEETLE (*Chaetocnema pulicaria*)

The corn flea beetle **(Photo 8.3)** is usually seen feeding on young corn plants in the spring. Damage on the foliage consists of thin lines etched into the tissue. Host species include corn and some other grasses, but not other vegetables. Different species attack brassicas and solanaceaous crops. Usually, the feeding damage is not severe enough to reduce yield, but the beetles can transmit Stewart's wilt (see below).

Cultural Control:

1. Crop rotation works fairly well.
2. Use varieties resistant or tolerant to Stewart's wilt (Zitter 2002; Cornell 2004a).
3. Corn flea beetle numbers are greatly reduced by cold winters with little snow cover.

Materials Approved for Organic Production:

None are as effective as the cultural controls.

CORN LEAF APHID (*Rhopalosiphum maidis*)

The corn leaf aphid **(Photo 8.4)** is a small, grayish green, soft-bodied insect that can build up in high numbers during hot, dry seasons. The primary damage caused by corn leaf aphids is contamination to the ear due to sooty molds or the presence of the insect. Corn leaf aphids are often seen in mid to late season if their natural enemies have been killed by broad-spectrum insecticides. They are usually not a problem in organic sweet corn, but in high numbers, can drastically reduce the marketability of ears.

Cultural Control:

Avoid pyrethrum, or other broad-spectrum insecticides in corn.

Materials Approved for Organic Production:

1. If an aphid outbreak occurs, insecticidal soaps can be used (five good, one fair, and eleven poor results against all aphid species tested in recent studies).
2. Summer oils (two fair and three poor results) will provide some control.
3. Neem products can provide some control (four good, six fair, and four poor results in recent studies on all aphid species). Please see the neem material fact sheet for a discussion of the different types of neem products.
4. Kaolin clay will reduce aphid populations but will leave a white residue that may affect marketability.

EUROPEAN CORN BORER (*Ostrinia nubilalis*)

The European corn borer (ECB) overwinters as a full-grown larva in the lower six inches of the corn stalk or in other host plants. The larvae pupate in spring, and moths emerge and mate in grassy or weedy areas around field borders. Eggs are laid on the underside of corn leaves near the midrib **(Photo 8.5)**. The larvae initially feed in the leaf axils and whorl, creating a shot hole effect in the leaves. Later they move into the tassel or stalk, and their tunneling may cause it to break **(Photo 8.6)**. On more mature corn, the caterpillars may enter directly into the ear **(Photo 8.7)**. Though corn plants can tolerate a fair amount of foliar feeding, ear damage directly affects marketability. Contact the local Extension educator for a detailed scouting procedure for ECB (or see Hazzard & Westgate 2004).

Cultural and Biological Controls:

1. Sanitation is important to reduce the ECB overwintering sites. Corn stalks should be mowed short and disked into the soil soon after harvest is completed. Since ECB has many other host plants, crop rotation in a particular field may not reduce insect pressure.
2. Release of *Trichogamma* wasps has been shown to be effective; however, this parasite does not control the other caterpillar pests of corn. *Trichogramma ostriniae* is a tiny wasp that is smaller than a pinhead. The female wasp lays eggs inside the European

corn borer eggs. Usually, all of the ECB eggs in the mass are destroyed, and the whole egg mass turns black. For details on using this beneficial insect see: http://nysipm.cornell.edu/factsheets/vegetables/swcorn/trich_ost.pdf.

Materials Approved for Organic Production:

1. Bt var. kurstaki can be effective against ECB, but thorough coverage is needed. Since corn can tolerate high levels of vegetative damage, spraying only when the ears are threatened is important to avoid economic damage. Applications usually begin at the early tassel emergence stage if over 15% of the plants in a field are infested. Timing is important; good coverage before the worms bore into the plant (where sprays do not reach) is necessary for effective treatment. Applications should target tassels just as they start to open, so ECB larvae are exposed to the spray. Bt breaks down rapidly, so frequent applications may be needed. Later applications that target the ear zone may be needed if pheromone traps indicate that ECB moths are flying when corn is in the green silk stage.
2. Spinosad sprays have been shown to be very effective against this pest. Spinosad has longer residual activity than Bt, so fewer sprays are required. Recent studies have shown ten good and two poor results against ECB on sweet corn, peppers, and beans.
3. Alternating Bt and Spinosad sprays is recommended in order to avoid development of insecticide resistance.
4. Since European corn borers often enter corn ears from the side, the Zea-Later is not very effective against this pest.

FALL ARMYWORM (*Spodoptera frugiperda*)

Similar to the corn earworm, the fall armyworm (FAW) does not overwinter in the Northeast US. It usually arrives after mid-summer, though in some areas, it may appear very late or not at all. FAW seems to prefer whorl-stage corn for laying egg masses **(Photo 8.8)**. Their feeding produces large holes and ragged leaves **(Photo 8.9)**. Whorl-infested corn does not need treatment until 15% of the plants in a field are infested. Larvae can invade ears of silking corn, and damage is similar to the corn earworm.

Pheromone traps are useful for detecting flights.

Cultural Control:

None currently known.

Materials Approved for Organic Production:

1. Bt var. kurstaki can be used for FAW but is not highly effective, and good coverage is needed (one good result in recent studies).
2. If silking corn is present and numbers of moths are high, then the Zea-Later will be an effective control for larvae that enter through the silk channel, though not for any larvae that bore in through the side of the ears.
3. Foliar sprays of spinsosad that target the larvae are also effective.

CORN ROOTWORMS Northern corn rootworm (*Diabrotica longicornis*), Western corn rootworm (*Diabrotica virgifera virgifera*)

Corn rootworm beetles **(Photo 8.10)** feed on corn leaves and clip off silks. When present in high numbers, they can interfere with pollination. They may also transmit stalk and ear rot diseases. Adults emerge in July. The female lays eggs in the soil in late summer, and they hatch the following spring. The larvae feed on corn roots, reducing yield and causing stalks to lodge.

Cultural Control:

Crop rotation works very well for control of larval damage. In most cases, adult damage is not severe enough to warrant control unless populations build up in unrotated field corn near sweet corn fields.

Materials Approved for Organic Production:
None currently available.

SEEDCORN MAGGOT (*Delia platura*)

Seedcorn maggots **(Photo 8.11)** can greatly reduce stands of untreated seed in cold, wet soils. They are particularly attracted to decomposing organic matter, so corn planted in fields where manure or cover crops have been recently incorporated is especially susceptible to infestation. The female flies lay eggs near germinating seeds, and the larvae feed inside the sprouting seeds. Feeding damage also leads to rot.

Cultural Control:

1. Create conditions for rapid germination, including use of ridges and waiting until the soil has warmed.
2. In cold climates, consider row covers or transplants for the earliest sweet corn.
3. Be sure that raw manure and green plant residues are well incorporated and have time to decompose prior to seeding.

Materials Approved for Organic Production:
None currently available.

WESTERN BEAN CUTWORM (*Striacosta albicosta*)

Western bean cutworm (WBC) is a new pest of sweet corn that has been moving eastward from its historical range in the west. Field corn and dry beans are also hosts. This insect has one generation per year in late July to early August, and egg-laying females are most attracted to late whorl to tassel emergence stage fields. Masses of 50-200 eggs **(Photo 8.12)** are laid on the upper leaf surface near the emerging tassel, and larvae feed on the tassel and surrounding tissue for a short time before moving to the ear. Multiple larvae may infest the same ear **(Photo 8.13)**. Adults overwinter in the soil, and overwintering may be more successful in light, sandy soils. Moths may be monitored using pheromone traps, and fields in an attractive stage should be scouted for egg masses and newly hatched larvae after the flight peak. Check with the local extension program to see if WBC is being monitored in a given area.

Cultural Control:
Because moths are strong flyers, rotation may reduce, but not eliminate infestations.

Materials Approved for Organic Production:
Spinosad and Bt products are labeled for western bean cutworm, but efficacy information is not available. Spray timing is crucial; target newly hatched larvae before the bore into the ear, where they are protected from the insecticide.

BROWN MARMORATED STINK BUG (*Halyomorpha halys*)

Brown marmorated stink bug (BMSB) is an exotic, introduced pest with a wide host range that includes sweet corn. It was first confirmed as an agricultural pest in 2010. Adults are shield-shaped and mottled brown, with distinctive white bands on the antennae and markings at the edge of the abdomen **(Photo 8.14)**. Adults emit a distinctive odor when disturbed. Eggs are round and light green and are laid in clusters of 20-30 on the undersides of leaves. Immediately after hatching, nymphs are reddish orange with black markings, legs, and antennae; over time, they become mottled brown with white banding on the antennae and legs, resembling adults, but without wings **(Photo 8.15)**. BMSB damages sweet corn by feeding on kernels through the husks, causing incomplete kernel fill, kernel collapse, and discoloration. Information about BMSB can be found at: http://www.northeastipm.org/index.cfm/working-groups/bmsb-working-group/bmsb-information/.

Cultural Control:
Because of its wide host range, crop rotation is not a viable option. As more is learned about its biology and host preference, biological control or trap cropping may become useful.

Materials Approved for Organic Production:
Pyrethrum, neem, and *Beauveria bassiana* products are labeled for stink bug control, however efficacy information against BMSB is not yet available.

II. DISEASE CONTROL

While diseases of sweet corn occur annually, they generally do not become so severe that treatment is necessary. For identification purposes, four common corn diseases in the Northeast are described below. Resistant varieties are available for all of the commonly seen diseases and should be planted if a particular disease is severe in a given area. A list of resistant varieties can be found in the Cornell Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production. For additional information on sweet corn diseases or any vegetable disease, visit the Vegetable MD Online website (http://vegetablemdonline.ppath.cornell.edu/NewsArticles/CornWiltNews.htm).

DISEASES CAUSED BY BACTERIA

STEWART'S WILT (*Pantoea stewartii*)
This bacterial disease is common in the Northeast. It is spread by the corn flea beetle (*Chaetocnema pulicaria*), which carries the bacterium and introduces it into the plant through feeding wounds. Common symptoms include yellow, chlorotic stripes with irregular margins that can run down the length of the leaf **(Photo 8.16)**. If seedlings are infected prior to the five-leaf stage, they may wilt and die. Plants infected before the late whorl stage may not produce an ear. Because the pathogen overwinters in the flea beetle, prediction of the likelihood of a Stewart's wilt epidemic is possible based on mean monthly temperatures for December, January and February. If these months are very cold, there will be greater mortality of flea beetles, and Stewart's wilt will be less likely. Stewart's wilt forecast for the Northeast can be found at: http://www.nrcc.cornell.edu/grass/stewart_maps.html. The best approaches for avoiding Stewart's wilt are to plant resistant or tolerant varieties and to utilize crop rotation. The Cornell Vegetable MD website has a list of resistant varieties (Zitter 2002).

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

DAMPING OFF, SEED ROTS, POOR STAND (*Fusarium, Pythium, Diplodia* spp.)
These diseases are common when corn is planted in cold soil. When a seed is planted, it must imbibe (i.e., soak up) water prior to germinating. When seeds take in water, cell membranes may rupture. At warmer temperatures (above 55°F) cell membranes are quickly repaired, and there is no effect on germination. At lower temperatures, seed metabolism is very slow, reducing the rate of membrane repair. Thus, even in the absence of pathogens, germination in cold soil can be poor. Seed with damaged membranes will leak more carbohydrate into the soil and attract soil-inhabiting pathogens. These pathogens attack seedlings during germination and often result in poor stands.

Cultural Control:

1. Create conditions for rapid germination, including use of ridges and waiting until the soil has warmed to plant.
2. Consider row cover or transplants for the earliest sweet corn.
3. Avoid poorly drained soils.

Materials Approved for Organic Production:
Biological seed treatments, such as Kodiak (*Bacillus subtilis*) or Plant Shield (*Trichoderma*), may be effective.

COMMON RUST (*Puccinia sorghi*)
Common rust is appropriately named, as the fungus causes the leaves of infected corn plants to look rusty. Oval-shaped, rust- or cinnamon-colored pustules are scattered over infected leaf surfaces **(Photo 8.17**). Heavy dew, moderate temperatures, and high nitrogen favor this disease, which spreads annually to the Northeast by spores blowing from Southern regions. Some sweet corn varieties are more tolerant than others, and should be planted if possible. If feasible, staggered plantings should be spatially separated, so fungal spores from earlier plantings are less likely to infect later plantings.

COMMON SMUT (*Ustilago maydis*)
Smut is usually found on the ears, but can also be seen on tassels and stems. This fungal disease is very dramatic and easy to identify, as large galls are produced **(Photo 8.18)**. A young gall appears white and smooth, and black fungal spores develop inside as it ages. An older gall will split open, revealing thousands of spores. Removing galls before they break can reduce inoculum. Young galls can be eaten and are considered a delicacy in some cultures; they taste a bit like mushrooms. Some corn varieties are more resistant to smut than others, and these should be planted if smut has been a problem in previous years.

NORTHERN CORN LEAF BLIGHT (*Exserohilum turcicum*)
Northern corn leaf blight (NCLB) causes long, gray to tan lesions on the lower leaves and progresses to the younger leaves. The lesions are fairly easy to identify, as they are commonly referred to as 'boat' or 'cigar' shaped. The disease is not remarkably common, but does occur every year. NCLB frequently arrives at the end of the season, particularly in dry years, so yield losses are generally minimal; however, yield reductions may occur if leaves become covered with lesions and are destroyed. The fungus favors wet conditions and high humidity. The best method of control is to plant resistant varieties. A one- to two-year rotation away from corn is recommended. Crop debris should be destroyed by tillage, which will initiate decomposition.

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Organic Insect and Disease Control for Umbelliferous Crops

INTRODUCTION

This group of crops belongs to the family Umbelliferae or Apiaceae. This large family is commonly referred to as the umbel family because of the distinctive, umbrella-like inflorescence. Many members of the family are biennial root crops, and flowering is not seen during crop production (e.g., carrots and parsnips). Other umbelliferous crops are grown for their stalks or foliage and are not usually grown to flowering stage, including celery, parsley, dill, cilantro, and lovage. Others, like coriander (cilantro), dill, caraway, cumin, and fennel, are grown for their seeds. In this family, the fruit (called a schizocarp) splits into two parts at maturity, each containing a single seed.

I. INSECT CONTROL

CUTWORMS (many species)

Cutworms are occasional early-season pests of carrots and other umbelliferous crops. In some years, they cause major losses, while in other years, there are no losses at all. Cutworms are the larvae of approximately a dozen different species of night-flying moths. They are greasy-looking caterpillars that have a habit of curling into a "C" shape when disturbed. Most species that attack carrots overwinter as partially grown larvae, so they become active very early in the spring when the carrots first germinate and are very susceptible to damage. Cutworms hide in the soil during the day and feed at night. Some species feed and cut off young seedlings at the soil surface, while others may climb and feed on leaves.

Cultural Control:

1. Since most species lay their eggs on vegetation in late summer or fall, keeping fields clean of weeds and crops in the fall helps. This advice is counter to recommendations to keep soil cropped in the fall, so management decisions should be based on how severe the problem is. Fall plowing exposes larvae to birds and other predators.
2. Alternatively, cultivating fields in the spring, after vegetation has appeared and grown a few inches, can starve cutworms before crops are planted. In most areas spring cultivation is not practical for early season production. In regions that allow for delayed planting, a few shallow cultivations during this "starving period" can starve cutworms and expose them to birds and other predators.

Materials Approved for Organic Production:

1. Entomopathogenic nematodes have shown good efficacy when environmental conditions are favorable (warm, moist, but not soggy soil). *Steinernema carpocapsae* has been shown to be very effective against cutworms, although reports are not specifically for carrot production. Success with nematodes depends on proper application methods. Irrigation may be necessary to keep the soil moist for at least two weeks after application. Be sure to carefully follow the instructions from the supplier.
2. Baits - Spinosad or Bt will kill the caterpillars, but getting the pest to consume the insecticide as a foliar application before significant damage is done is difficult. However, farmers have reported good results using these materials in baits. The bait is spread on the ground near the plants or prior to planting to disinfest an area.
    a. Spinosad - Seduce (OMRI Listed) is a new, ready to use formulation bait that has shown promising results against cutworms.
    b. Bt - A bait made from Bt is often recommended and has received good reports from some farmers. The following

method of using Bt is not described on the label. This off-label use is permitted by EPA under FIFRA 2ee, but growers should check with their state pesticide regulators about specific local regulations. The bait is made by: determining the application area; mixing the highest concentration solution of Bt allowed on the label; and then mixing in a bit of molasses, alfalfa meal, or bran. Dampen the mix if necessary. Spread the bait along the planted or planned rows in the evening.

CARROT RUST FLY *(Psila rosae)*

The carrot rust fly is not a common pest, but when it occurs, it is a major problem because maggots make carrots unmarketable. Larvae are light yellowish maggots that burrow through the carrot, leaving rust-colored tunnels **(Photo 9.1)**. The adult is a slender, blackish fly that emerges in the spring (around the time that 250 base 40°F degree days have accumulated) from pupae overwintering in the soil. After a short mating period, the females seek out umbelliferous plants and lay eggs on the soil near the base of the plants. Eggs hatch in 7-10 days, and the young larvae move downward into the soil, attracted to carbon dioxide emitted by the plant, and begin feeding on the developing root. When the plants are small, larvae will feed on young roots, causing misshapen carrots and possibly seedling wilt or death. In the Northeast, a second generation of rust fly peaks in late July and August (at about 1150 base 40 degree days), and larvae from this generation tunnel into the tap roots. Damage tends to occur in the lower two-thirds of the root. Larvae that mature form pupae and overwinter in the soil. Carrots that are harvested in the fall may have remnant tunnels or immature larvae. Parsley, celery, parsnips, and wild carrots are also hosts, but carrot is the most economically important crop infested by the larvae.

Cultural Control:

1. Plan planting and harvesting to avoid peak flights.
2. Crop rotation of a mile or more from other umbelliferous crops and weeds works well but is often impractical because of the many wild umbelliferous weeds that also serve as hosts.
3. Row covers are the best management. Install row covers before adults emerge.

Materials Approved for Organic Production:

Several azadirachtin products, PyGanic, garlic products, and a sesame oil product are labeled for use against carrot rust fly, but efficacy information is lacking.

CARROT WEEVIL (*Listronotus oregonensis*)

Most umbelliferous crops and wild plants are hosts to the carrot weevil. Some other species with tap roots are also hosts, such as curly dock and plantain. Though the carrot weevil is more widespread than the carrot rust fly, it causes damage that is somewhat similar. The larvae of this beetle are white grubs that tunnel into the root just below the epidermis, leaving a thin layer of cells above the tunnel. By maturity, this layer collapses and leaves visible, open channels. Most commonly, the damage is to the upper third of the root. In celery, the damage is near the base of the petiole and often can be tolerated when trimming removes the damaged tissue before marketing. In more extreme cases, the tunneling destroys the base of the plant and may severely injure the roots, causing the plant to wilt and die.

The carrot weevil spends the winter as an adult and can be found in or near carrot fields in crop debris, weeds, or grassy fields. Often, crops near the boarders of the field suffer more damage because the adults are entering from nearby overwintering sites.

Cultural Control:

1. Reduce habitat for overwintering adults. Remove debris from crop fields and surrounding land. Mow grass short in surrounding fields. Kill fall cover crops early in the spring, and till fields deeply to kill overwintering adults.

2. Crop rotation is recommended.
3. Plan to plant after the spring flight (sow after accumulation of 450 degree-days above 45º F).

Materials Approved for Organic Production:
There are no materials approved for organic production.

TARNISHED PLANT BUG *(Lygus lineolaris)*

The tarnished plant bug (TPB) is a pest with a very wide range of hosts, including about three hundred species of weeds and crops **(Photo 9.2)**. In its earliest stages (i.e., nymphs), the TPB resembles an aphid, though as it develops, it looks more like an adult TPB without wings. In the umbels, it causes damage to celery stalks and leaves. This sucking insect causes cavities on the stalk where tissue has collapsed. Feeding on the leafy parts of celery, usually by nymphs, causes necrosis of the youngest leaves.

The tarnished plant bug overwinters as an adult in sheltered sites, such as edges of woods and hedgerows or in crop residue. They become active in early spring and feed and lay eggs on weeds and early-flowering crops, such as strawberries and alfalfa. Nymphs have similar feeding habits and cause similar damage as the adult. There are two to three generations per year.

Cultural Control:
1. The best control of this pest is use of floating row covers installed at planting.
2. Managing weeds and keeping headlands mowed short helps. However, avoid mowing nearby fields when crops are at a vulnerable stage, as doing so may drive the pest into cropland.
3. Decades ago, a Braconid wasp, *Peristenus digoneutis*, was introduced in the United States for biological control of the tarnished plant bug, and it has since spread throughout much of the Northeast. Parasitism rates are reported to be as high as 70%, so using management strategies that conserve them, and other natural enemies, should be helpful.

Materials Approved for Organic Production:
Insecticides have only limited effect on TPB because of the rapid re-infestation that occurs from non-treated areas.
1. Pyrethrum gives limited control (40-60% control in the older literature; one poor result in recent studies).
2. Neem has shown some promise, but more studies are needed (two fair results against TPB in recent studies).

APHIDS (many species, especially the green peach aphid)

Aphids sometimes aggregate on celery, but infestation is not common on farms that do not spray often with broad-spectrum insecticides. When present, the damage is seen as distorted leaves.

Cultural Control:
1. Encourage natural enemies by diversifying the habitat in headlands and woods surrounding the field.
2. Refrain from using broad-spectrum insecticides (see the Brassica Crop chapter for more details).

Materials Approved for Organic Production:
1. Soap: Scout plantings once or twice each week, and if aphid populations are increasing, apply insecticidal soap sprays. Do not wait until aphids reach high numbers and dense colonies; apply when numbers are low. Repeat applications two or three times, and ensure good coverage of the parts of the plant where aphids live, including the undersides of leaves.

2. Neem: Based on a limited number of studies, neem products gave good control of many aphids (see the neem chapter for a discussion of the different types of neem products).
3. Summer oils provide some control.
4. Rotenone is recommended in the older literature, but it is no longer registered as an insecticide.

ASTER LEAFHOPPER *(Macrosteles fascifrons)*

The aster leafhopper is a greenish tan insect that looks dark from the top. It has six black spots on the front of its head and is sometimes called the six-spotted leafhopper. This species has been reported to overwinter as eggs in the north, but the major source is from jet stream migrations from the southern United States. There can be three to five generations per year.

Aster leafhoppers feed on a wide variety of plants, beginning with early weeds and crops, such as lettuce, winter grains, and early flowers. Later, they move onto summer crops, including carrots, celery, and parsnips. When severe, leafhopper feeding distorts leaves, but it does not cause economic damage in Umbels unless it carries the aster yellows pathogen. Aster yellows is caused by a mycoplasma-like organism transmitted by leafhoppers, especially the aster leafhopper (see below for details on the disease). Adults migrating from the south may have acquired the aster yellow mycoplasma during the previous season. To acquire the mycoplasma, the leafhopper must feed on an infected plant for at least eight hours; the pathogen must then incubate in the leafhopper for about three weeks before it can be transmitted to another plant. A feeding period of eight hours is also required to transmit the disease to a new plant.

Cultural Control:
Managing leafhoppers in carrots and other crops in this family is only important if they are carrying the aster yellows pathogen. If aster yellows has been a problem in a given area, managing weeds may be useful. Common weed hosts include thistle, fleabane, wild lettuce, sow thistle, chicory, wild carrot, galinsoga, dandelion, plantain, and cinquefoil.

Materials Approved for Organic Production:
Spraying for the aster leafhopper should be based on monitoring with sweep nets; however, monitoring is only important if the pests are known to be carrying the aster yellows pathogen. There is no a quick and easy way to determine if they are infected. Some states with commercial production of susceptible crops (e.g., Michigan) monitor for leafhopper numbers and infectivity levels.

1. Pyrethrum has been shown to control leafhoppers.
2. Surround is labeled for leafhoppers, but has shown mixed results.

PARSLEYWORM *(Papilio polyxenes)*

The parsley worm is a caterpillar with black and white banding and yellow spots along the black bands **(Photo 9.3)**. The larva of the black swallowtail butterfly, it is a voracious feeder on parsley, dill, fennel, and occasionally carrots. It spends the winter as a pupa (chrysalis) attached to trees, buildings, etc. In mid spring, adults emerge and lay eggs singly on plants in the carrot family. The caterpillar feeds for about 3 weeks. Since this insect is a valued bit of natural fauna, and the pest never builds to large numbers, moving it to a non-crop host is the best option for control.

WEBWORMS

Webworms are more of a problem in the south and west than they are in the Northeast, but occasionally the garden webworm (*Achyra rantalis)* or the alfalfa webworm (*Loxostege sticticalis*) reaches levels of concern in New York and New England **(Photo 9.4)**. Webworms begin feeding on the underside of a leaf, and as they get larger, they eat through the leaf, creating large notches or holes. As their name implies, webworms spin webs among the leaves **(Photo 9.5)**. Damage from young or small numbers of webworms may go unnoticed, but as the larvae mature, they can consume leaves rapidly and destroy a whole crop. Webworms overwinter in the soil either as pupae or larvae. In the spring, the moths emerge and lay eggs on the undersides of leaves either singly or in short rows. There can be two or more generations per year, but the first is the most damaging because it feeds when plants are small and vulnerable.

Cultural Control:
Weed management is important to keep nearby populations small.

Materials Approved for Organic Production:
Bt and spinosad will give good control. Early detection is important to prevent significant damage.

TWO SPOTTED SPIDER MITE (*Tetranychus urticae*)

Spider mites have piercing mouthparts that rupture the epidermal cells of plants, causing a stippled appearance. Celery is the only umbelliferous crop that is significantly damaged by spider mites. In large numbers, they can cause the leaves to become bronze or silvery with a fine silk webbing. Mites are favored by hot, dry weather. They are very small and difficult to see with the naked eye. A hand lens is necessary to check for mites on the undersides of leaves. Populations can build rapidly; each female can lay up to 100 eggs, and the cycle from egg to adult can be completed in 7-14 days. If large populations are left unchecked, plants may loose vigor, yellow, and die.

Cultural Control:

1. Spider mites have many natural enemies, including several species of predatory mites. Avoid using broad-spectrum insecticides that may kill beneficial insects. Mites are often localized in small areas of a field, so spot treatment may suffice and spare beneficial insects.
2. Overhead irrigation or heavy rains may suppress mites.

Materials Approved for Organic Production:

1. Mites can be controlled with summer weight oils. Be sure to read the label and follow carefully. Phytotoxicity is possible with some crops, especially when used in conjunction with sulfur or copper fungicides.
2. Entrust is labeled but not shown to be effective at normal use rates. It has been demonstrated to be somewhat effective at high rates (see Spinosad Material Fact Sheet for references).
3. Insecticidal soap has been shown to offer fair control.

II. DISEASE CONTROL

DISEASES CAUSED BY BACTERIA

BACTERIAL LEAF BLIGHT *(Xanthomonas campestris* pv. *carotae)*

Bacterial leaf blight affects only carrot. The first symptoms are small, yellow spots that expand quickly into irregular, brown, water-soaked lesions surrounded by a yellow halo **(Photo 9.6)**. The centers of the spots may become tan and dry. Lesions are common on the leaf margin and progress along the edge of the leaf. The infection will typically progress down the main leaf and petiole veins. This progression of the disease distinguishes it from Alternaria and Cercospora leaf blights (see below). Bacterial leaf blight can be an explosive disease under hot, rainy, and windy conditions.

This bacterium is a common contaminant of carrot seed and can also persist on crop debris. It does not persist in the soil once the debris is decomposed. Spreading occurs mainly by splashing water, though it can also be transmitted by insects and farm machinery. Symptoms appear when bacterial populations build to high levels. Persistent leaf wetness and warm temperatures are needed for bacterial populations to grow.

Cultural Control:

1. Management begins with using clean seed. Seed produced in arid areas is less likely to be infested.
2. Hot water treatment is recommended for suspect seed lots (122° F for 20 minutes).
3. Plow crop debris under immediately after harvest.
4. A two-year crop rotation is recommended to allow crop debris to fully decompose.

Materials Approved for Organic Production:
Copper based materials have been shown to be effective if applied as soon as the first symptoms are seen.

ASTER YELLOWS

Aster yellows is a disease caused by a phytoplasma, which is a very small bacterium that lacks a cell wall. Phytoplasmas are obligate parasites (cannot live outside a host plant or insect vector), and species within this group cause a wide array of diseases, such as coconut lethal yellowing, peanut witch's broom and elm yellows. The organism lives in the phloem (cells responsible for nutrient transport) of plants. The species that causes aster yellows has a wide range of hosts including lettuce, asters, celery, carrot, and many weeds. Phytoplasmas are transmitted from plant to plant by insects, mainly leafhoppers.

A characteristic symptom of aster yellows on carrot is yellowing of the veins of young leaves. The leaves also appear narrower than normal. Yellowing progresses until the entire leaf is chlorotic. Later, a mass of dwarfed, sickly leaves develops from the crown of the carrot **(Photo 9.7)**. Diseased plants are more susceptible to bacterial soft rot.

Cultural Control:
Control measures are limited to managing the leafhopper insect vector (see above).

Materials Approved for Organic Production:
There are no materials approved for organic production.

DISEASES CAUSED BY FUNGI AND FUNGUS-LIKE ORGANISMS

ALTERNARIA LEAF BLIGHT *(Alternaria dauci)*

Carrot seedlings may be infected by Alternaria leaf blight that has overwintered in the soil, on crop debris, or on seed. The symptoms of seedling infection are similar to damping off. Later in the season, infections of mature plants may result from wind-blown spores from nearby fields, crop residue, weeds, or equipment. Moisture on the leaf surface is necessary for spores to germinate, so the disease is favored by rainy seasons. Foliar lesions first appear on the margins of the leaflets and begin as greenish brown, water-soaked areas, which later enlarge and turn dark brown. When much of the leaf is infected, the whole leaf eventually yellows, collapses, and dies. When lesions form on the petiole, the leaves die quickly. Older leaves are more susceptible to infection; often the young leaves appear healthy while all of the older leaves are dead and have collapsed **(Photo 9.8)**.

Cultural Control:

1. Crop rotation is critical if Alternaria leaf blight was a problem the previous year. The pathogen can survive until diseased tissue decomposes. Burying diseased residue at the end of the season, and a two to three year rotation is recommended.
2. Growers should use clean seed.
3. Hot water treatment of the seed helps to reduce infection. Soak seed in hot water (122°F; 50°C) for 20 minutes. Do not soak longer, or seed could be damaged.
4. Use resistant varieties if leaf blight has been a problem in the past.
5. Thin plants to allow good air flow for quicker drying.
6. If there are healthy, young leaves late in the season, even if most of the older leaves are dead, an application of fertilizer may be enough to encourage carrots to reach marketable size.

Materials Approved for Organic Production:
Serenade and copper-based products offer some reduction in severity of the disease, but have not been shown to reduce the percentage of plants that become infected.

CERCOSPORA LEAF BLIGHT *(Cercospora carotae)*

Cercospora leaf blight is often more destructive than Alternaria because it affects young tissue as well as older tissue and may appear earlier in the growing season. The first symptoms are spots that turn tan with a very dark rim and a chlorotic halo **(Photo 9.9)**. Infections along the edge of the leaf are somewhat crescent-shaped and follow the leaf margin while spots in the center of the leaf are circular. As the spots enlarge, they coalesce, and the whole leaf turns brown, withers, and dies. Both leaves and petioles are affected. The disease does not affect the root. Cercospora is carried on infected seed, crop debris, and wild carrot weeds. The spores are generally dispersed by wind but can also be transported in splashing water and on farm equipment. Spore germination is dependent on at least 12 hours of leaf wetness.

Cultural Control:

1. Use clean seed.
2. Fall plowing of crop debris and a two to three year crop rotation is recommended if Cercospora was a problem during the previous year.
3. Manage weeds to improve air flow and avoid alternate hosts.
4. Use less susceptible varieties of carrots if Cercospora leaf blight is a common problem.

Materials Approved for Organic Production:
Serenade and copper-based products offer some reduction in severity of the disease, but have not been shown to reduce the percentage of plants that become infected.

SCLEROTINIA ROT/COTTONY ROT/PINK ROT *(Sclerotinia sclerotiorum)*

Sclerotinia sclerotiorum can affect all of the umbel crops. It is the same pathogen that causes white mold, which affects many vegetables, including tomatoes, beans, lettuce, peppers, and many weeds. It is the most destructive disease of stored carrots. Infected roots often show no symptoms in the field, but the disease develops in storage. In stored carrots, *Sclerotinia* causes a dark-colored, soft, watery rot that quickly becomes covered with a very white, cottony growth of fungal mycelium **(Photo 9.10)**. Black sclerotia form amid the mycelium. In the field, the base of the plant may develop symptoms, and the crown, petiole, and leaves may become dark and covered with the characteristic white, cottony mycelium and sclerotia.

Sclerotia can survive for more than a decade in the soil. When conditions are conducive (saturated soils for more than two weeks), they may germinate and produce fruiting bodies called apothecia, which produce millions of spores that become airborne. Spores that land on senescing tissue germinate. Healthy tissue near the infected area can then be colonized if wet conditions persist for more than two days. The infection can then spread throughout the plant, including the roots. Roots are rarely directly infected by mycelium in the soil; however, infection can take place in storage if healthy roots are in contact with infected roots, infested boxes, or equipment.

Cultural Control:

1. Good weed management is essential since the high relative humidity under heavy weed pressure is conducive to spore production, germination, and infection of crop tissue. Furthermore, many weeds are hosts for *Sclerotinia sclerotiorum*.
2. Crop rotation for three years with non-host crops such as onions, beet, spinach, corn, and grass family green manures will help to maintain low levels of sclerotia in the soil.
3. All cultural practices that reduce the duration of leaf wetness will reduce spore survival and tissue infection.
4. The key to reducing the disease in storage is to harvest when cold, cull and clean crop, sanitize containers, and keep storage temperatures at 32° F.

Materials Approved for Organic Production:
*Coniothyrium minitans (*Contans). Contans is a fungus that, once applied and incorporated into the soil, attacks and destroys the white mold sclerotia. Follow the directions on the label carefully because success is dependent on eliminating near-surface sclerotia that are likely to germinate and produce apothecia and spores. Using enough of the material to reach all of the sclerotia in the soil profile would be cost prohibitive. Contans requires 3 to 10 weeks to effectively colonize and destroy sclerotia. Apply Contans to a *Sclerotinia*-infested field immediately following harvest at 1 lb/A, and incorporate the debris into the soil. Alternatively, apply 3-4 months before the onset of disease at 2 lb/acre, followed by shallow incorporation (or irrigate) to about a 1 to 2 inch depth. After application, do not till deeply, or sclerotia that are deeper than the Contans treated zone will be brought to the surface.

CRATER ROT *(Rhizoctonia carotae)*

Crater rot is a post harvest disease of carrots in long-term storage. It is caused by a soil-inhabiting fungus that is thought to be able to survive indefinitely in the soil without a host. *Rhizoctonia carotae* infection takes place in the soil or possibly in contaminated storage containers. Very high humidity or a film of water on the carrots enhances disease development.

The infection is most likely to take place in the field, though symptoms do not appear until later in cool, high humidity storage. The first symptoms are small, white knots of fungal growth. Small pits appear under these spots and enlarge into dry, sunken craters **(Photo 9.11)**. White patches of mycelia spread, and sometimes a whole crate of carrots may be covered with a cottony mycelium that can be confused with white mold. Microscopic examination may be required to positively identify the disease.

Cultural Control:

1. Cultural practices that encourage quick drying of the soil surface, such as wide spacing, shallow cultivation, and good weed management, will lower incidence of field infection.
2. After harvest, keep carrots cold (32^{o} F) with humidity no higher than 95%.
3. Clean and disinfect storage containers.

Materials Approved for Organic Production:
There are no materials approved for organic production.

CROWN ROT *(Rhizoctonia solani)*

Rhizoctonia solani may cause damping off of carrot seedlings shortly after germination when the soil is wet and warm. It can cause sporadic crown rot infections, especially when conditions are warm and wet at harvest. Petioles and crown tissues develop cankers that may penetrate several millimeters into the root. The dark brown lesions are more common near the crown, and later a dry rot may develop. A thin, white to tan layer of mycelia may grow near the crown, and when carrots are pulled, it holds a clump of soil to the carrot. Secondary invasion by bacteria may cause a soft rot.

This pathogen can survive many years in the soil, as a saprophyte or as sclerotia, and infect carrots at any point in the growing season. Decay may not be noticed until the carrots are harvested and in storage.

Cultural Control:

1. Avoid injury to the crown, or hilling soil over the crown when cultivating.
2. Encourage quick drying of the soil surface with wide row spacing, shallow cultivation, and good weed management.

Materials Approved for Organic Production:
There are no materials approved for organic production.

CAVITY SPOT *(Pythium sp.)*

Cavity spot is caused by a common, soil-borne water mold that can persist for many years on different hosts. It is, to some degree, a cosmetic problem because it does not reduce total yield; however, it does reduce yield of blemish-free, marketable carrots, so the economic impact can be great. Dark, sunken lesions develop that are elongated across the root **(Photo 9.12)**. Lesions on small carrots are minute and not a marketing concern, but the lesions quickly become large and unsightly as the carrot approaches full marketable size. There are no foliar symptoms.

Cultural Control:

1. Excessive moisture favors this disease, so site selection and practices that promote good drainage are important.
2. Due to the persistent nature of this pathogen, good weed management is important.
3. Crop rotation to Sudangrass, rapeseed, and mustard have been reported to suppress *Pythium*, but wet soil in poor condition will overshadow any benefit.

Materials Approved for Organic Production:

There are no materials approved for organic production.

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CHAPTER 1 - Allium

Photo 1.1 Onion maggot larvae.

Photo 1.2 Onion thrips damage.

Photo 1.3 Leek moth larva in onion leaf.

Photo 1.4 Leek moth damage to leeks.

Photo 1.5 Onion sour skin.

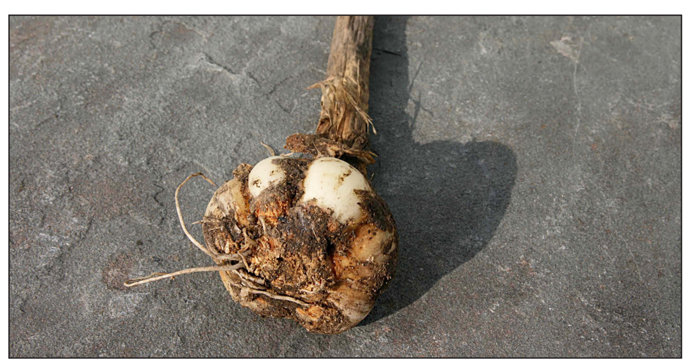

Photo 1.6 Garlic bloat nematode.

Photo 1.7 Botrytis leaf blight.

Photo 1.8 Botrytis neck rot (courtesy Jim Lorbeer).

Photo 1.9 Botrytis porri on garlic.

Photo 1.10 Purple blotch.

Photo 1.11 White rot garlic.

Photo 1.13 Fusarium basal rot on garlic (courtesy Crystal Stewart).

Photo 1.12 White rot sclerotia.

Photo 1.14 Penicillium garlic.

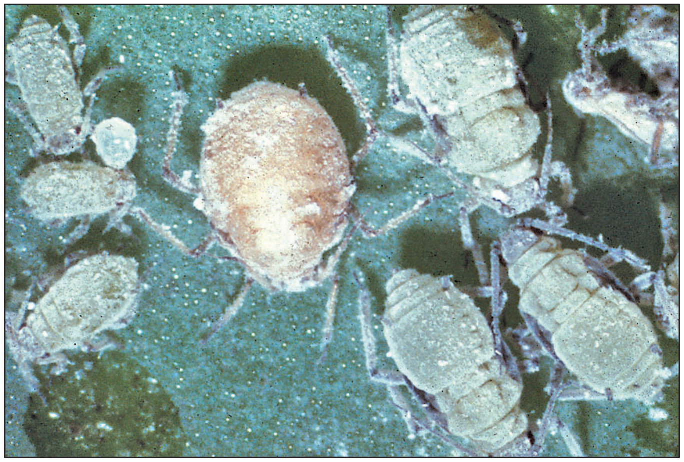

Photo 2.1 Cabbage aphid colony.

Photo 2.2 Imported cabbage worm larva.

Photo 2.3 Imported cabbageworm adult.

Photo 2.4 Cabbage looper larvae.

Photo 2.5 Diamondback moth larva.

Photo 2.6 Cabbage maggot larvae feeding on roots.

Photo 2.7 Cabbage maggot eggs, larva, pupa and adult.

Photo 2.8 Flea beetles.

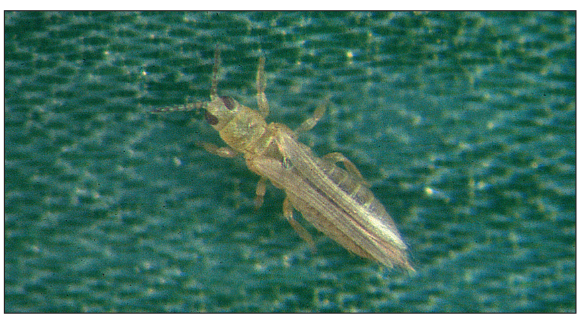

Photo 2.9 Onion thrips greatly magnified.

Photo 2.10 Onion thrips damage.

Photo 2.11 Swede midge adult.

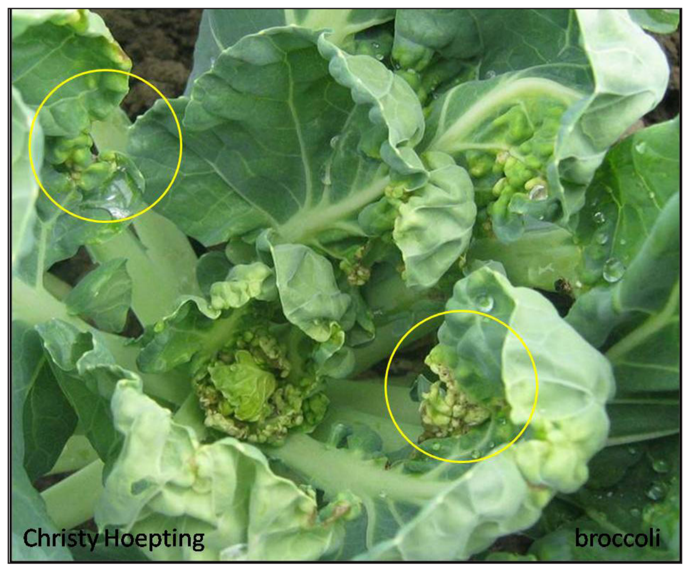

Photo 2.12 Swede midge damage on broccoli (courtesy Christy Hoepting).

Photo 2.13 Black rot symptoms on cabbage.

Photo 2.14 Alternaria leaf spot symptoms on cabbage.

Photo 2.15 Black leg symptoms on cauliflower (courtesy G.S. Abawi).

Photo 2.16 Club root symptoms on Brussels sprouts (courtesy G.S. Abawi).

Photo 2.17 Downy mildew symptoms on broccoli (courtesy G.S. Abawi).

Photo 2.18 White mold symptoms on cabbage.

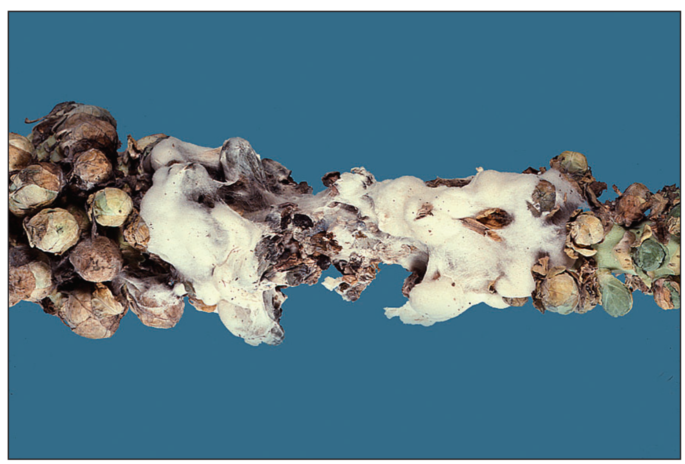

Photo 2.19 White mold symptoms on Brussels sprouts (courtesy G.S. Abawi).

CHAPTER 3 - Chenopods

Photo 3.1 Seedcorn maggot on spinach seedling.

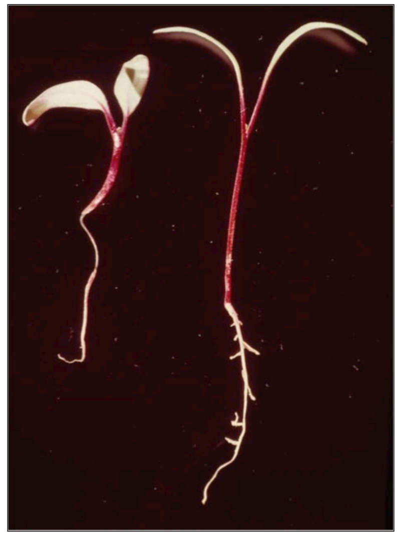

Photo 3.4 Damping off of beet (courtesy G.S. Abawi).

Photo 3.2 Spinach leaf miner damage.

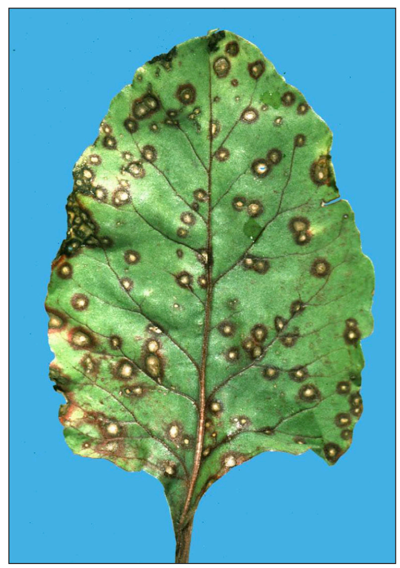

Photo 3.5 Cercospora leaf spot on beet (courtesy G.S. Abawi).

Photo 3.3 Garden webworm.

Photo 3.6 Downy mildew on winter spinach in high tunnel (courtesy Becky Sideman).

Photo 4.1 Squash bug adults.

Photo 4.2 Squash bug nymphs and eggs.

Photo 4.3 Squash vine borer.

Photo 4.4 Striped cucumber beetle adult.

Photo 4.5 Young angular leaf spot lesions.

Photo 4.6 Older angular leaf spot lesions (courtesy T.A. Zitter).

Photo 4.7 Bacterial wilt symptoms on pumpkin.

Photo 4.8 Black rot symptoms on butternut squash (courtesy T.A Zitter).

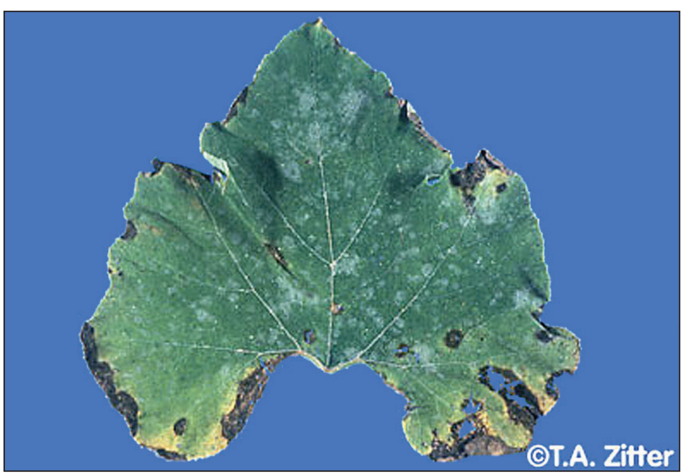

Photo 4.9 Gummy stem blight foliar symptoms (courtesy T.A. Zitter).

Photo 4.10 Downy mildew symptoms on cucumber.

Photo 4.11 Fusarium crown rot symptoms on zucchini (courtesy G.S. Abawi).

Photo 4.12 Phytophthora blight symptoms on pumpkin.

Photo 4.13 Young powdery mildew lesion.

Photo 4.14 Severe powdery mildew.

CHAPTER 5 - Legumes

Photo 5.1 Seedcorn maggot damage to bean seedling.

Photo 5.3 Mexican bean beetle larva.

Photo 5.2 Mexican bean beetle adult.

Photo 5.4 Potato leafhopper adult.

Photo 5.5 Potato leafhopper nymph.

Photo 5.6 Hopperburn on bean from potato leafhopper feeding.

Photo 5.7 Common bacterial blight on bean (courtesy G.S. Abawi).

Photo 5.8 Powdery mildew on pea (courtesy Meg McGrath).

Photo 5.9 Gray mold on pea.

Photo 5.10 White mold on bean.

Photo 5.11 Sclerotia of white mold.

Photo 5.12 Anthracnose on bean (courtesy G.S. Abawi).

CHAPTER 6 - Lettuce

Photo 6.1 Aster leafhopper (courtesy W. Cranshaw, Colorado State University, www.insectimages.org).

Photo 6.2 Grey garden slug.

Photo 6.3 Tarnished plant bug adult.

Photo 6.4 Aster yellows symptoms (courtesy S. Vanek and NEON).

Photo 6.5 Older downy mildew lesions.

Photo 6.6 Young downy mildew infection.

Photo 6.7 Botrytis grey mold symptoms (courtesy G.S. Abawi).

Photo 6.8 Lettuce drop symptoms (courtesy G.S. Abawi).

Photo 6.9 Lettuce drop epidemic in a field (courtesy G.S. Abawi).

Photo 7.1 Potato aphids.

Photo 7.2 Asiatic garden beetle.

Photo 7.3 Colorado potato beetle adult.

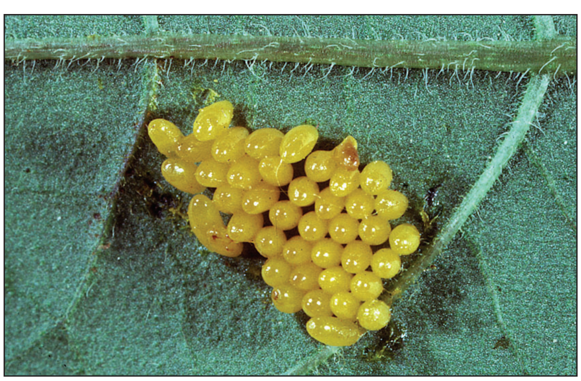

Photo 7.4 Colorado potato beetle eggs.

Photo 7.5 Colorado potato beetle larva.

Photo 7.6 European corn borer in potato plant stem.

Photo 7.7 Potato flea beetle adult.

Photo 7.8 Hornworm larva.

Photo 7.9 Potato leafhopper and its damage called "hopperburn".

Photo 7.10 Tarnished plant bug adult.

Photo 7.11 Bacterial canker symptoms on tomato fruit and leaflet.

Photo 7.12 Bacterial speck symptoms on tomato fruit.

Photo 7.13 Bacterial spot lesions on pepper fruit.

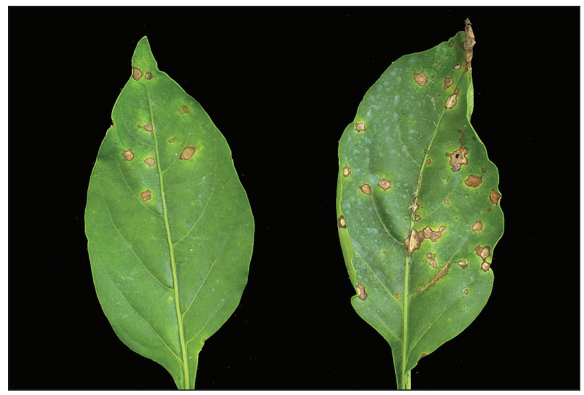

Photo 7.14 Bacterial spot symptoms on pepper leaves.

Photo 7.15 Common scab of potato (courtesey K.L. Perry).

Photo 7.16 Tomato anthracnose symptoms.

Photo 7.17 Black scurf of potato (right) and healthy tuber (left) (courtesy K.L. Perry).

Photo 7.18 Early blight symptoms on tomato.

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Photo 8.9 Fall armyworm larva.


Photo 8.10 Corn rootworm adult.


Photo 8.11 Seedcorn maggot larva (courtesy of B. Nault).


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Photo 8.14 BMSB Adult (photo courtesy of Peter Jensch).

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Photo 8.17 Common rust symptoms.

Photo 8.18 Typical symptoms of common smut.

Photo 9.1 Carrot rust fly larva.

Photo 9.2 Tarnished plant bug adult.

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Photo 9.6 Bacterial leaf blight on carrot (courtesy G.S. Abawi).

Photo 9.7 Aster yellows of carrot (courtesy of G.S. Abawi).

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Photo 9.10 White mold (Sclerotina rot) on carrot.

Photo 9.11 Crater rot on carrot (courtesy G.S. Abawi).

Photo 9.12 Cavity spot on carrot (courtesy G.S. Abawi).

MATERIAL FACT SHEET
Bacillus subtilis

MATERIAL NAME: *Bacillus subtilis*

MATERIAL TYPE: Microbial

U.S. EPA TOXICITY CATEGORY: III "Caution"

USDA-NOP: Considered non-synthetic, allowed. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION: *Bacillus subtilis* is a ubiquitous, naturally occurring, saprophytic bacterium that is commonly recovered from soil, water, air, and decomposing plant material. Under most conditions, however, it is not biologically active and is present only in the spore form. Different strains of *B. subtilis* can be used as biological control agents in different situations. There are two general categories of *B. subtilis* strains; those that are applied to the foliage of a plant and those applied to the soil or transplant mix when seeding.

The *B. subtilis* strain QST 713 is a naturally occurring strain that was isolated in 1995 by AgraQuest Inc. from soil in a California peach orchard. This product is applied to foliage (NYDEC 2001). In contrast, the *B. subtilis* strain GB03 was discovered in Australia in the 1930's and is applied either as a seed treatment or directly to soil. Neither strain is considered a genetically modified organism.

HOW IT WORKS:
B. subtilis bacteria produce a class of lipopeptide antibiotics including iturins. Iturins help B. subtilis bacteria out-compete other microorganisms by either killing them or reducing their growth rate (CPL 2002). Iturins can also have direct fungicidal activity on pathogens.

B. subtilis products are made for many uses. For plant disease control, these include foliar application and products applied to the root zone, compost, or seed. When applied directly to seeds, the bacteria colonize the developing root system, competing with disease organisms that attack root systems (CPL 2002).

According to the manufacturer, *B. subtilis* inhibits plant pathogen spore germination, disrupts germ tube growth, and interferes with the attachment of the pathogen to the plant. It is also reported to induce systemic acquired resistance (SAR) against bacterial pathogens (NY DEC 2001). According to an Agraquest sales representative, the lipopeptide activity in the Serenade product is what provides disease control; any living *B. subtilis* cells in this product have only a minor effect (Cline, personal communication, 2004).

According to the manufacturer, the GB03 strain (Kodiak) delivers extended protection against plant pathogens through three distinct modes of action:

1. Colonies of *B. subtilis* take up space on the roots, leaving less area or source for occupation by disease pathogens.
2. Kodiak feeds on plant exudates, which also serve as a food source for disease pathogens. Because it consumes exudates, Kodiak deprives disease pathogens of a major food source, thereby inhibiting their ability to thrive and reproduce.
3. Kodiak combats pathogenic fungi through the production of a chemical (an iturin) that inhibits the pathogen's growth (Gustafson 2004). Backman et al. (1997) reported

that 60-75% of the seed used for the US cotton crop was treated with Kodiak for suppression of *Fusarium* and *Rhizoctonia* pathogens.

Note: Kodiak is not OMRI Listed at the time of publication

TYPES OF PESTS IT CONTROLS:
Iturins are reportedly active against the fungus *Sclerotinia fruticola*, which causes rots of harvested stone fruit. *B. subtilis* has also been tested for control of the pathogenic fungus *Verticillium*. *B. subtilis* has been used in conjunction with *Streptomyces gramicifaciens* for control of root rot in cucumber, corky rot of tomato, and carnation wilt. According to manufacturers, Norway maple inoculated with *B. subtilis* also shows increased resistance to fungal diseases. It is also claimed to suppress diseases caused by *Fusarium spp*. and *Rhizoctonia spp* (CPL 2002).

FORMULATIONS AND APPLICATION GUIDELINES:
The labels require use of personal protective equipment (long-sleeved shirt, long pants, gloves, shoes, socks, dust/mist filtering respirator) to mitigate the risk of dermal sensitivity and possible allergic reactions.

AVAILABLE STRAINS
QST 713 is a foliar application product predominantly used against powdery mildew.

GB03 is a soil application or seed treatment product predominantly used to control root-infecting fungi. Note: at the time of publication no formulations of GB03 were OMRI Listed.

MBI 600 is used for soil application or seed treatment.

B. subtilis var. *amyloliquefaciens* strain FZB 24 is also used for soil application.

OMRI LISTED PRODUCTS:
***Bacillus subtilis* strain QST 713**

Rhapsody (Agraquest Inc)
Rhapsody ASO (Agraquest Inc)
Serenade ASO (Agraquest Inc)
Serenade Garden Disease Control Ready-To-Use (Agraquest Inc.)
Serenade Garden Disease Control Concentrate (Agraquest Inc.)
Serenade MAX (Agraquest Inc.)
Serenade SOIL (Agraquest Inc.)

References to OMRI listed products in this Guide are based on the 2012 OMRI PRODUCT List. Please consult www.omri.org for changes and updates in the brand name product listings.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI)
The EPA Workers Protection Standard requires a minimum of 4 hours before reentering a treated field. PHI (days to harvest) is zero.

AVAILABILITY AND SOURCES
B. subtilis products are available in a number of strains and formulations. The OMRI listed products are generally available from pesticide dealers.

EFFECT ON THE ENVIRONMENT
According to information submitted by the manufacturer and supported by reviewers at NY DEC, when used as a seed inoculant, both *B. subtilis* and *Bradyrhizobium japonicum* (the naturally occurring nitrogen fixing bacteria used in HiStick, a soybean seed inoculant) are ubiquitous in the environment. The microbes used in this combination product are not genetically modified and have been used in the past by farmers with no reports of negative impacts on crops. The US EPA required limited toxicological data and established an exemption

from tolerance for residues of *Bacillus subtilis* in or on all raw agricultural commodities when applied as a seed treatment for growing agricultural crops (NY DEC 2000).

The US EPA Biopesticides and Pollution Prevention Division documents indicate that *B. subtilis* MBI 600 is non-toxic and non-pathogenic to birds and insects, and no aquatic exposures are anticipated. No adverse effects to fish or wildlife resources are likely through labeled use of this product, and no impact to groundwater is anticipated.

The Department's evaluation of non-target organisms found the Serenade Biofungicide product to be practically non-toxic to mammals and birds. Label instructions are adequate to protect aquatic organisms and bees. Modeling of maximum use rate applications did not exceed toxicity thresholds for birds, mammals, or aquatic organisms (NY DEC 2000).

EFFECT ON HUMAN HEALTH:
In terms of human health, reviewers found the *B. subtilis* bacteria to be relatively benign. It is not a known human pathogen or disease causing agent. *B. subtilis* produces the enzyme subtilisin, which has been reported to cause dermal allergic or hypersensitivity reactions in individuals repeatedly exposed to this enzyme in industrial settings. The oral, dermal, and pulmonary acute toxicity data, as well as eye and skin irritation data on the active ingredient and the formulated product, indicate that neither the *B. subtilis* strain QST 713 nor the Serenade Biofungicide product was very toxic, irritating, pathogenic, or infective to laboratory animals by the above-noted routes of exposure. The Serenade Biofungicide product elicited a mild contact hypersensitivity response (tested on guinea pigs), indicating that it is a potential skin sensitizer (NY DEC 2001).

No toxicological effects were reported for *B. subtilis* MBI 600 following oral or dermal inhalation studies, and no infectivity or pathogenicity was observed. HiStick N/T (based on data for the formerly labeled product Epic) may be somewhat irritating to eyes and skin and may cause skin reactions from direct contact (NY DEC 2000).

EFFICACY

Serenade

In many tests, Serenade showed good results against onion diseases, downy mildew in grapes, and powdery mildew on greenhouse tomatoes. Other trials showed poor to fair efficacy. Trials against fireblight in apples showed some efficacy, though low. This disease is notoriously difficult to control, so even low levels of efficacy are promising.

Serenade is often used and trialed in rotation or combination with other fungicides, such as copper products. Results from such trials are not included here, because it is impossible to attribute efficacy data from them directly to Serenade. There is, however, some indication that this use of Serenade may allow for reduced frequency of application of the companion fungicides.

Kodiak

NOTE: At the time of publication, no Kodiak formulations were OMRI Listed
Kodiak seed treatment must be evaluated differently from spray products directed against pathogens. In several trials, yield was used as a measurement of the efficacy of the treatment. Kodiak treatment showed significant yield increases of 11% in potato in one trial and 15% in beans in one trial, and a non-significant increase of 28% in beans in one trial. Since the cost of treatment is small, such increases may make treatment worthwhile for farmers.

In four other studies, Kodiak gave little or no visible control of root rot pests, but in one of the four it provided a significant 22% control of Fusarium root rot in beans, and in another its use resulted in an 81% stand increase in chickpeas.

A summary of university field trials shows the efficacies of *B. subtilis* use on various vegetable (Fig. 1) and fruit crops (Fig. 2) commonly grown in the Northeast.

In Figures 1 and 2 below, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

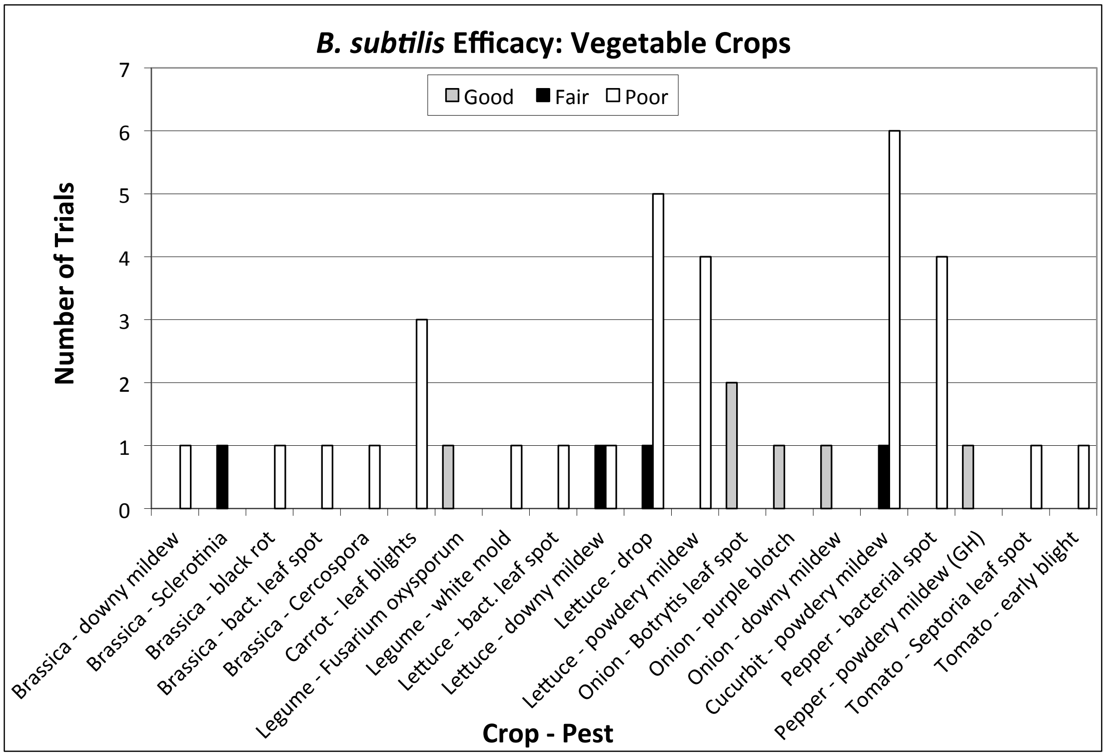

Figure 1. Efficacy of *B. subtilis* products against diseases of vegetable crops

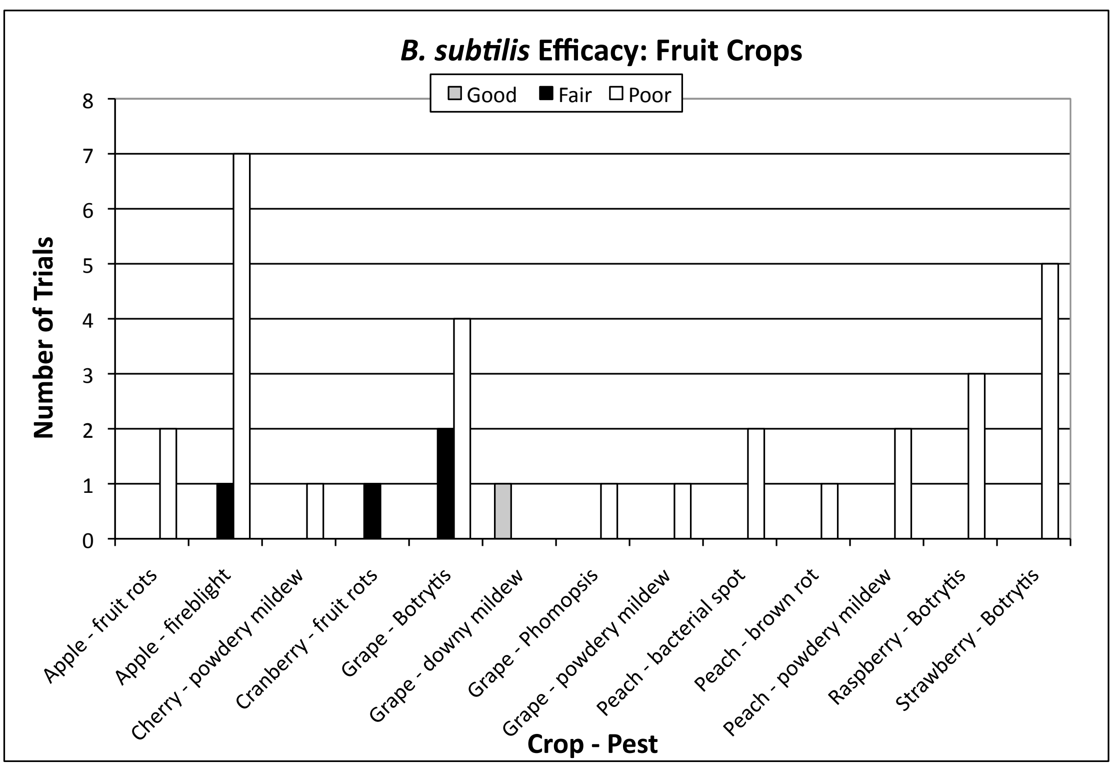

Figure 2. Efficacy of products against diseases of fruit crops

Because university trials are often conducted in fields with intentionally high levels of disease inoculum, and untreated control and ineffective treatments may be producing secondary inoculum, the level of pest control obtainable is likely to be higher than shown in situations where fields are completely treated, and a good program of cultural controls has also been implemented.

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MATERIAL FACT SHEET
Bacillus thuringiensis (Bt)

MATERIAL NAME: *Bacillus thuringiensis* (Bt)

MATERIAL TYPE: Microbial-derived

U.S. EPA TOXICITY: Category: III, "Caution"

USDA-NOP:
Types that are considered natural are allowed; however, types that are either derived or inserted into crops using genetic engineering are prohibited (see below under "Types of Bt"). Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION: The active ingredients in Bt products are proteins produced by *Bacillus thuringiensis* (Bt) bacterium. Some activity also occurs from the spores.

Bt is a member of the genus *Bacillus*, a diverse group of spore-forming bacteria that consists of more than 20 species. The species *B. thuringiensis* is common in terrestrial habitats, including soil, dead insects, granaries, and on plants (AAM 2002). Bt has many subspecies that possess a variety of crystalline proteins with distinct insecticidal properties. Some subspecies work only against Lepidoptera (caterpillars), while others work against only Coleoptera (beetles) or the larvae of flies and mosquitoes (Diptera). It is important to use the subspecies of Bt appropriate for the target insect type (Siegel 2000) (See below for details).

The products allowed for certified organic production typically contain derivatives of bacterial cultures that include the protein active ingredient (i.e., endotoxin), spores, and adjuvants, such as wetting agents.

HOW IT WORKS:
Unlike many insecticides, Bt must be eaten by a susceptible insect in order to be effective. The microorganism produces both spores (resting stage) and a crystalline protein (an endotoxin). When eaten by the insect, this endotoxin becomes activated and binds to the insect gut, creating a pore through which gut contents can enter the insect's body cavity and bloodstream. The insect ceases to feed and dies within a few days.

APPLICATION GUIDELINES:
There are dozens of Bt proteins, some of which are toxic to particular types of insects. Generally, the following guidelines can be used for commercial products:

Bt *kustaki*: caterpillars
Bt *aizawa*i: caterpillars
Bt *tenebrionis* (also called Bt San Diego): beetles
Bt *israelensis:* fly larvae (including fungus gnats, blackflies, and mosquitoes)

Not all species of caterpillars, beetles, or flies are susceptible to the subspecies of Bt listed above (see efficacy section). The most important factor is using the right subspecies of Bt for the insect pest in question.

Because Bt must be eaten by the insect in order to be effective, application of the spray to the plant where and when the insect is feeding is critical. Many insects feed on the undersides of leaves and in concealed parts of the plant, so thorough coverage is required. Bt breaks down within two to three days, so reapplication may be warranted.

As with most insecticides, young larvae are generally more susceptible than older larvae, so treatments should be timed accordingly. Early detection and application are crucial for good control.

The spray deposit may only last for a few days before it is broken down by sunlight. Efficacy may be improved with additional ingredients that promote adherence to leaf surfaces (e.g., stickers) or UV light inhibitors that protect Bt from photo degradation.

As with any natural or synthetic insecticides, insect populations can develop resistance to Bt; resistance has already occurred with some populations of Colorado potato beetle and diamondback moth (Tabashnik et al. 2003). To avoid development of resistance, Bt should only be applied when needed and as part of an overall integrated pest management program that includes cultural and biological controls. If multiple sprays are needed, best practice is to spray a single generation of the insects and use another material or tactic for the next generation. Alternating pest treatments decreases the selection for resistance to any one treatment.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI):
The reentry interval is four hours (twelve hours for Bt *tenebrionis*), and the pre-harvest interval is 0 days. Bt is exempt from tolerance on all raw commodities.

AVAILABILITY AND SOURCES: There are currently over 100 Bt microbial insecticides registered in the US, but this list is based primarily on only 4 subspecies of Bt. Bt products are readily available in stores that sell agricultural products. Since not all Bt products are allowed for certified organic production because of prohibited inert ingredients or genetically engineered active ingredients, ***be sure to check with a certifier before use.***

TYPES OF Bt
Bt products vary in their origin and manufacturing process. Some origins and formulations are not allowed for use in certified organic production.

APPROVED TYPES
The first Bt products, including many still available today, were made from naturally occurring, wild type species of Bt (e.g. DiPel, Javelin, and XenTari). Newer strains of Bt have been created through a process called "conjugation" or "transconjugation." This phenomenon is known to occur in nature and is analogous to hybridization in higher organisms. Two or more subspecies of Bt are mixed together in a way that facilitates the formation of new strains from which individuals with desirable qualities from both parents may be selected. This method of production is permissible because it does not fall under the NOP definition of "excluded methods" (genetic engineering).

PROHIBITED TYPES
The newest form of Bt manufacturing is through recombinant DNA (rDNA) techniques, where specific genes linked to the expression (production) of crystalline protein toxins are inserted into bacterial cells. Novel combinations of toxins are the result of this process. This method of Bt manufacturing is not acceptable in organic production systems.

Products formulated with prohibited solvents or other prohibited, inert ingredients are not allowed for organic production. For instance, at the date of this publication, there are no OMRI listed Bt *tenebrionis*-based products available for the management of Colorado potato beetle.

In addition to manufactured products, Bt genes for the expression of crystalline proteins have also been inserted directly into crops by rDNA techniques. Bt corn and cotton are grown widely in the US, China, Australia, India, and to a lesser extent, in about a dozen other countries. Such genetically engineered crops are not permitted in organic production systems.

OMRI LISTED PRODUCTS (This is a partial list. Check http://www.omri.org for many more):
Bacillus thuringiensis* subsp. *aizawai

Agree WG (Certis USA)
XenTari DF (Valent BioSciences Corp) - wild type
XenTari WDG (Valent BioSciences Corp) - wild type

Bacillus thuringiensis* subsp. *kurstaki

Deliver (Certis USA)
Biobit 32 (Valent BioSciences Corp)
DiPel 2X (Valent BioSciences Corp) - wild type
DiPel DF (Valent BioSciences Corp) - wild type
Javelin WG (Certis USA) - wild type

Bacillus thuringiensis* subsp. *israelensis

Gnatrol WDG (Valent BioSciences Corp)
VectoBac WDG (Valent BioSciences Corp)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

EFFECTS ON THE ENVIRONMENT:

Wildlife: As part of the testing procedures for registration, Bt products were fed to birds and fish, and the results have indicated no adverse effects.

Natural enemies: Parasites and predators, important natural enemies of many insect pests, are generally not harmed directly by sprays or deposits of Bt.

Other non-targets: Other susceptible hosts that are not the target of the spray may also be killed. These may include rare moths and butterflies in certain sensitive habitats, but the impact is likely to be minimal with carefully targeted applications.

For a more detailed summary of environmental studies of Bt, see Siegel (2000).

EFFECTS ON HUMAN HEALTH:

Because an insect's gut structure and physiology are vastly different from a human's, Bt does not have the same effect on the human gut as it has on the gut of susceptible insects. The rapid breakdown by solar radiation results in little or no residue on crops. There have been a few isolated reports of Bt found in human tissues, but these appear to be secondary infections. When spraying Bt, applicators should exercise caution by protecting eyes and open wounds. A very small percentage of the human population is susceptible to allergic responses from exposure to Bt in relatively high doses (Bernstein et al. 1999).

VEGETABLE EFFICACY TRIALS SUMMARY:

OMRI-listed Bt products have very similar efficacy results as the entire array of Bt products, though there are currently no listed formulations effective against Colorado potato beetle. Listed Bt products are generally effective against most lepidopteran species affecting brassicas and tomatoes; formulations for caterpillar pests have little effect on other types of insects, such as beetles and aphids. If applied thoroughly to all plant parts (Bt residue must be ingested to be effective), they can also be effective against the European corn borer on corn; however, because delivery of the product to the feeding site is difficult, they have not been as effective against corn earworm caterpillars. Trials with Zea-later, a hand-held device that squirts a measured amount of material into the silk channel, have proved very promising (Hazzard & Westgate 2004). While no recent studies have tested Bt products against European corn borer on peppers, properly timed applications of Bt products could be effective. Approved products with either Bt *aizawai* or Bt *kurstaki* strains have performed similarly against caterpillars in recent studies. Three weekly applications of Bt *aizaiwi* have been shown to be effective against squash vine borer when applied during the moth flight. (See the Cucurbits chapter for more information).

A database of university trials of Bt products was compiled for this fact sheet. University-based trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. The level of pest control is likely to be higher on fields in which a good program of cultural controls has been implemented.

In Figure 1, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74% and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

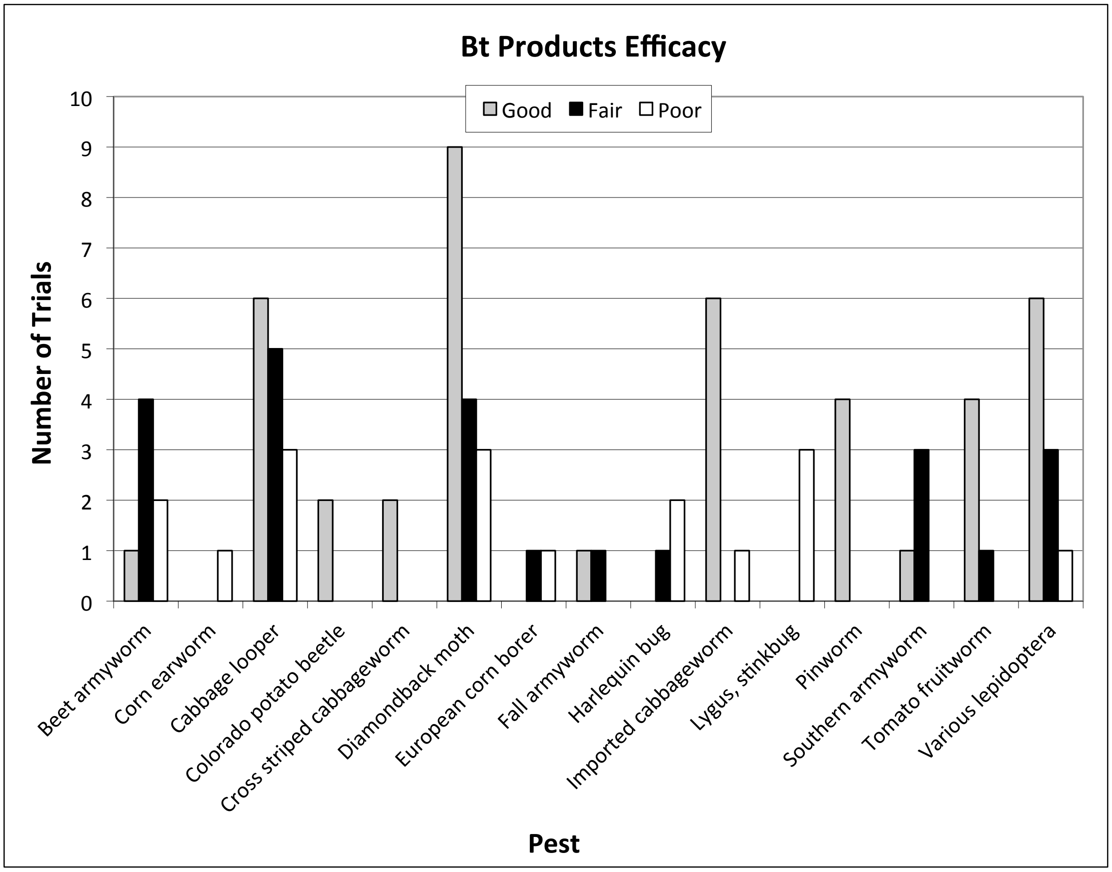

Figure 1. Efficacy of Bt products against various insect pests.

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MATERIAL FACT SHEET
Beauveria bassiana

MATERIAL NAME: *Beauveria bassiana*

MATERIAL TYPE: Biological (fungus)

U.S. EPA TOXICITY CATEGORY: III, "Caution"

USDA-NOP:
Considered non-synthetic, allowed. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION:
Beauveria bassiana is a fungus that is commonly found in soils worldwide. Insects vary in susceptibility to different strains. Strains have been collected from different infected insects and cultured to create specific products for commercial use. There are two commonly used strains, GHA and ATCC 74040. These products are produced through fermentation. The spores (conidia) are extracted and formulated into a sprayable product.

HOW IT WORKS:
Beauveria bassiana kills pests by infection when the insect comes into contact with fungal spores. An insect can come into contact with fungal spores in several ways: by having the spray droplets land on its body, by contacting a treated surface, or by consuming plant tissue treated with the fungus (the latter is not a major method of uptake). Once the fungal spores attach to the insect's skin (cuticle), they germinate, sending out structures (hyphae) that penetrate the insect's body and proliferate. It may take three to five days for insects to die, but infected cadavers may serve as a source of spores for secondary spread of the fungus. Insects can also spread the fungus through mating (Long et al. 2000). High humidity and free water enhance activity of the conidia and the subsequent infection of the insect. Fungal spores are readily killed by solar radiation and infect best in cool to moderate temperatures (Goettel et al. 2000; Wraight and Ramos 2002).

Because the spores may have a short life, ensuring that the spray or spray deposit has sufficient opportunity to contact the insect is important; therefore, good coverage with a large number of droplets that contain a high concentration of spores is essential. Care should be taken to apply the material to the undersides of the leaves or wherever the pest primarily occurs. For insects that bore into a plant (e.g. the European corn borer), control will be very difficult. For best results, applications should be made during the early growth stages of the insect before much damage has occurred, as several days may pass before the insect dies. Speed of kill depends on the number of spores contacting the insect, insect age, susceptibility, and environmental conditions; however, the time to death is generally slower than with most other insecticides.

One formulation of *B. bassiana*, Mycotrol, is reported to be sensitive to high temperatures, with best results at application temperatures between 70°F and 80°F. Slow growth at warmer temperatures may make this a poor option for growers in southern states (Kuepper 2003).

TYPES OF PESTS IT CONTROLS:
Commercial products containing different strains of *Beauveria* are commonly labeled for insects such as thrips, whiteflies, aphids, caterpillars, weevils, grasshoppers, ants, Colorado potato beetle, and mealybugs.

FORMULATION AND APPLICATION GUIDELINES:
Both liquid and powder formulations are available. In one study, an ES (emulsifiable suspension) formulation showed better ability to withstand rain than the comparable WP (wettable powder) form. Read labels for specific application guidelines, including determination of reentry interval (REI) and pre-harvest interval (PHI).

For some pest species, a baited formulation may be most effective (Bextine and Thorvilson 2002); however, no baited formulations are currently OMRI Listed.

GENERAL GUIDELINES: Range of efficacy will depend on the susceptibility of the species in question, pest population levels, and environmental conditions at time of application; however, there are several important considerations for this product:

1. **Look before spraying.**
   Apply only when the insect is seen on the plant, and do not apply as a preventative spray because the residue may be gone in a few days.
2. **A single application may not be sufficient.**
   Since the fungus is rapidly broken down by sunlight and washed off the plant by rain, multiple applications may be required to provide adequate control. The product is best used as a suppressant rather than an eradicant, and thresholds (i.e., treatment guidelines) developed for other products may not be appropriate. There is evidence that the fungus can overwinter in insects and may suppress pest populations over the long term, especially with repeated applications (Groden et al. 2002).
3. **Use against earlier stages of the insect.**
   B. bassiana is more effective on younger stages of insects than on older stages (e.g., large larvae or adults).
4. **Consider compatibility.**
   Do not tank mix with any fungicides not allowed on the label (note: the Mycotrol label states that it is compatible with "some fungicides"). Applying subsequent fungicide sprays within 4 days after a *B. bassiana* application may also reduce its efficacy. Note other label cautions about tank-mixing with adjuvants or other materials.
5. **Humidity is a factor.**
   Beauveria is likely to be more effective in farm microclimates with high relative humidity, such as valley bottoms (Lo et al. 1999).
6. **Watch for phytotoxicity.**
   There have been some reports of phytotoxicity to young tomato greenhouse transplants with an ES formulation, so testing prior to large-scale application is advisable.

AVAILABILITY:
B. bassiana is widely available from garden and farm supply mail order companies. Be sure to verify registration status in the state where it will be used.

OMRI LISTED PRODUCTS:

Mycotrol O (Laverlam International Corp.) *Beauveria* bassiana strain GHA

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

EFFECT ON HUMANS AND THE ENVIRONMENT:

Humans: There are no expected health risks to humans who apply this insecticide or to people who eat the crops that have been treated with the fungus. The two commercial strains of *B. bassiana* (GHA and ATCC 74040) have been tested against rats and rabbits, and the results indicate they are not considered to be pathogenic, infective, or toxic. Precaution should be taken, however, as they can be skin, eye, and lung irritants.

Wildlife: Considered non-toxic to mammals, birds, and plants.

Natural enemies and bees: Since this product is used to control a broad range of insect types (including beetles and ants), natural predators in these insect classes could also be affected. For example, research has shown that there is significant mortality of convergent lady beetles when exposed to *B. bassiana*. Caution should be used during application when natural predators are present and when honeybees are actively foraging.

EFFICACY:

While *B. bassiana* affects a wide variety of insect groups (beetles, caterpillars, thrips, aphids, etc.), the variability of control of any one insect can be large and depends on environmental factors, timing of sprays, the stage of the insect, and the insect's inherent susceptibility to the fungal strain. *Beauveria bassiana* products have not shown consistently effective pest control in university trials, though some studies conducted in the Northeast have shown promise. Decent control of the diamondback moth on cabbage seedlings was achieved by well-timed sprays with good coverage (Shelton et al. 1998). Additional field trials have indicated that fair to good, season-long control of the caterpillar complex on cabbage can be achieved with multiple sprays (Vandenberg et al. 1998). In areas where insects like the diamondback moth and Colorado potato beetle have become resistant to spinosad, *B. bassiana* can be used by organic growers as part of an integrated control program. Control of the Colorado potato beetle has been variably successful and largely dependent on the population pressure and application methods, as well as the factors mentioned above (Wraight and Ramos 2002).

In the mid-1990s, studies conducted on the tarnished plant bug (TPB), a major pest of strawberries, indicated that TPB populations and their damage could be reduced to about half through four applications of a product containing *B. bassiana* (Kovach and English-Loeb 1997). However, it probably needs to be applied early in pest population development, as the most damaging TPB problems occur around bloom, and the usual IPM treatment thresholds are not appropriate because the material is slow acting. The authors suggest that it may work best in settings that have moderate TPB populations, such as in strawberry plantings that include cultivars that are more tolerant to TPB damage (e.g., "Honeoye).

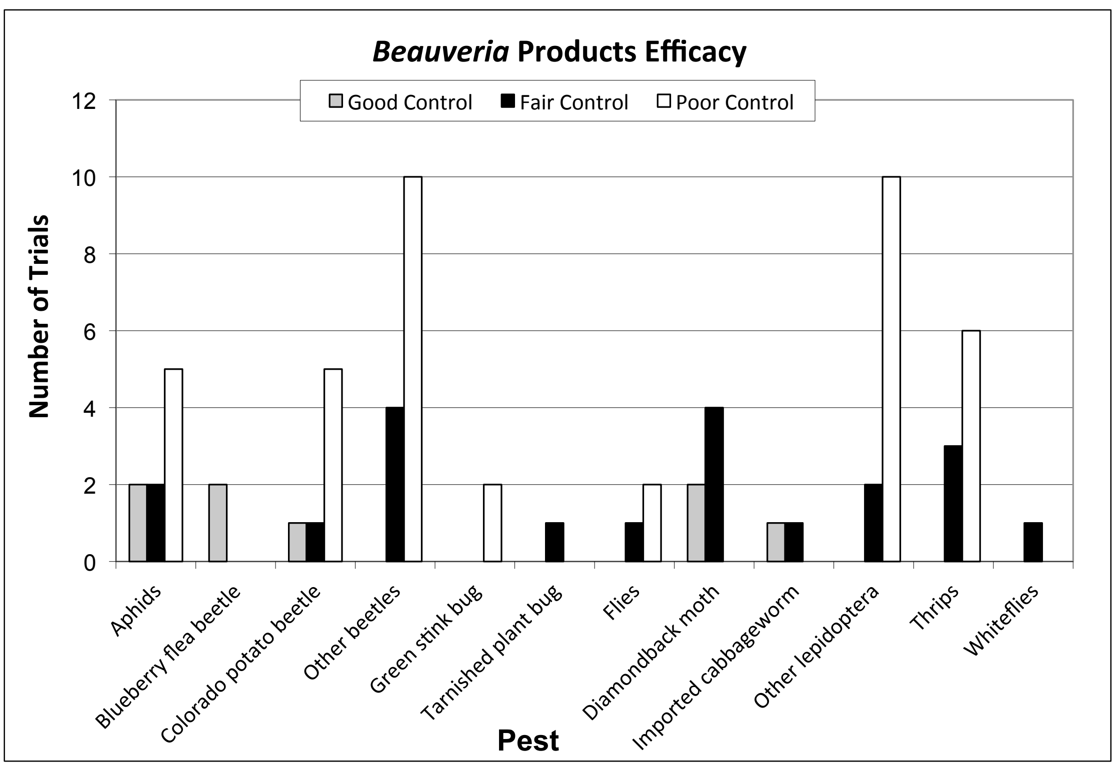

Figure 1. Efficacy of *Beauveria* products against insect pests of vegetable crops.

A summary of university field trials of *Beauveria bassiana* products on vegetable crops commonly grown in the Northeast reveals variable efficacy even within the same pest group (Fig. 1). These trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. The level of pest control is likely to be higher on fields in which a good program of cultural controls has also been implemented.

In Figure 1, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

Variable results in these studies indicate more testing is needed, particularly for beetles, thrips, and aphids. Western flower thrips are not very susceptible to the GHA strain, according to lab studies (Wraight and Ramos 2002).

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MATERIAL FACT SHEET
Bicarbonate (Potassium or Sodium)

MATERIAL NAME: *Bicarbonate (Potassium or Sodium)*

MATERIAL TYPE: Mineral

U.S. EPA TOXICITY CATEGORY: III, "Caution"

USDA-NOP:
Considers sodium bicarbonate as non-synthetic and allowed. Potassium bicarbonate is considered synthetic and is permitted for plant disease control. The related chemical ammonium carbonate is permitted only for use as bait in traps for insect control. Organic crops destined for export to Japan may not be produced using potassium bicarbonate (NOP 2000).

MATERIAL DESCRIPTION:
These products rely on a bicarbonate salt (usually potassium bicarbonate) as the active ingredient. They are promoted for use against powdery mildew diseases. The use of baking soda (sodium bicarbonate) as a fungicide is not a new idea; in Alfred C. Hottes' *A Little Book of Climbing Plants*, published in 1933, mention is made of using one ounce of baking soda per gallon of water to control powdery mildew on climbing roses. The author credits the idea to a Russian plant pathologist, A. de Yaczenski (Williams & Williams 1993).

HOW IT WORKS:
According to the Kaligreen product label, these products disrupt the potassium or sodium ion balance within the fungal cell, causing the cell walls to collapse.

OMRI LISTED PRODUCTS:

Kaligreen (Otsuka AgriTechno Co.,LTD)
MilStop Broad Spectrum Foliar Fungicide (BioWorks, Inc.)
Monterey Bi-Carb Old Fashioned Fungicide (Lawn and Garden Products, Inc.)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

Note: Baking soda (sodium bicarbonate) cannot legally be used as a pesticide unless it is an ingredient in an EPA registered product.

FORMULATIONS AND APPLICATION GUIDELINES:
These products are 82-85% potassium bicarbonate and 15-18% surfactants and other inert ingredients. The potassium bicarbonate is microencapsulated and used at rates of 1-5 lb/acre. The pH of the spray solution should be kept at 7.0 or above. Bicarbonate products may be phytotoxic if used at rates above 5 lb/acre. Several studies have shown much better efficacy against powdery mildew when oils are added to bicarbonate products, typically at the rate of 0.5-1.0% (Kuepper et. al. 2001, Ziv & Zitter 1992).

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI):
The EPA Workers Protection Standard requires a minimum of 4 hours before reentering treated areas for Kaligreen and one hour for Milstop. There is usually a one-day to harvest PHI requirement. Monterey Bi-Carb Old Fashioned Fungicide is not labeled for use on commercial farms.

AVAILABILITY AND SOURCES:
Available through several mail order suppliers.

EFFECT ON THE ENVIRONMENT:
The active ingredient is a salt of two ions that are very common in nature. It is non-flammable and not considered to be a carcinogen. Neither the active ingredient nor its decomposition products (potassium ions, bicarbonate or carbonate ions, water, or carbon dioxide) have chronic toxic effects. The effects of the inert ingredients are unknown, but in order to meet NOP requirements, approved formulations must be on the EPA's August, 2004 list 4, "Inerts of Minimal Concern."

EFFECT ON HUMAN HEALTH:
The oral LD50 of Kaligreen is 3358 mg/kg for rats (Kaligreen MSDS); that of Milstop is 2700 (Milstop MSDS). The Federal EPA ruled (as of December, 1996) that sodium and potassium bicarbonates are exempt from residue tolerances. The decision facilitated the development and release of commercial bicarbonate products for horticultural use (Kuepper et al. 2001). Sodium bicarbonate has been a component of many foods, and widely consumed over hundreds of years.

EFFICACY:
A summary of field trials compares the efficacy of bicarbonate use on vegetables and fruit commonly grown in the Northeast. These university-based trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. The level of pest control is likely to be higher on completely sprayed fields in which a good program of cultural controls has been implemented. Furthermore, many of these trials were implemented without adding oil or other adjuvants to the spray mixture, which might improve efficacy.

In the figures below, "good control" means statistically significant reductions in either disease severity or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

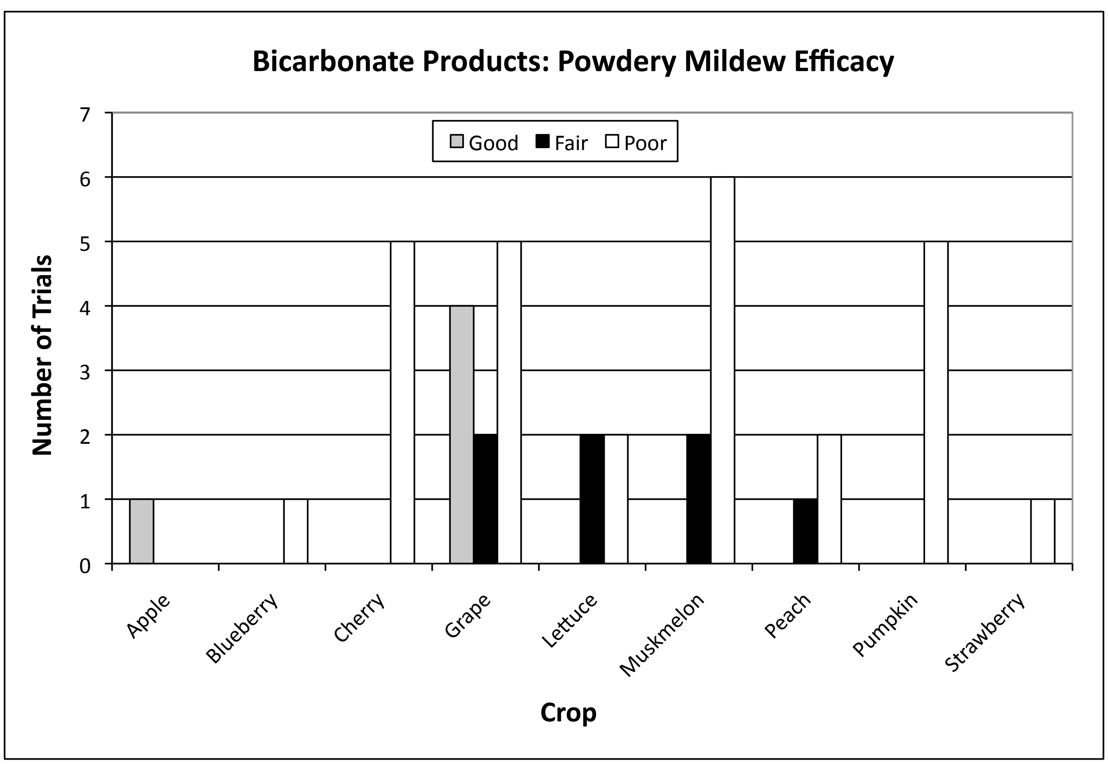

Figure 1. Efficacy of bicarbonates against powdery mildew in different crops.

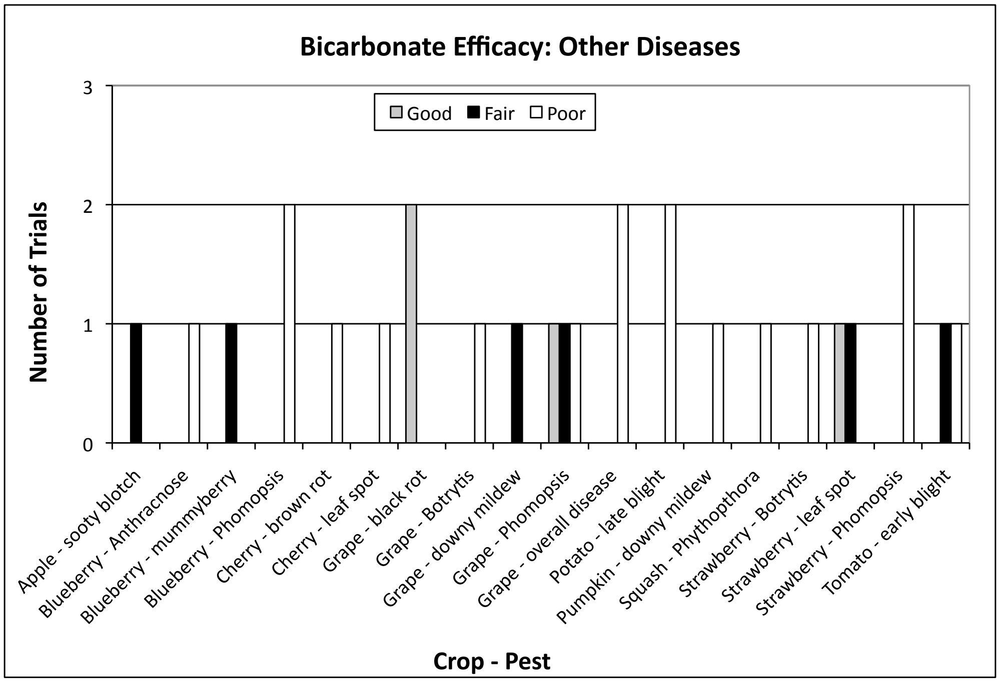

Figure 2. Efficacy of bicarbonates against diseases other than powdery mildew.

Bicarbonate products give **at least partial control** of many powdery mildew diseases (Fig. 1). Powdery mildews have a more superficial nature on the plant surface that may allow more contact with the product. Many other diseases do not appear to be affected by bicarbonate products, perhaps because they penetrate deeper into plant tissues. In some studies, however, potassium bicarbonate has given good control of diseases such as black rot and Phomopsis on grapes and strawberry leaf spot (Fig. 2).

Among the 68 trials reviewed for this fact sheet, bicarbonate products gave only **poor results** against some diseases. These included anthracnose and Phomopsis on blueberry, brown rot and leaf spot on cherry, *Botrytis* on grapes and strawberries, potato late blight, downy mildew on pumpkins, *Phytophthora* on squash, and powdery mildew on strawberry.

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MATERIAL FACT SHEET
Coniothyrium minitans

MATERIAL NAME: *Coniothyrium minitans*

MATERIAL TYPE: Microbial

U.S. EPA TOXICITY CATEGORY: III, "Caution"

USDA-NOP:
Considered non-synthetic, allowed. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION:
Coniothyrium minitans is a fungus that can be utilized as a biological control against the fungal pathogens *Sclerotinia sclerotiorum* and *Sclerotinia minor* (causal agents of white mold on many plant species). First identified in 1947, *C. minitans* is naturally occurring and can be found in soils worldwide. (Pavlitz & Belanger 2001).

This biocontrol fungus is sold as conidia (spores), which are dried and mixed with glucose. The product is then mixed with water and sprayed onto the soil (Fravel 1999).

HOW IT WORKS:
C. minitans attacks and destroys the sclerotia (overwintering structures) of *S. sclerotiorum* and *S. minor* in the soil (Kuepper 2001). Normally these sclerotia will germinate in the spring and summer, producing spores that infect many crops. If *C. minitans* is applied either just after harvest in the fall or in early spring, many of the sclerotia will be destroyed.

There is currently only one strain of *C. minitans* (CON/M/91-08) labeled for use as a biological control. This product is sold under the trade name Contans.

TYPES OF PESTS IT CONTROLS:
C. minitans controls only two pests; *S. sclerotiorum* and *S.minor*. These sclerotinia pathogens have a wide host range of several hundred species of plants, including many vegetables and ornamentals. They commonly cause white mold on cole crops and beans and are occasionally found on tomatoes and peppers. Additionally, they cause leaf drop on lettuce and white mold in carrots, especially in storage.

FORMULATIONS AND APPLICATION GUIDELINES:
Contans is sold as a water dispersible granule that is applied directly to the soil surface. Thorough and uniform coverage it is necessary for effective treatment. Following application and before planting, the fungal spores must be incorporated into the top one to two inches of soil. To avoid unearthing new sclerotia, the soil should not be disturbed below the treatment depth. This incorporation can be done by water (rainfall or irrigation) or cultivation. Contans can also be applied to plant debris in the fall after harvest.

The shelf life of dried conidia is greater than 6 months. The manufacturer states that after 18 months, the activity is reduced by 25%.

Contans is harmful if swallowed, absorbed through skin, or inhaled. The label requires applicators to wear long-sleeved shirts, long pants, waterproof gloves, shoes, and socks. Additionally, all mixers, loaders, and applicators must wear dust/mist-filtering respirators.

OMRI LISTED PRODUCTS:

Coniothyrium minitans strain CON/M/91-08
Contans WG Marketed by Encore Technologies, LLC
Manufactured by Prophyta Biologischer Pflanzenschutz GmbH

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI):
The EPA Workers Protection Standard requires a minimum of 4 hours before reentering treated areas, and has a 0 days pre-harvest interval.

EFFECT ON THE ENVIRONMENT:
Risk to the environment appears to be low. *C. minitans* is resistant to decomposition by light, but not resistant to high temperatures (above 104 degrees F). It is insoluble and has been found to have low toxicity to fish and algae. In the absence of host sclerotia (a food source), its biocontrol ability is thought to persist at low levels, if at all.

EFFECTS ON HUMAN HEALTH:
Risk to public health appears to be minimal (Table 1).

Table 1. Toxicity of *C. minitans* through different exposure routes

Acute oral LD50 (rat)	Relatively non-toxic (>2500mg/kg)
Acute dermal LD50 (rat)	Relatively non-toxic (>2500mg/kg)
Acute intraperitoneal LD50 (rat)	Relatively non-toxic (>2000mg/kg)
Acute inhalation toxicity (rat)	Relatively non-toxic (>12.74 mg/liter air)
Eye irritation (rabbit)	None
Skin irritation (rabbit)	None

EFFICACY:
The *C. minitans* product is variable in its effectiveness, as are many biological products. It can be effective against both *S. sclerotiorum* and *S. minor* (Fig. 1). Factors that cause the observed variability in field trials are unknown, but may include treatment rate, number of treatments, soil moisture and temperature at the time of treatment, whether the treatment was incorporated into the top 2 inches of soil, and whether new sclerotia were brought to the surface by tillage after treatment. Results appear to be somewhat better against *S. sclerotiorum* than *S. minor* (Fig. 2).

In Figure 1, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

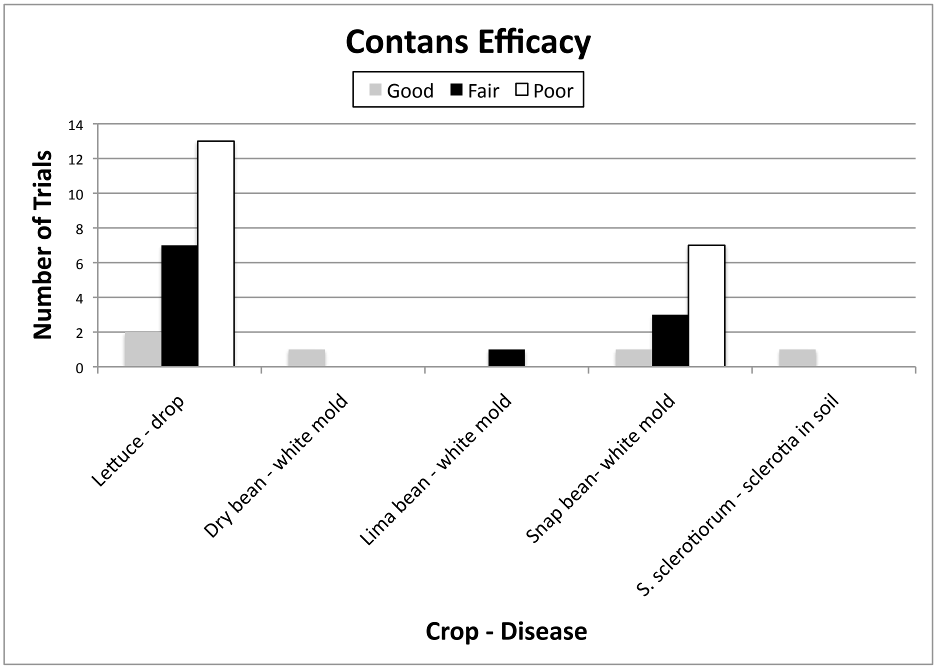

Figure 1. Efficacy of Contans against *Sclerotinia* diseases in vegetables.

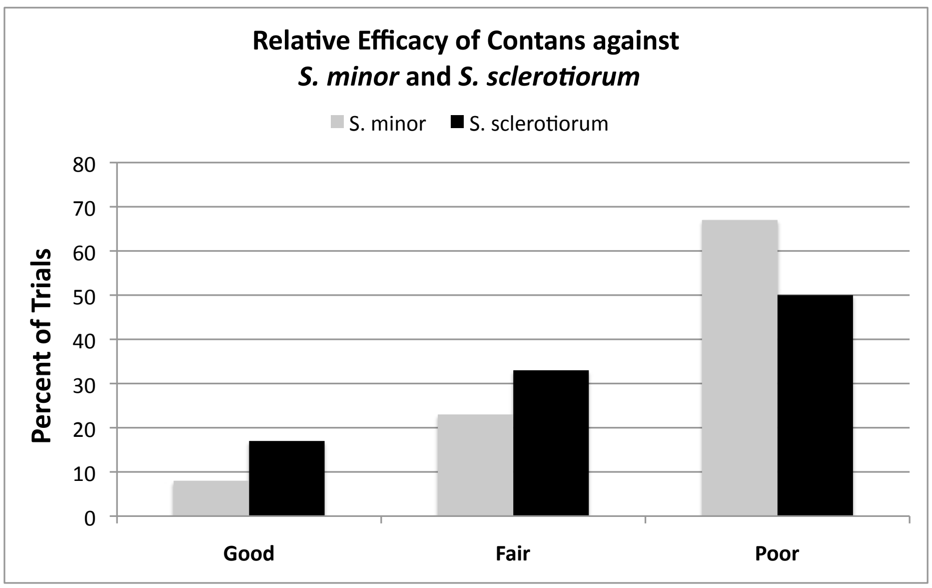

Figure 2. Relative efficacy of the Contans product against *Sclerotinia minor* and *S. sclerotiorum.*

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MATERIAL FACT SHEET
Copper products

MATERIAL NAME: Copper products

MATERIAL TYPE: Mineral-based fungicide/bactericide

U.S. EPA TOXICITY CATEGORY: Varies by form. Copper hydroxide and copper sulfate are Category I, "Danger." Basic copper sulfate and copper oxychloride are Category II, "Warning." Copper oxide and copper octanoate are Category III, "Caution."

USDA-NOP:
Considered synthetic, allowed with restrictions. The following forms are permitted for use in plant disease control:

1. Coppers, fixed - copper hydroxide, copper oxide, copper oxychloride, copper octanoate, includes products exempted from EPA tolerance. Use as an herbicide is not permitted (NOP: 7CFR 205.601(i)(1)).
2. Copper sulfate (NOP: 7CFR 205.601(i)(2)).
3. Copper sulfate is also permitted for use as an aquatic algaecide and for tadpole shrimp control in rice production. (NOP: 7CFR 205.601(a)(4) and (e)(3)).

Copper-based materials must be used in a manner that minimizes accumulation in the soil (NOP: 7CFR 205.601(i)(1) & (2)). It is recommended, and some certifiers require, that soil testing is done to establish a baseline for background levels of copper in the soil and that subsequent testing be done to monitor any accumulation. See below for a discussion of copper in soil.

MATERIAL DESCRIPTION:
Copper fungicides can be described as insoluble compounds, yet their action as fungicides and bactericides is due to the release of small quantities of copper (Cu++) ions when in contact with water. Copper hydroxide is more water soluble at low pH (high acidity). This product should be applied in a spray solution (such as water) at a pH above 6.0; if the solution is more acidic, phytotoxicity could occur. Bordeaux mixes are preparations of copper sulfate and calcium hydroxide (hydrated lime), working in much the same way as the newer copper fungicides, which are effective at lower rates of application.

HOW IT WORKS:
Toxic copper ions are absorbed by germinating spores. Following absorption into the fungus or bacterium, the copper ions link to various chemical groups present in many proteins (e.g., imidazoles, phosphates, sulfhydryls, hydroxyls) and disrupt their function. Thus, the mode-of-action of copper hydroxide (or any other copper fungicide) is the non-specific denaturation (disruption) of cellular proteins. For best results, copper must be on the plant surface before the spore germinates and reapplied as plants grow to maintain coverage and prevent disease establishment.

OMRI LISTED PRODUCTS (NOT INCLUDING COPPER FERTILIZERS):

Badge X2 (Isagro USA)
Camelot O Fungicide/Bactericide (SePRO Corporation)
Basic Copper 53 (Albaugh, Inc.)
Champ WG (NuFarm Americas, Inc.)
Chem Copp 50 (American Chemet Corporation)
COC WP (Albaugh, Inc.)
Copper Sulfate Crystals (Chem One Ltd.)
CS 2005 Algaecide/Bactericide/Fungicide (Magna-BonII, LLC)
CSC Copper Sulfur Dust Fungicide (Martin Operating Partnership, L.P.)

Cueva Fungicide Concentrate (W Neudorff GmbH KG)
Cueva Fungicide Ready to Use (W Neudorff GmbH KG)
Nordox 30/30 WG (NORDOX AS)
Nordox 75WG (NORDOX AS)
Nu Cop 50 WP (Albaugh, Inc.)
Nu Cop 50 DF (Albaugh, Inc.)
Ortho elementals Garden Disease Control (The Ortho Group)
PHT Copper Sulfur Dust (J.R. Simplot Company)
Ready-to-Use Worry Free Brand Copper Soap Fungicide (Lilly Miller Brands)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

FORMULATION AND APPLICATION GUIDELINES:
See labels for application guidelines. There is often a wide range of allowable rates, which is in part due to the phytotoxic effects copper can have on some plants. Higher rates provide more control, but also increase chances for phytotoxicity. Reading the product label and following the recommended rate for each crop is essential.

Some mixtures, such as oil and copper products, are strongly phytotoxic to some crops. For instance, citrus and apples have little tolerance, while this combination is sometimes used on tomatoes without damage.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI)
REI and PHI vary with formulations. Handle all copper products with care, and follow the label instructions carefully.

AVAILABILITY AND SOURCES:
OMRI-listed copper products are not widely available in the Northeast. Champ WG, Cueva Fungicide Concentrate, Cueva Fungicide Ready to Use, and Nu Cop 50 WP are available from a few farm chemical distributors and mail-order companies. If late blight has been a problem in past years, plan ahead, and work with local distributors to have a copper-based fungicide on hand.

EFFECTS ON THE ENVIRONMENT AND HUMAN HEALTH:
Small amounts of copper are necessary for the life and health of both plants and animals. The following discussion is centered on the effects of excessive levels.

LEAF PERSISTENCE
Copper will generally remain on leaf surfaces for one to two weeks or until it is washed off by rain or overhead irrigation.

FATE IN WATER AND SOIL
Copper is bound (i.e., adsorbed) to organic materials as well as to clay and mineral surfaces. The degree of adsorption in soils depends on the acidity or alkalinity of the soil. Because copper sulfate is highly water soluble, it is considered one of the more mobile metals in soils; however, due to its binding capacity, its leaching potential is low in all but sandy soils (Extoxnet 1996).

Copper is a necessary plant and animal nutrient, but at high levels, it is toxic to plants and other organisms. It is always present at a background level but can be a concern in situations of heavy agronomic use of copper compounds. Agricultural soils are reported to have average background levels of 20-30 ppm (Baker 1990), with the average overall US level found to be 15.5 ppm (Holmgren 1993). Some vineyard soils in Europe, which have seen intensive use of copper sulfate-containing Bordeaux mixtures for 100 years, have soil concentrations ranging from 100 - 1500 ppm (Besnard 2001).

In New York, maximum soil concentration rates for copper have been recommended based on soil type; rates range from 40 ppm in sandy soils, to 60 ppm in silt loam, to 100 ppm in clay soils. These rates have been suggested in order to protect against phytotoxicity and negative impacts on soil life (Harrison et al. 1999). Typically, each spray with a copper-based fungicide results in an application of 1 to 4 lb. of copper per acre, raising the topsoil concentration from 0.5 to 2 ppm; often several copper sprays are made per season. Under a heavy copper spray program, toxic topsoil levels could be reached in a matter of decades.

WILDLIFE:

Effects on birds: Copper sulfate is practically nontoxic to birds. It poses less of a threat to birds than to other animals. The lowest lethal dose (LDLo) is 1000 mg/kg in pigeons and 600 mg/kg in ducks. The oral LD50 for Bordeaux mixture in young mallards is 2000 mg/kg (Extoxnet 1996).

Effects on aquatic organisms: Copper sulfate is highly toxic to fish. Even at recommended rates of application, this material may be poisonous to trout and other fish, especially in soft or acid waters. Its toxicity to fish generally decreases as water hardness increases. Fish eggs are more resistant to the toxic effects of copper sulfate than young fish. Copper sulfate is also toxic to aquatic invertebrates, including crab, shrimp, and oysters. It is used as a pesticide to control tadpole shrimp in rice production. The 96-hour LC50 of copper sulfate to pond snails is 0.39 mg/L at 20 C. Higher concentrations of the material caused some behavioral changes, such as secretion of mucous and discharge of eggs and embryos (Extoxnet 1996).

Effects on other organisms: Bees are negatively affected by Bordeaux mixture. Copper sulfate may be poisonous to sheep and chickens at normal application rates. In some orchards, most animal life in soil, including large earthworms, has been eliminated by the past extensive use of copper-containing fungicides (Extoxnet 1996). Copper has been found to suppress rates of nitrogen fixation by *Rhizobium* bacteria under some situations at relatively high copper levels of 235 ppm (OMRI 2001). Earthworms are sensitive to several heavy metals and may accumulate them in their tissues.

NATURAL ENEMIES:

Copper is a relatively non-specific bactericide and fungicide and can kill naturally occurring microorganisms on leaves as well as those that have been applied as biocontrols, including *Bacillus* sp., *Trichoderma*, and others.

EFFECT ON HUMAN HEALTH:

Acute toxicity. The oral LD50 of copper sulfate is 472 mg/kg in rats. Toxic response in humans has been observed at 11 mg/kg. Ingestion of copper sulfate is often not toxic because vomiting is automatically triggered by its irritating effect on the gastrointestinal tract. Symptoms are severe, however, if copper sulfate is retained in the stomach, as in the unconscious victim. Injury to the brain, liver, kidneys, and stomach and intestinal linings may occur in copper sulfate poisoning. Copper sulfate can be corrosive to the skin and eyes. It is readily absorbed through the skin and can produce a burning pain as well as the other symptoms of poisoning resulting from ingestion. Skin contact may result in itching or eczema. It is a skin sensitizer and can cause allergic reactions in some individuals. Eye contact with this material can cause conjunctivitis, inflammation of the eyelid lining, cornea tissue deterioration, and clouding of the cornea (Extoxnet 1996).

Copper hydroxide is less acutely toxic, with an oral LD50 in rats of 833 mg/kg. It is also not readily absorbed through the skin, with a dermal LD50 of over 5000 mg/kg in rats (Nufarm Americas Inc. 2004). Copper ocnatoate has oral and dermal LD50's of >2000 mg/kg (Certis USA, 2009)

Metabolism: Absorption of copper sulfate into the blood occurs primarily under the acidic conditions of the stomach. The mucous membrane lining of the intestines acts as a barrier to absorption of ingested copper. After ingestion, more than 99% of copper is excreted in the feces; however, residual copper is an essential trace element that is strongly bio-accumulated. It is stored primarily in the liver, brain, heart, kidney, and muscles (Extoxnet 1996).

Chronic Toxicity: Vineyard sprayers experienced liver disease after 3 to 15 years of exposure to copper sulfate solution in Bordeaux mixture. Long-term effects are more likely in individuals with Wilson's disease, a condition that causes excessive absorption and storage of copper. Chronic exposure to low levels of copper can lead to anemia. The growth of rats was retarded when given dietary doses of 25 mg/kg/day of copper sulfate. Dietary doses of 200 mg/kg/day caused starvation and death (Extoxnet1996).

Reproductive effects: Copper sulfate has been shown to cause reproductive effects in test animals. Testicular atrophy increased in birds as they were fed larger amounts of copper sulfate. Sperm production was also interrupted to varying degrees. Reproduction and fertility was affected in pregnant rats given this material on day 3 of pregnancy (Extoxnet 1996).

Teratogenic effects: There is very limited evidence about the teratogenic effects of copper sulfate.
Mutagenic effects: Copper sulfate may cause mutagenic effects at high doses. At 400 and 1000 ppm, copper sulfate caused mutations in two types of microorganisms. Such effects are not expected in humans under normal conditions (Extoxnet 1996).

Carcinogenic effects: Copper sulfate at 10 mg/kg/day caused endocrine tumors in chickens that were given the material outside of the gastrointestinal tract through an intravenous or intramuscular injection; however, the relevance of these results to mammals, including humans, is not known (Extoxnet 1996).

Organ toxicity: Long-term animal studies indicate that the testes and endocrine glands are affected (Extoxnet 1996). Heart disease occurred in the surviving offspring of pregnant hamsters given intravenous copper salts on day 8 of gestation.

EFFICACY:
Copper is labeled for use on over 100 crop plants to control fungal and bacterial diseases. Reading the label and using the product according to the labeled instructions for specific crops are very important. In general, copper is more effective against bacterial than fungal pathogens; however, it is widely used to control both bacterial and fungal diseases on tomato.

PEST SPECIFIC OBSERVATIONS
A summary of university field trials of copper hydroxide and copper sulfate products on fruit and vegetable crops commonly grown in the Northeast is compiled in Figure 1. These university-based trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. The level of pest control is likely to be higher on treated fields in which a good program of cultural controls has also been implemented.

Copper product trials demonstrated only poor results for:

- Bean—Botrytis
- Spinach—Stemphylium leaf spot; downy mildew
- Brassicas—black rot; bacterial spot; Alternaria
- Cucurbits—Phytophthora; downy mildew; anthracnose
- Lettuce—bacterial leaf spot
- Onion—purple blotch
- Tomato—anthracnose

In Figure 1, only pest species which responded to copper products at a "good" or "fair" level are included. "Good control" means statistically significant reductions in either disease severity or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

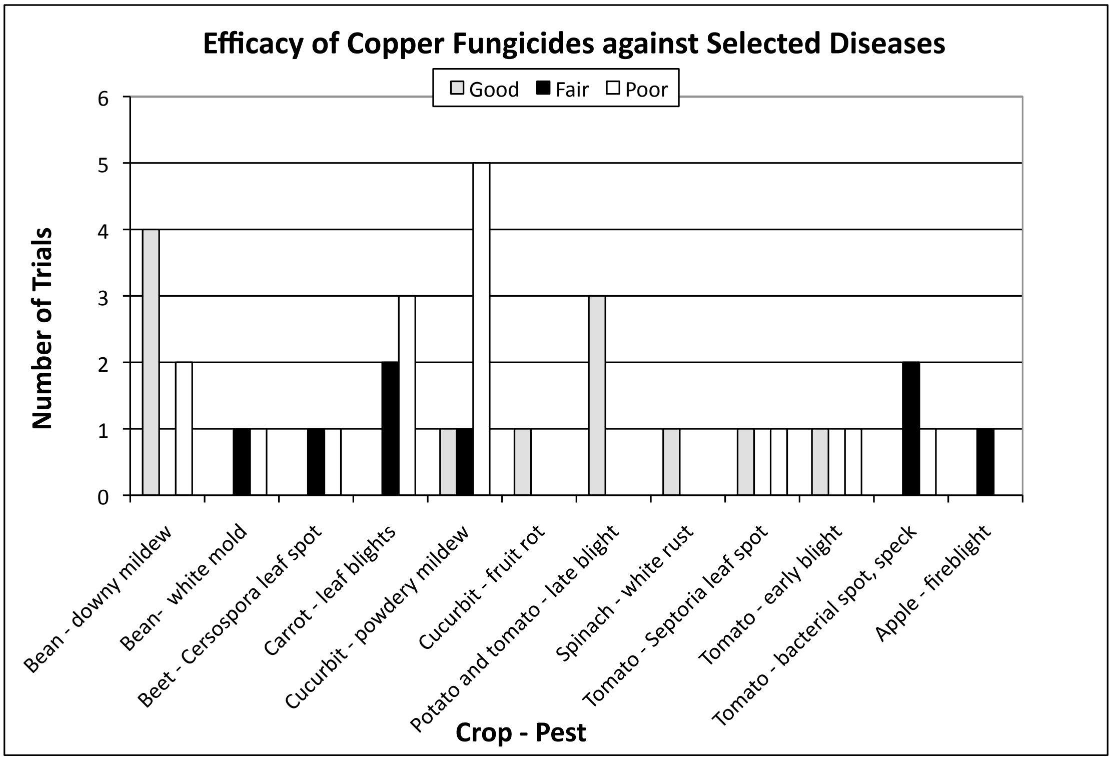

Figure 1. Efficacy of copper against diseases showing a "Fair" or "Good" response.

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MATERIAL FACT SHEET
Hydrogen Peroxide, Hydrogen Dioxide

MATERIAL NAME: Hydrogen Peroxide, Hydrogen Dioxide

MATERIAL TYPE: Inorganic chemical

U.S EPA TOXICITY CATEGORY: I, "Danger"

USDA-NOP:
Synthetic, allowed with restrictions. May be used for plant disease control or as an algaecide, disinfectant, or sanitizer if the requirements of 205.206(e) are met. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological or botanical material must be documented in the organic system plan (NOP 2000). May be used as an adjuvant or inert ingredient in passive pheromone dispensers.

MATERIAL DESCRIPTION
Hydrogen peroxide is an odorless, colorless liquid. Aqueous solutions are used at a range of concentrations for bleaching paper, fabric, hair, and food; as a disinfectant and antiseptic; and in sewage and wastewater treatment. An 80% solution is used in rocket propulsion (Patniak 2003). Products with concentrations between 27 and 33% are used for surface sterilization and plant disease management in agricultural settings. These products are diluted to concentrations between 1:100 and 1:300 for use as surface disinfectants for non-porous surfaces and for soil, plant drench, or foliar applications.

HOW IT WORKS:
Hydrogen peroxide is a strong oxidizing agent. It reacts with substances with which it comes into contact by taking electrons. Rust and fire are both oxidative processes. When living tissue or microorganisms come into contact with oxidizing agents, the cell membrane is oxidized and disrupted, causing the cell to break open and die. Hydrogen peroxide is reactive and short-lived in the environment and has no residual activity (HERA 2005).

TYPES OF PESTS IT CONTROLS
Hydrogen peroxide is a general disinfectant, killing microorganisms with which it comes into contact. Some formulations are labeled for foliar applications to plants in order to control bacterial and fungal pathogens. Product labels include a wide variety of crops and a wide variety of pests. Some formulations are labeled for use in irrigation lines to control soil-borne pathogens. Other formulations are labeled for surface disinfection of greenhouse structures, pots, benches, and tools. Some formulations are labeled for both uses.

FORMULATIONS AND APPLICATION GUIDELINES
Hydrogen peroxide is generally available as a 27%-33% concentrate liquid formulation that is diluted for foliar application and surface sterilization. It works best when diluted with water that contains low levels of organic or inorganic materials and a neutral pH. Tanks should be thoroughly rinsed with water before mixing. Hydrogen peroxide mixes readily with water with no settling.

Workers who are handling concentrate should wear protective eyewear and rubber gloves. Applicators and handlers must wear coveralls over long-sleeved shirts, long pants, socks, and chemical-resistant footwear.

Various dilution guidelines exist for different uses:

- May be used as a pre-plant dip treatment for control of damping-off, root rot, and stem rot diseases at a 1:100 dilution.

- May be used at a 1:100 dilution as a soil drench at the time of seeding or transplanting, or as a periodic treatment for control of soil-borne diseases.
- Foliar treatments for control of fungal and bacterial pathogens are applied at a 1:100 to 1:300 dilutions. Test a few plants for sensitivity before spraying an entire field.
- For disinfestation of clean, non-porous surfaces, such as pots, flats, trays, cutting tools, benches and work areas, equipment, and structures, use at a dilution of 1:100 to 1:300. Remove soil and plant debris from surfaces before application.

OMRI LISTED PRODUCTS

Di-Oxy Solv Plus (Flo-Tec, Inc.)
GreenClean Broad Spectrum Algaecide/Bactericide Liquid (BioSafe Systems)
Oxidate (BioSafe Systems)
PERpose Plus (A Growing Alternative, Inc.)
TerraClean 5.0 (BioSafe Systems)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings." after list.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL

Keep unprotected persons out of treated areas until sprays have dried.
REI: 1 hour for applications in enclosed structures.
PHI: 0 hours.

AVAILABILITY AND SOURCES

Widely available online and from agricultural chemical suppliers.

EFFECT ON THE ENVIRONMENT

The undiluted concentrate formulation of agricultural products is toxic to birds and fish. Do not contaminate ponds, streams, or other environmental water sources when disposing of wash water or rinsate. Exposed, treated seed may be hazardous to birds and other wildlife. It is also highly toxic to bees and other beneficial insects exposed to direct contact; it should not be applied or allowed to drift onto blooming crops or weeds when bees are actively foraging. Similarly, it should not be applied or allowed to drift onto crops where beneficials are part of an integrated pest management strategy. Once residues have dried, they are considered non-toxic.

EFFECT ON HUMAN HEALTH

"Hydrogen peroxide breaks down rapidly in the environment to oxygen and water and is not expected to cause adverse effects to humans or the environment when users follow label directions" (US EPA 2011). Low concentrations (3-6%) available in pharmacies may be used as an antiseptic to clean wounds and are generally harmless if used according to directions.

Higher concentrations (~30%, the concentration of undiluted disease management products) are highly corrosive and can cause irreversible damage to eyes and mucous membranes. Concentrate may be fatal if swallowed or absorbed through skin. Breathing vapor of concentrated product should be avoided.

Hydrogen peroxide degrades to oxygen and water. Once an application has dried, it is regarded as harmless.

EFFICACY

While hydrogen peroxide products are labeled for control of a wide variety of fungal and bacterial pathogens on an equally wide variety of crops, in University trials, control levels have been disappointing for most pathogens. In some cases, applications of hydrogen peroxide actually increased disease levels. These university-based trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. The level of pest control is likely to be higher on completely sprayed fields in which a good program of cultural controls has been implemented.

In Figures 1 and 2, "good control" means statistically significant disease reductions of 75% or more, compared to an untreated control. "Fair control" includes trials with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

In vegetable trials, levels of disease suppression all fell into the "poor" category (Fig. 1). In fruit, a few studies reported results in the "good" and "fair" categories in trials against blister spot, sooty blotch, fly-speck, and cedar apple rust in apple; brown rot in peach; and Anthracnose in strawberry (Fig. 2).

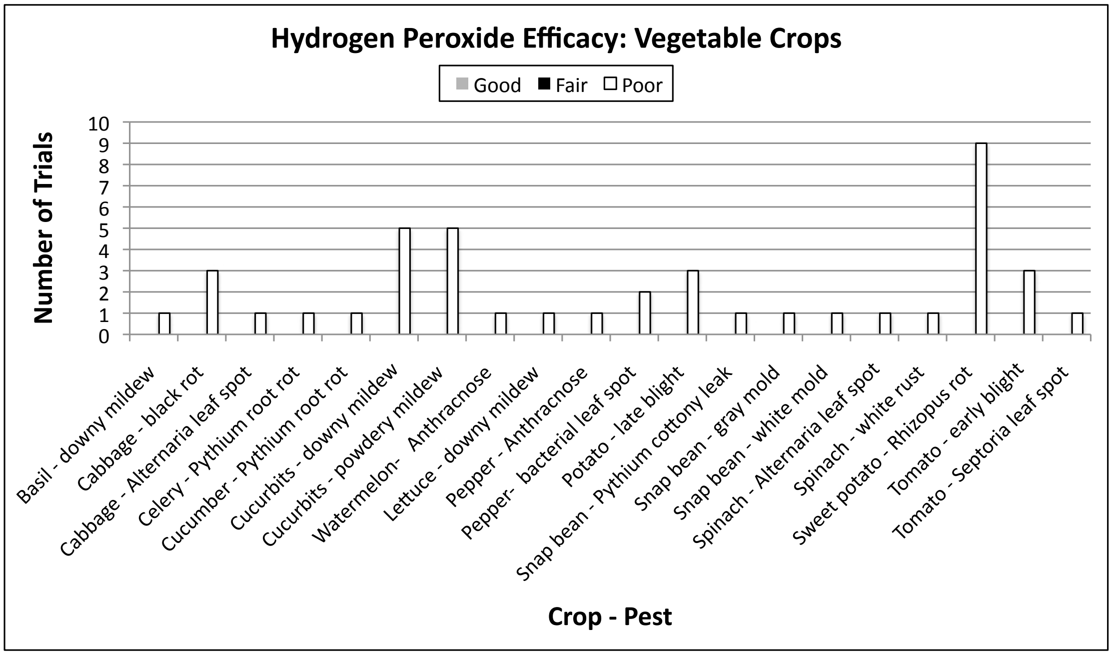

Figure 1. Efficacy of hydrogen peroxide products against diseases of vegetable crops.

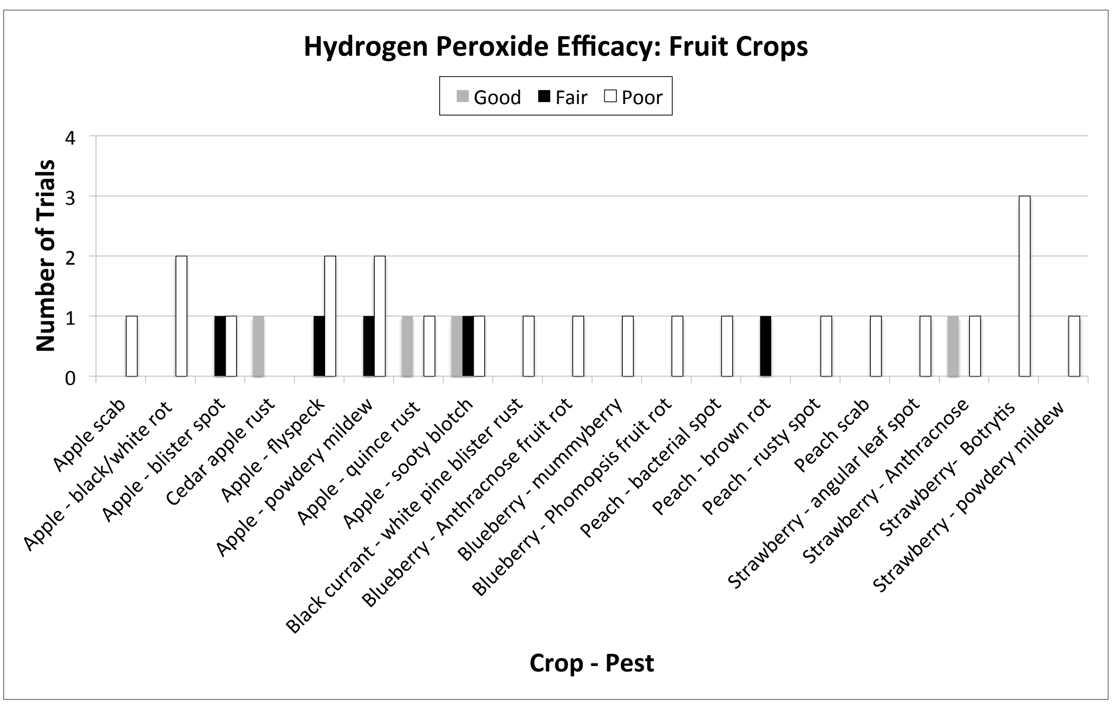

Figure 2. Efficacy of hydrogen peroxide products against diseases of fruit crops.

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MATERIAL FACT SHEET
Kaolin clay

MATERIAL NAME: Kaolin clay

MATERIAL TYPE: Mineral particle film.

U.S. EPA TOXICITY CATEGORY: Category III, "Caution"

USDA-NOP:
Considered non-synthetic, allowed. Pests may be controlled through mechanical and physical methods, including non-synthetic controls such as repellants. Diseases may be controlled through application of biological, botanical, or non-synthetic mineral inputs (NOP 2000).

ACTIVE INGREDIENT DESCRIPTION:
Kaolin is a naturally occurring clay that results from weathering of aluminous minerals, such as feldspar, with kaolinite as its principal constituent (ATTRA 2004). Kaolin is a common mineral, "generally regarded as safe" (GRAS) by the U.S. Food and Drug Administration. It is used as an anti-caking agent in processed foods and an additive to cosmetics, toiletries, and health products. It is also used as an "inert" carrier in some pesticides and enhances the performance of some microbial products (Rasad & Rangeshwaran 2000).

For application as a plant protectant, kaolin is ground and processed to reach a uniform particle size. Applied in suspension in water, kaolin produces a dry white film layer of interlocking, microscopic particles on the surface of leaves, stems, and fruit after evaporation of the water.

HOW IT WORKS:
This material has several modes of activity (Stanley 1998). Kaolin acts as a physical barrier, preventing insects from reaching vulnerable plant tissue, and it acts as a repellent by creating an unsuitable surface for feeding or egg-laying. The uniform white film may also disrupt the insect's host-finding capability by masking the color of the plant tissue. Furthermore, particles of kaolin act as an irritant to the insect. After landing on a treated surface, particles of kaolin break off and attach to the insect's body, triggering an excessive grooming response that distracts the pest.

Kaolin formulations have also been shown to suppress diseases in greenhouse and field studies (Haggag 2002; Puterka et al. 2000; Glenn et al. 1999) and to kill insects in stored grain (Mostafa and Al Moajel 1991). Labeled products for these purposes are not currently available in the US. The use of Surround (a trade name for kaolin clay) can increase overall fruit yields in regions with high light and temperature levels (Puterka et al. 2000). In these situations, it can act as an anti-transpirant, reducing stress on the plant.

Surround has caused both yield increases and decreases in vegetable trials (Maletta, personal communication). In eggplant, it reduced marketable yields and plant growth, while in potato it increased yields of 'Superior' but not 'Norland' variety, even though it had no effect on potato leafhopper levels.

FORMULATION AND APPLICATION GUIDELINES:
Kaolin clay is available as a wettable powder to be mixed with water. Application can be made with most commercially available spray equipment, but large amounts of water are required. To prevent caking, it is suggested that the material either be added during mechanical agitation or to first completely mix the necessary amount in a small amount of water before filling up the tank to the recommended volume. It may be tank mixed with soaps and most pesticides,

but not copper, sulfur, or Bordeaux mixtures. Precipitation, curdling, uneven film formation, or changes in viscosity are signs of incompatibility (Engelhard 2001). Check nozzles frequently because they can become clogged when spraying or damaged by the abrasion of the mineral. In order to keep the material suspended in water, periodic shaking is recommended for a backpack sprayer, or for larger equipment, use of an automatic agitation mechanism is suggested. Efficacy is only achieved with thorough coverage. Care should be taken to cover the entire surface of the crop, and reapplication is needed after rainfall and during rapid plant growth.

Hydraulic sprayers at full dilution apply a better coverage than mist blowers with concentrated sprays.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI):
Four hour REI. May be applied up to the day of harvest.

AVAILABILITY AND SOURCES:
Kaolin clay is available from several mail-order suppliers as well as regional agricultural chemical suppliers in fruit regions.

OMRI LISTED PRODUCTS:

Surround WP, Engelhard Corporation.

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

CONCERNS:
The white film, while non-toxic, may reduce marketability if not removed. It can be wiped or brushed and washed off after harvest. To avoid this post-harvest task, applications can be discontinued earlier to allow for natural weathering of the material. Care should be taken to protect workers from the dust generated during mixing and application.

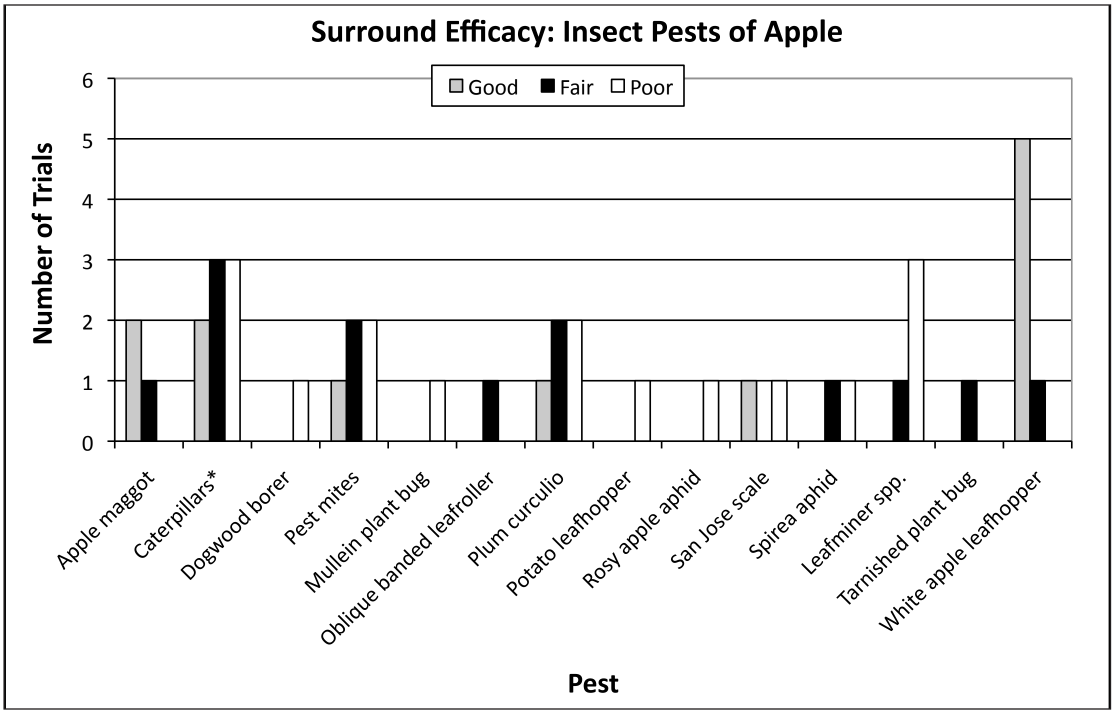
EFFECT ON THE ENVIRONMENT:
Effects of kaolin clay on the environment have not been assessed. Soil effects are likely to be similar to natural kaolin clay in the soil. Since Surround is applied at high concentrations, beneficial insects that come into contact with the direct spray would likely be affected, but to a lesser extent once the material dries on the plant.

EFFECT ON HUMAN HEALTH:
Inhalation of dust can cause lung damage. Use a respirator when handling. The LD50 is above 5000 mg/kg (Engelhard Corp 2003).

TYPES OF PESTS IT CONTROLS:
Surround has been shown to be effective against several orchard pests, including apple maggot, white apple leafhopper, and pear psylla (Heacox 1999). It generally gives at least fair control of plum curculio and several species of fruit pest caterpillars (codling moth, oriental fruit moth, tufted apple bud moth, lesser appleworm). However, university trials also show that heavy use is harmful to beneficial species and can lead to a flare up of European red mites or San Jose scale.

Surround has shown potential against pepper weevil, cabbage aphid, and onion thrips on vegetables in field trials, though more research is needed. In a lab trial against onion thrips, Surround significantly reduced oviposition and hatch rate, increased larval mortality, and decreased feeding (Larentzaki et al. 2008). In a corresponding field study, Surround delayed colonization on plants (Larentzaki et al. 2008). It has been effective against flea beetles in the lab but has not had as much success in the field. It has shown some repellancy against the silverleaf whitefly in the lab (Liang and Liu 2002). Surround has shown inconsistent results against the striped cucumber beetle in field trials; however, it was applied on a weekly basis in these trials. Some growers have reported better results against the cucumber beetle when Surround is used twice weekly when plants are small and more susceptible to damage from this pest.

An experimental kaolin product has also given good control of grape and cucurbit powdery mildew and brown rot in peaches in controlled trials. This product is not currently available commercially.



*Codling moth, oriental fruit moth, tufted apple bud moth, lesser appleworm

Figure 1. Efficacy of Surround against insect pests of apple.

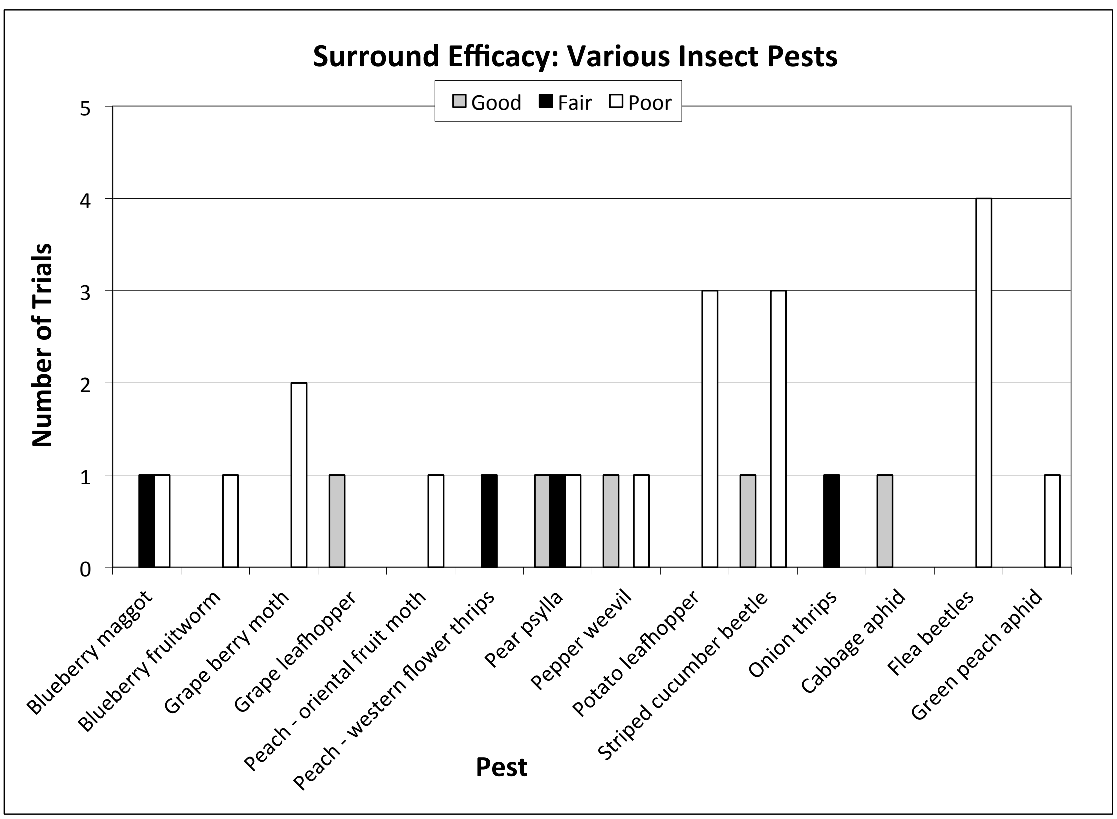


Figure 2. Efficacy of Surround against insect pests of crops other than apple.

A summary of recent university field trials of Surround on fruit and vegetable crops commonly grown in the Northeast is compiled in Figures 1 and 2. Note that university-based trials typically test products with untreated buffer rows and other conditions that may create unusually severe pest pressure.

In Figures 1 and 2, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

The level of pest control obtainable on completely treated fields in which a good program of cultural controls has also been implemented is likely to be higher than shown below, especially for a product like Surround, which acts as a repellant or host disguise.

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MATERIAL FACT SHEET
Neem (azadirachtin, neem oil, neem oil soap)

MATERIAL NAME: Neem (azadirachtin, neem oil, neem oil soap)

MATERIAL TYPE: Botanical

U.S. EPA TOXICITY CATEGORY: III, "Caution" (Neemix carries a "Warning" signal word)

USDA-NOP:
Considered a non-synthetic, botanical pesticide; its use is regulated. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION:
Neem products are derived from the neem tree, *Azadiracta indica*. The neem tree is native to southern Asia and can grow in most arid, sub-tropical, and tropical areas of the world (Copping 2001). Called Sarva Roga Nirvani, a "cure of all ailments" in Sanskrit, neem has been used for centuries for medical, cosmetic, and pesticidal purposes. Although Indian scientists were researching the use of neem as early as the 1920s, there was little global attention until a German entomologist noticed, in 1959, that neem trees in the Sudan resisted an attack of migratory locusts. Since that time, there has been considerable research and commercialization of neem products (Ruckin 1992).

Neem pesticide products are usually made by crushing neem tree seeds, and then using water or a solvent, such as alcohol, to extract the pesticidal constituents. Other products are made from cold-pressed neem seed oil or from further processed neem oil. Neem products produced with different extraction techniques may result in different biologically active chemicals (or amounts of chemicals) in a product; thus, the efficacy of different products can be highly variable. Neem cake is the residual seed meal remaining after extraction of oil from seeds; it is often sold as a fertilizer product.

Neem products can be grouped into two classes:
Azadirachtin-based products
Includes AZA-Direct, Azatrol, Neemix.

Neem oil products
Trilogy (also packaged as Triact, Green Light Neem Concentrate, and Green Light Rose Defense) is neem oil that has had the azadirachtin and at least some other components separated from it. It is called "clarified hydrophobic extract of neem oil." One hundred percent cold pressed neem oil is also being sold as a "plant wash," but has no pesticide label.

HOW IT WORKS:
Pesticide active ingredients are based on neem seed extracts, including azadirachtin, neem oil, and neem oil soap. Azadirachtin, one of the more than 70 compounds produced by the neem tree, acts mainly as an insect growth regulator, but also has anti-feedant and oviposition (egg-laying) deterrent properties. First isolated in 1968, azadirachtin is thought to be the most bioactive ingredient found in the neem tree; however, such speculation may be due to it having been investigated more thoroughly then the other compounds (Thacker 2002; Quarles 1994). Most commercially available neem products list azadirachtin as the primary active ingredient. Such products are broad-spectrum insecticides, which work by contact or ingestion. As an insect growth regulator, azadirachtin prevents insects from molting by inhibiting production of ecdysone, an insect hormone. Azadirachtin is chemically similar to ecdysonlids, the hormones responsible for triggering molts (Weinzierl & Henn 1991). As an anti-feedant, after ingestion, it

may cause an insect to stop feeding due to secondary physiological effects. As an egg-laying deterrent, volatile compounds from neem may repel some insects from depositing eggs on a plant surface.

There is evidence that other compounds found in neem have insecticidal attributes that contribute to a given product's efficacy. A study conducted at Washington State University, in conjunction with the W.R. Grace and Company (manufacturers of the neem product Margosan-O at the time), found that products containing both azadirachtin and neem oil have greater efficacy in controlling aphids than either ingredient alone (Stark & Walter 1995). They hypothesize that neem oil may help spread the chemicals on both plant and insect surfaces and allow them to penetrate into the insect more effectively. Neem seed oil is formulated and used somewhat like other horticultural oils and controls some foliar diseases as well as certain insects and mites. The oil is also made into an insecticidal soap, which probably acts similarly to other insecticidal soaps by disrupting insect membranes (see Soap chapter). At this time, there are no known OMRI-listed neem/soap products.

The mechanisms for neem's effects on mites (Miller & Uetz 1998), snails (Mostafa & Abdel-Megeed 1996), and disease organisms (EPA) have not been reported.

Active neem constituents can be absorbed through plant roots and systemically move upward through the plant in xylem tissues (Gill & Lewis 1971; Larew 1988; Nisbet et al. 1993; Osman & Port 1990). This uptake works best when sufficient quantities are applied to the root zone. Systemic effects are much less apparent from foliar sprays and may differ widely depending on plant species. Neem constituents last much longer within the plant than when sprayed on the leaves. Over time, however, they become diluted by plant growth.

APPLICATION GUIDELINES:
Neem products are generally sold as emulsifiable concentrates (EC). While Copping (2001) reports no known incompatibilities with other crop protection agents, phytotoxicity may be a problem when combining neem oil or soap products. Read labels for specific application guidelines including determination of re-entry interval (REI) and pre-harvest interval (PHI). Range of efficacy will depend on the susceptibility of species in question and environmental conditions at time of application; however, there are several other considerations for improving the efficacy of this product:

1. Make multiple applications. Frequent applications are more effective than single sprays because neem does not persist well on plant surfaces. Like most other botanically derived materials, it can be rapidly broken down by sunlight and washed away by rain (Thacker 2002).
2. Use against immature insects. Azadirachtin-based insecticides act on immature stages of insects more effectively than on eggs or adults. To avoid a build-up of pest populations, it is important to target insects in an early stage of their life cycle. For instance, neem would likely have little effect on an infestation of striped cucumber beetle adults; however, when applied to potato plants early in the season, it has been shown to greatly reduce larval activity of Colorado potato beetle.
3. Begin applications before pest levels are high. Anti-feedant and egg-laying repellant effects show best results in low to moderate pest populations.
4. Neem is reported to work best under warm temperatures (Schmutterer 1990).
5. Neem's systemic properties suggest that applying it to transplants just before planting to the field could be an effective and inexpensive way to control certain pests. Similarly, applying neem with relatively large amounts of water, in directed sprays over the rows of small seedlings, could be a very efficient method of application. In one study, neem applied through a drip irrigation system significantly reduced lettuce aphids on romaine by over 50% (Palumbo et al. 2001).

AVAILABILITY AND SOURCES:
Widely available from garden and farm supply mail order companies.

OMRI LISTED (This is a partial list. Check http://www.omri.org for many more):
Azadirachtin-based

- AZA-Direct (Gowan Company, USA)
- Azatrol (PBI Gordon, USA)
- Azera Insecticide (also contains pyrethrum) (MGK Co.)
- Concern Garden Defense Multi-Purpose Spray (Woodstream Corp.)
- Neemix 4.5 Botanical Agricultural Insecticide/Insect Growth Regulator (Certis USA)
- Safer Brand End All Insect Killer (Woodstream Corp, Can.)
- Safer Brand BioNEEM Multi-Purpose Insecticide and Repellent Concentrate (Woodstream Corp.)

Neem Oil

- Triact 70 Fungicide/Miticide/Insecticide (Certis,USA)
- Trilogy Fungicide/Miticide/Insecticide (Certis USA)
- Green Light Neem Concentrate (Green Light Co., USA)
- Green Light Rose Defense Concentrate (Green Light Co., USA)
- Green Light Rose Defense Ready-To -Use (Green Light Co.)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

EFFECTS ON THE ENVIRONMENT AND HUMAN HEALTH

Environmental fate: Azadirachtin reportedly breaks down within 100 hours in water or light. It is relatively immobile in soil (Martineau 1994).

Wildlife: Azadirachtin is considered relatively non-toxic. Rat oral LD50 of azadirachtin is >5000 mg/kg. However, cold-water extract of fresh neem leaves caused mortality in guinea pigs and rabbits after four weeks of feeding trials. This extract produced reversible infertility in rats and mice after six weeks (Extoxnet). Azadirachtin is not likely to accumulate or cause long-term effects (Miller & Uetz 1998). Fish toxicity is moderate, and azadirachtin is not expected to kill fish under normal use.

Natural enemies: Azadirachtin is considered relatively safe to adult beneficials. It is reported to be relatively harmless to bees, spiders, ladybeetles, parasitoid wasps, and adult butterflies. Product labels advise not to apply when honeybees are actively foraging (EPA). In a few trials, negative effects have been noted on immature stages of beneficial species exposed to neem (Qi et al. 2001; Banken & Stark 1997). However, neem products are generally thought to be suitable for inclusion into integrated pest management programs (Lowery & Isman 1994; Ruckin 1992).

Other non-target organisms: Considered to be generally non-toxic. Neem leaves added to the soil increased earthworm weight and survival (Extoxnet); however, the effects of neem on many non-target organisms have not been studied.

Effects on human health: Studies of azadirachtin mutagenicity and acute toxicity have shown that it likely does not pose a significant risk to human health. However, some people have exhibited skin and mucous membrane irritation from neem seed dust (Weinzierl & Henn 1991). Note that most studies have been done on azadirachtin and may not show the effects of a whole neem product. Neem is used in some commercial human hygiene products.

EFFICACY

AZADIRACHTIN-BASED PRODUCTS

Neem extracts have been shown to affect over 200 insect species, including some species of whiteflies, thrips, leafminers, caterpillars, aphids, scales, beetles, true bugs, and mealybugs (Thacker 2002; Copping 2001). Although neem products are labeled for many species, efficacy against them varies greatly.

Besides insects, other pests, including mites (Miller & Uetz.1998; Smitley & Davis 2000) and snails (Mostafa & Abdel-Megeed 1996), have been reported to be susceptible to neem.

A summary of field neem efficacy trials on vegetables and fruit commonly grown in the Northeast is compiled below. These university-based trials typically test products with untreated buffer rows and other conditions that may create unusually severe pest pressure. The level of pest control is likely to be higher when good programs of cultural controls and other sound pest management tactics have been implemented.

In the figures below, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

Vegetable arthropod pests (Fig. 1):
Beetles (Coleoptera): Fair to good control has been obtained against Colorado potato beetle and Mexican bean beetle. The few published studies on flea beetles show poor to fair efficacy. Results have been mostly poor against pepper weevil.

Caterpillars (Lepidoptera): Neem gives fair control of most caterpillars. Good results have been obtained against beet armyworm, cabbage looper, and diamondback moths.

Thrips (Thysanoptera): Efficacy has mostly been poor, with one fair result, against onion thrips.

Aphids (Homoptera): Generally good control has been observed, except for fair control against green peach aphid.

True bugs (Hemiptera): Promising results against squash bug. Fair control of stink bugs was demonstrated in two trials.

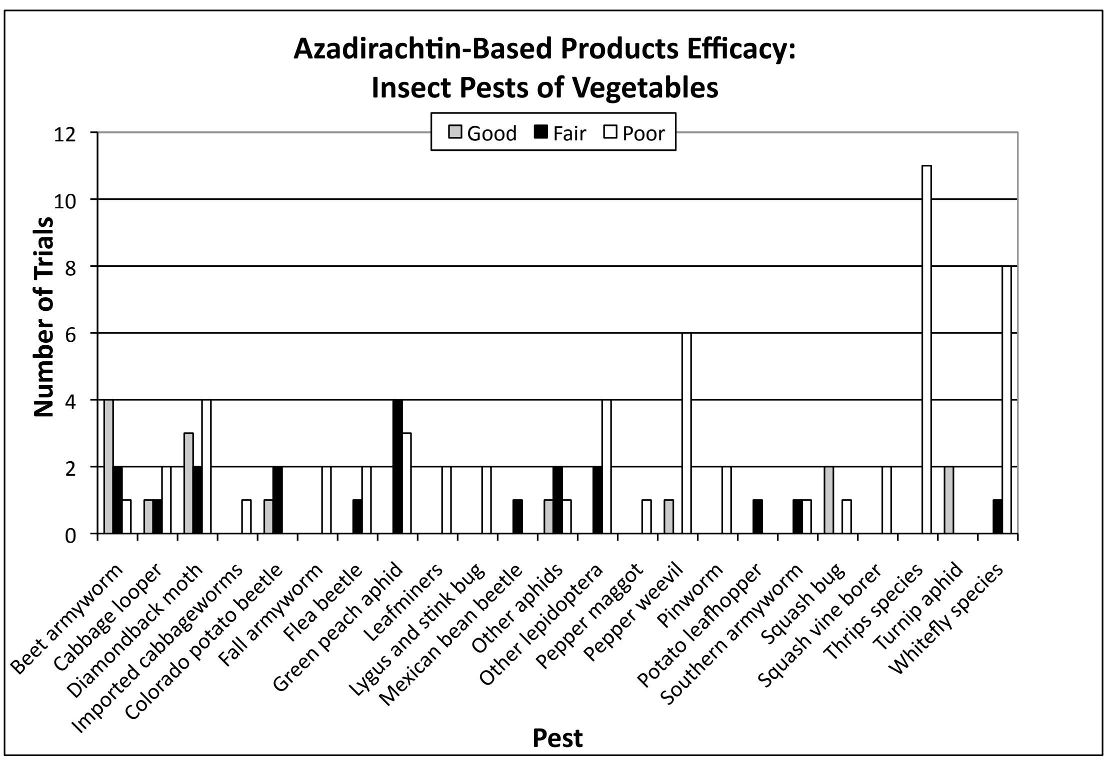

Figure 1. Efficacy of azadirachtin-based products against insect pests of vegetable crops.

Other: There is one study showing fair control of potato leafhopper. Results have generally been poor against whiteflies, pepper maggots, and psyllids.

Azadirachtin-based neem products showed good results against beet armyworm and aphids (less so vs. green peach aphid). Less reliable results were obtained against squash bug, diamondback moth, Colorado potato beetle, flea beetle, and Southern armyworm. No neem products were effective against pepper maggot, squash vine borer, thrips, or whiteflies (Figure 1). Products tested include Align, Amvac Aza, AZA-Direct, Azatin, Azatin XL, Fortune Aza, NeemAzal T/S, Neemix .25, and Neemix 4.5.

FRUIT CROPS

On fruit crops (Fig. 2), neem products have shown good results against: aphids, including rosy apple aphid and wooly apple aphid; tarnished plant bug; leafhoppers, including eastern grape leafhopper and rose leafhopper; and spotted tentiform leafminer. Results have been mixed against white apple leafhopper, the apple lepidopteran complex, and mites, while those against beetles, flies, blueberry caterpillars, psyllids, and scale have been poor.

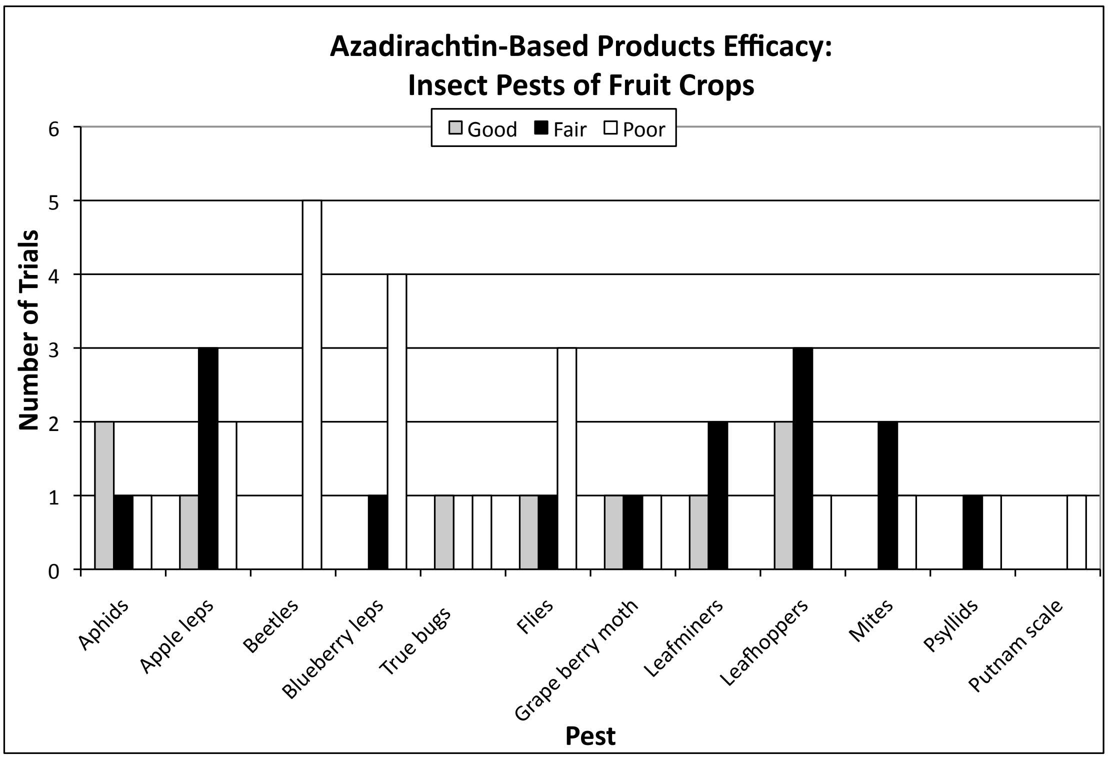

Figure 2. Efficacy of azadirachtin-based products against insect pests of fruit crops.

GREENHOUSE APPLICATIONS

Neem has good potential for greenhouse use. Although relatively few research trials have been conducted, some reports indicate good to excellent results against leafminers, mealybugs, aphids, mites, flies, fungus gnats larvae, and whiteflies (Fig. 3). Often these results have been obtained with only one application. There is generally a three to seven day delay after application until maximum effect. As with most pesticides, efficacy will be improved with better spray coverage. Results have been variable according to the plant species treated, but good results have been obtained on chrysanthemum, coleus, marigold, pansy, wandering Jew, German ivy, and poinsettia. Poor control with neem in greenhouses has been noted against mealybugs on jade plant and black vine weevils on strawberries. Performance has been mixed against psyllids on tomatoes.

More research is needed in this area, but there is clearly good potential for successful use of neem products against commercial greenhouse pests.

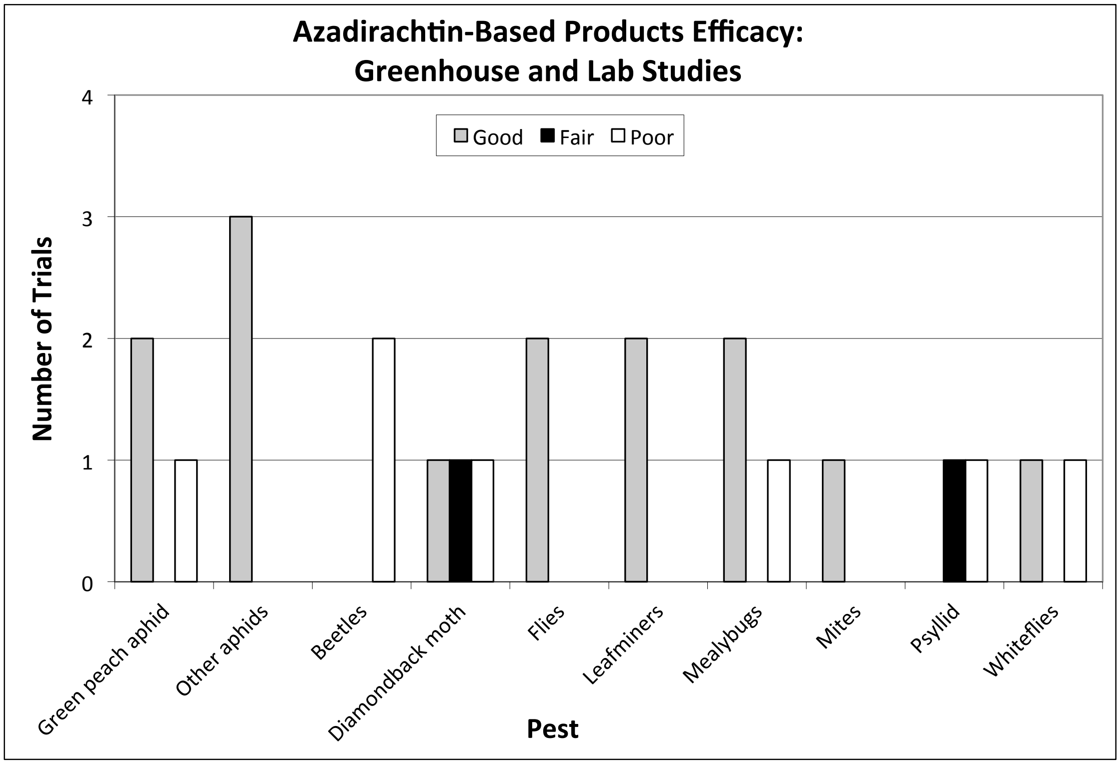

Figure 3. Efficacy of azadirachtin-based products in greenhouse and laboratory trials.

NEEM OIL PRODUCTS

Neem oil is the active ingredient in the products labeled as Trilogy (for food crops) and Triact (greenhouse and ornamentals). They have both insecticidal and fungicidal properties. Figure 4 summarizes results from outdoor food-crop field trials for these

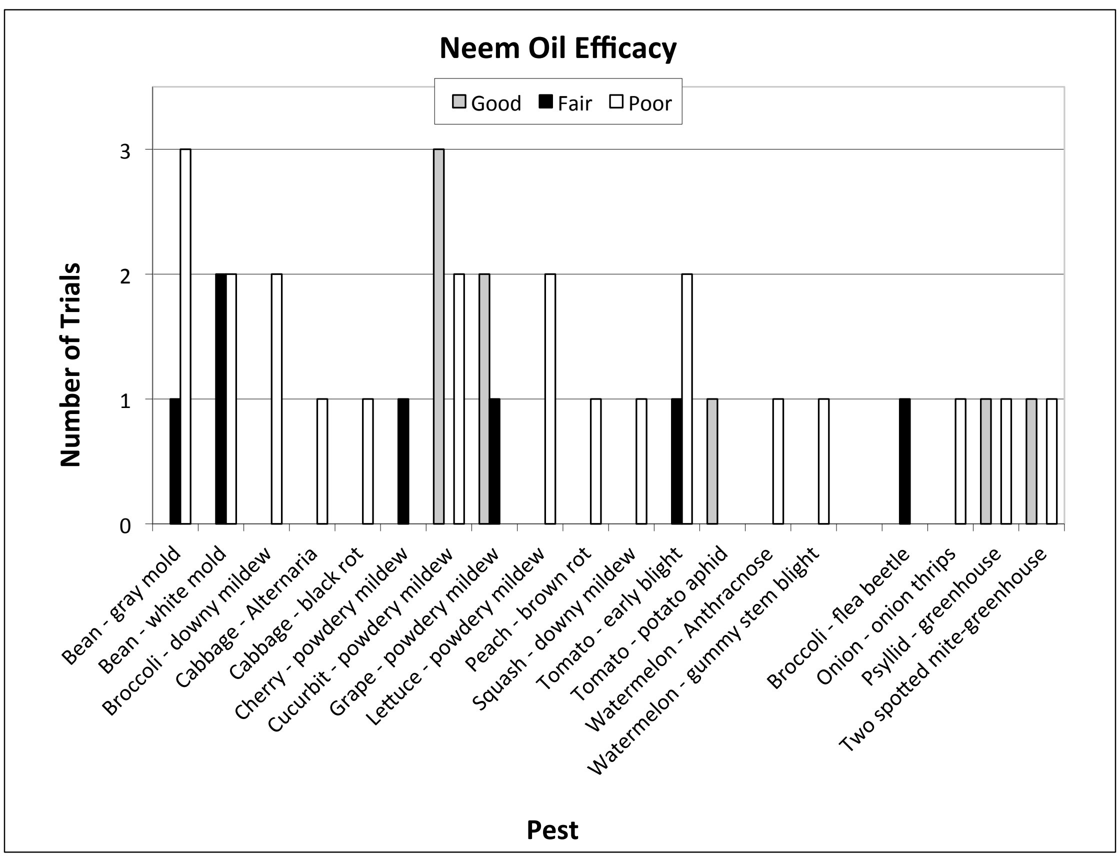

Figure 4. Efficacy of neem oil based products against plant diseases and selected arthropods.

products. Best results were obtained against powdery mildew in cucurbits and grapes. All powdery mildew studies with good control used multiple applications, from three to ten times per season. The positive gray mold study used 2 applications. The oil products were also promising against some insect and mite pests.

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MATERIAL FACT SHEET
Oils

MATERIAL NAME: Oils

ACTIVE INGREDIENT NAME: Petroleum (mineral), fish, plant, and essential oils. See the Neem chapter of this guide for information on neem oil.

ACTIVE INGREDIENT TYPE: Synthetic and natural oils

U.S. EPA TOXICITY CATEGORY: III, "Caution"

USDA-NOP:
Certain fractions of petroleum oils (narrow range oils) are considered synthetic and allowed for insect, mite, and disease control. "Narrow-range oils" are highly refined petroleum oils with a median boiling point from 415-440 °F under controlled vacuum conditions. They are allowed for both dormant and growing season uses for insect or disease control. Allowed oils can also be derived from vegetable and fish sources. Approved products may not contain any prohibited inert components. Preventive, cultural, mechanical, and physical methods must be the first choice for pest control, and conditions for use of a botanical or synthetic material permitted on the National List must be documented in the organic system plan (NOP 2000).

ACTIVE INGREDIENT DESCRIPTION:
Three types of related oil products are discussed here. Petroleum oils (sometimes called mineral oils) have a long history in crop protection. The first recorded use of oils for pest control was in 1865, when a petroleum distillate (kerosene) was used against scale insects on orange (Agnello 2002). In the 1990's, the availability of highly refined, lighter weight, higher purity oils with sunscreens to reduce phytotoxicity extended the use of mineral oil products to control pests on crops in full foliage. These are often referred to as "summer weight oils" or "light weight horticultural oils." There are well-defined standards for the composition, phytotoxicity, and pesticidal activity of petroleum oils (Agnello 2002).

Petroleum oils are derived from crude oil, which is separated into fractions by heat in a distillation tower. Different fractions are composed of hydrocarbons of various weights, structures, and boiling points, and each fraction may have different pesticidal properties. The term "narrow range oils" refers to the fact that these approved spray oils are highly refined and relatively homogeneous. The range of boiling points for their constituents is relatively narrow. It is measured as the 10 to 90 percent distillation range (the measurements at which 10 percent and 90 percent of the oil has distilled). Spray oils should have a 10 to 90 percent distillation range of 80°F or less. The narrower this distillation range, the more predictably the spray oil will perform on pests and plants (Whitmire n.d). Oils with median boiling points (i.e., the distillation midpoint or the point at which 50 percent of the oil has distilled) of 415-440 °F are not phytotoxic, yet persist long enough to smother pests. Oils with a high percentage of constituents whose boiling points are above 455 °F tend to be phytotoxic (Davidson et al. 1991). Spray oils with midpoints below 400 °F have poor pesticidal activity. Petroleum oils are variable depending on the geographic source of the oil.

Plant and fish oils are chemically classified as lipids, containing long-chain hydrocarbons (Sams & Deyton 2002). Lipids include fatty acids, some alcohols, glycerides, and sterols. The chemical and physical properties of plant- and fish-derived spray oils are determined largely by the structure of the fatty acids. The fatty acids most commonly found in plant oils are palmitic, steric, linoleic and oleic acids (Sams & Deyton 2002). Plant oils are primarily derived from seeds (e.g., soy and canola), while fish oils are by-products of the fish processing industry. Although there is interest in using botanical and fish oils as pesticides, one of the factors limiting their use is the variability in oil composition and the absence of well-defined standards for pesticidal usage (Sams & Deyton 2002).

Another category of products currently available includes mixtures of essential plant oils, such as wintergreen, clove, and rosemary. These are generally pressed from leaves, stems, or flowers, rather than seeds, and then separated by distillation. They may be formulated with mineral oil in products labeled for insect, disease, and weed control. Some are exempt from EPA labeling requirements (see Appendix F).

HOW THEY WORK:
Petroleum oils are widely used to control the egg stage of various mites and insects by preventing the normal exchange of gases through the egg surface or interfering with the egg structure. When used against other stages of insects and mites, oils can block the respiratory system, causing suffocation or breakdown of the outside tissue (cuticle) of the insect or mite. Secondary toxicity mechanisms include penetrating and degrading arthropod tissues and fumigant effects of volatile oil components (Taverner 2002). Oils may also repel some pests (Stansly et al. 2002). Whether plant and fish-derived oils have similar modes of action is unclear. Oils derived from all sources may also alter the behavior of insects and mites, causing them to avoid laying eggs or disrupting their feeding. Additional work is needed in this area to determine which fractions may cause this behavior and to what extent such changes in behavior may affect pest management.

Besides direct control of insects and mites, oils may also provide some control of insect-vectored plant viruses. Stylet oils are derived from petroleum and, when sprayed on plants, inhibit the ability of aphids to acquire a non-persistently transmitted virus from infected plants and transmit it to other plants (Davidson et al. 1991). Scientists believe that oils interfere with the retention of virus organisms on insect stylets (Wang & Pirone 1996).

Both petroleum and plant oils suppress some fungal diseases, especially powdery mildew. While the mechanism is not clear, it may involve disruption of fungal membranes or interference with spore attachment or germination. Oils may also increase host plant resistance response (Northover & Timmer 2002).

Oils are often added to other pesticide products to improve efficacy. In this sense, they are considered spray adjuvants, even though they may have pesticidal activity on their own.

An application of fish oil can be used as a fruit thinner in organic fruit production, sometimes in conjunction with lime sulfur. Evidently, it works by suppressing photosynthesis, indicating that crop yield should be examined in studies of fish oil and other oil products. Mineral and soybean oils have been shown to delay bloom and thin the crop in peaches, most likely by suppressing respiration (Sams et al. 2002).

Essential oils have a different mode of action. They are volatile oils found in some plants that have strong aromatic components and give distinctive flavor or scent to the plant. Typically, they are liquid at room temperature and transform to a gaseous state at slightly higher temperatures. Against arthropods (i.e., insects and mites), essential oils may be repellents or induce other behavioral modifications. Research indicates that the rapid action of some oils against certain pests is indicative of a neurotoxic mode of action (Koul et al. 2008). The mechanism of action against fungal pathogens is unknown, but may be related to essential oil's general ability to disrupt the integrity of cell walls and membranes (Koul et al. 2008). Essential oil products are generally mixtures of two or more essential oils, often including rosemary, peppermint, clove, or thyme oils. Essential oils are also formulated as burn-down herbicides, which will not be discussed here.

TYPES OF PESTS IT CONTROLS:
Oil products can control a wide range of soft-bodied insects, such as aphids, mites, thrips, whiteflies, mealybugs, and psyllids. In the 1940's, highly refined "white" oils were widely used

to control corn earworm (Barber 1944). The "Zea-later" is a tool marketed for applying a mix of plant oil and Bt directly into the silk channel of corn to control the corn earworm (Hazzard & Westgate 2004). As a fungicide, oils are primarily effective against powdery mildews.

Sams and Deyton (2002) state that oils are "the only widely used class of pesticides to which insects or mites have not developed resistance."

FORMULATION AND APPLICATION GUIDELINES:
Pure oils need emulsifiers to stay in suspension when they are mixed with water. Most oil products have an emulsifier already added. Detergents or surfactants may also be added to oil sprays or incorporated into oil products; while these ingredients may show some pest control efficacy themselves, they are usually considered to be inert adjuvants (Stansly et al. 2002). Good coverage is important. Several applications may be needed for full control of some pests.

Phytotoxicity can be a problem; it can show up as visible leaf damage or, more subtly, as yield reduction. In one study, while bi-weekly oil applications reduced whitefly counts on tomato leaves by two thirds, yield on the oil-treated plants was also reduced compared to untreated plants (Stansly et al. 2002). In another case, five oil sprays controlled powdery mildew in grapes, but sugar levels were reduced (Northover 2002).

Follow label recommendations to minimize phytotoxicity. Oils that evaporate very slowly have higher chances of phytotoxicity. For this reason, oil applications are not recommended on very humid days. Some crop varieties may be extra-sensitive. Oils are incompatible with sulfur and copper on some crops.

In order to avoid phytotoxicity on apples, VanBuskirk et al. (2002) recommend:
• Use oil in a dilute application (with a minimum of 200 gallons/acre on apples).
• Do not exceed an oil concentration of 1% (volume to volume).
• Do not apply when temperatures exceed 80 degrees F.
• Avoid large droplets.
• Ensure good tank agitation.
• Make sure oil is completely emulsified.

An oil product that makes a pesticide claim must be a registered pesticide, or in the case of certain essential oils, it may qualify as a pesticide that is exempt from registration. Other oil products are sold as stand-alone adjuvants, for use in tank mixes with registered pesticide products. Adjuvants do not have to be registered with the EPA, though a few states require registration. Be sure to follow label instructions in all cases.

OMRI LISTED PRODUCTS (This is a partial list. Check http://www.omri.org for many more):
Petroleum oils:

Organic JMS Stylet Oil (JMS Flower Farms, Inc.)
PureSpray Green (Petro Canada)
SuffOil-X (BioWorks, Inc.)

Plant oils:

GC-3, (JH Biotech, Inc.)
Eco E-rase (IJO Products, LLC)
Golden Pest Spray Oil (Stoller Enterprises)
Green Cypress Organic Spreader (Monterey Chemical, Co.)
Natur'l Oil (adjuvant) (Stoller Enterprises)
Pest Out (JH Biotech, Inc.)
Vegol (W Neudorff GmbH KG)

Fish based oils

Oleum Fish Oil (Alimentos Concentrados California SA de CV)
Organocide (Organic Laboratories, Inc)
SeaCide (Omega Protein, Inc)

Essential Oils

Ecotec (Brandt Consolidated, Inc.)
Ecotec G (Brandt Consolidated, Inc.)
Ed Rosenthal's Zero Tolerance Herbal Pesticide Concentrate (Quick Trading Company)
Ed Rosenthal's Zero Tolerance Herbal Pesticide Ready to Use (Quick Trading Company)
Sporatec (Brandt Consolidated, Inc.)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI):
Stylet Oil: REI is 4 hours; pre-harvest interval is 0 hours;
Golden Pest Spray oil (soy bean oil): REI 12 hrs.

Essential oil products that are currently on the market are generally exempt from EPA registration under FIFRA 25(b) and are exempt from REI and PHI requirements.

EFFECTS ON THE ENVIRONMENT:
Petroleum oils used on plants are lightweight and generally evaporate quickly. The environmental effects of oil vapors are not known. Oils have negligible ability to contaminate soil or groundwater. Plant and fish oils are not as volatile, but are broken down quickly by microbes on leaf surfaces and in the soil. They are unlikely to have any effect on wildlife or other non-target species (Ebbon 2002).

EFFECT ON NATURAL ENEMIES:
Oils can kill beneficial mites and cause flare-ups in pest mite populations, as shown in one grape field study (Walsh et al. 2000). Oils are unlikely to have a major effect on most beneficial species unless they are exposed to direct sprays. Eggs and immatures are generally more susceptible to oil than adults.

EFFECTS ON HUMAN HEALTH:
Measurable oil residues from field spraying are unlikely to remain on crops at time of harvest, so consumer exposure risk is very small. Most oils are of low toxicity to workers who are mixing sprays.

EFFICACY:
Oils have a long history of effective use on fruit trees, but they have not been used as extensively in vegetables and other crops. Oils are generally used against mite and scale pests, particularly in dormant sprays on fruit crops; however, lightweight horticultural oils can also be used on fruit during the season with little, if any, phytotoxic damage.

The addition of oil products likely improves the efficacy of other organically approved pesticides, though product combinations are not included in this review. For instance, combining oil and potassium bicarbonate is thought to produce better anti-fungal results than either substance alone.

A database of university trials of oil products was compiled for this fact sheet. University-based trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. The level of pest control is likely to be higher on fields in which a good program of cultural controls has been implemented.

In the figures below, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74% and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

For this fact sheet, efficacy data for individual species have been combined into groupings, such as caterpillars, beetles, and true bugs (Hemiptera). Pesticide efficacy can vary based on

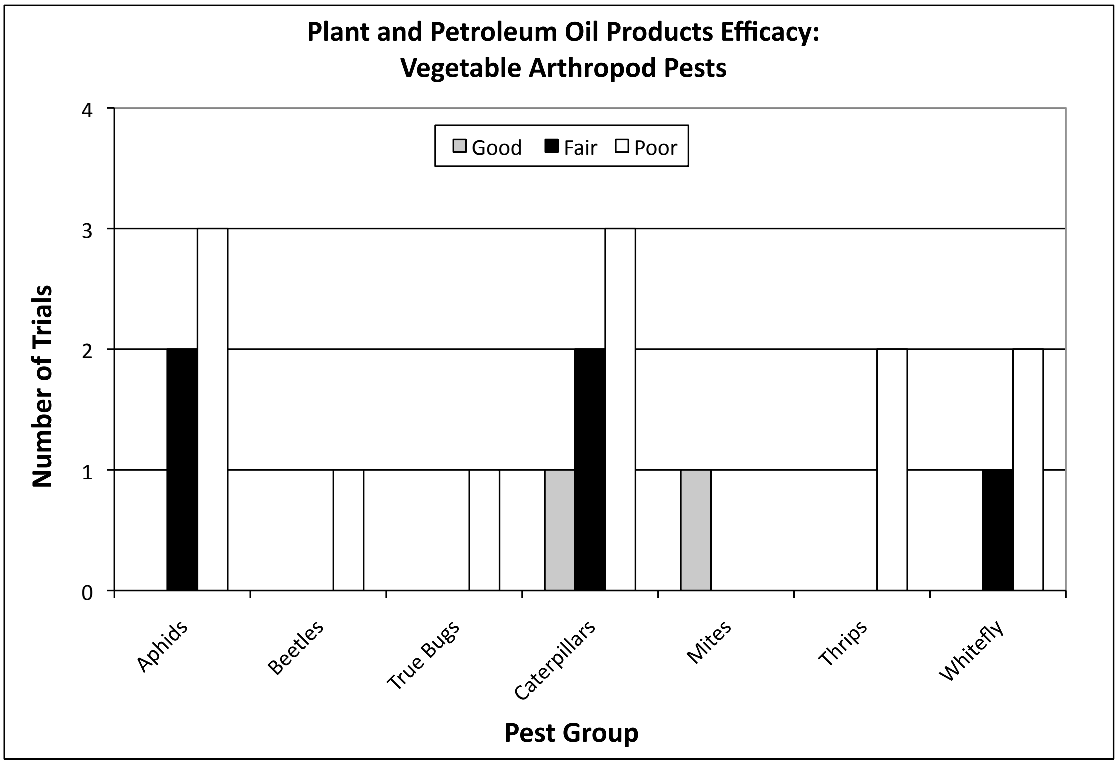

Figure 1. Efficacy of plant and petroleum oils against arthropod pests of vegetables.

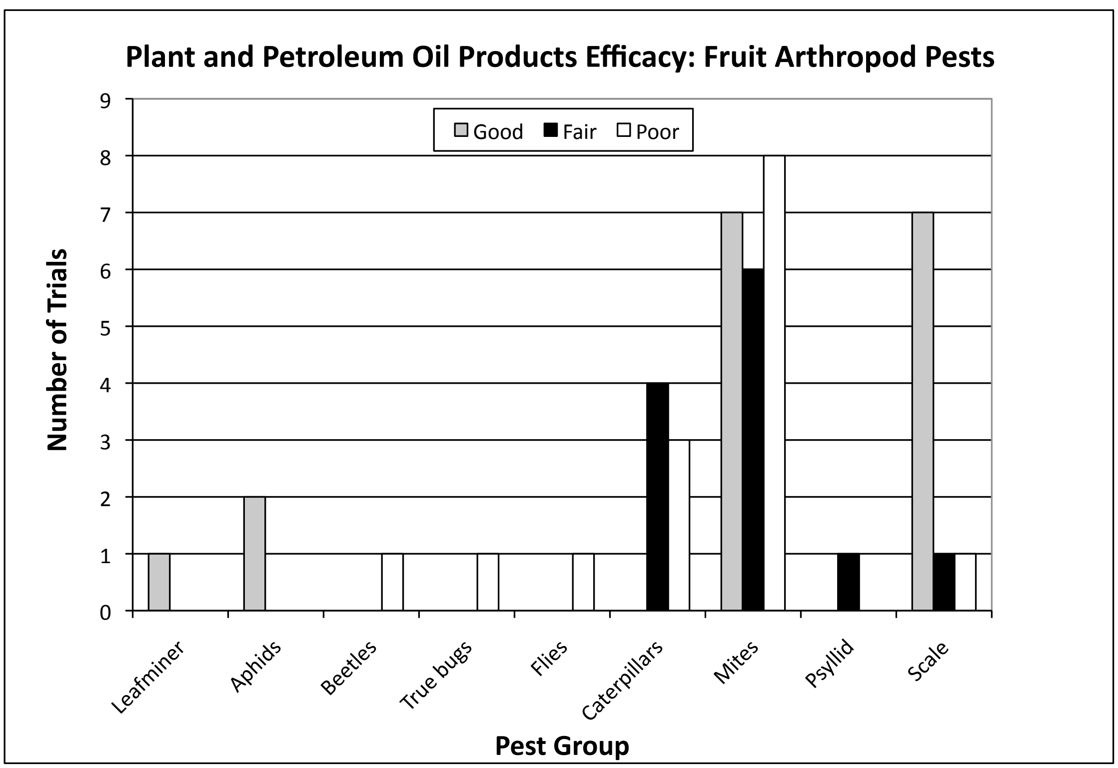

Figure 2. Plant and petroleum oil efficacy against arthropod pests of fruit.

the individual species in a group, as well as the life stage to which the pesticide is applied; therefore, the efficacy data should be considered only as a general guide.

Against vegetable insect pests, plant and petroleum oil products have been only partially effective, except for a good result in one trial against pest mites (Fig. 1). On fruit crops, oils have

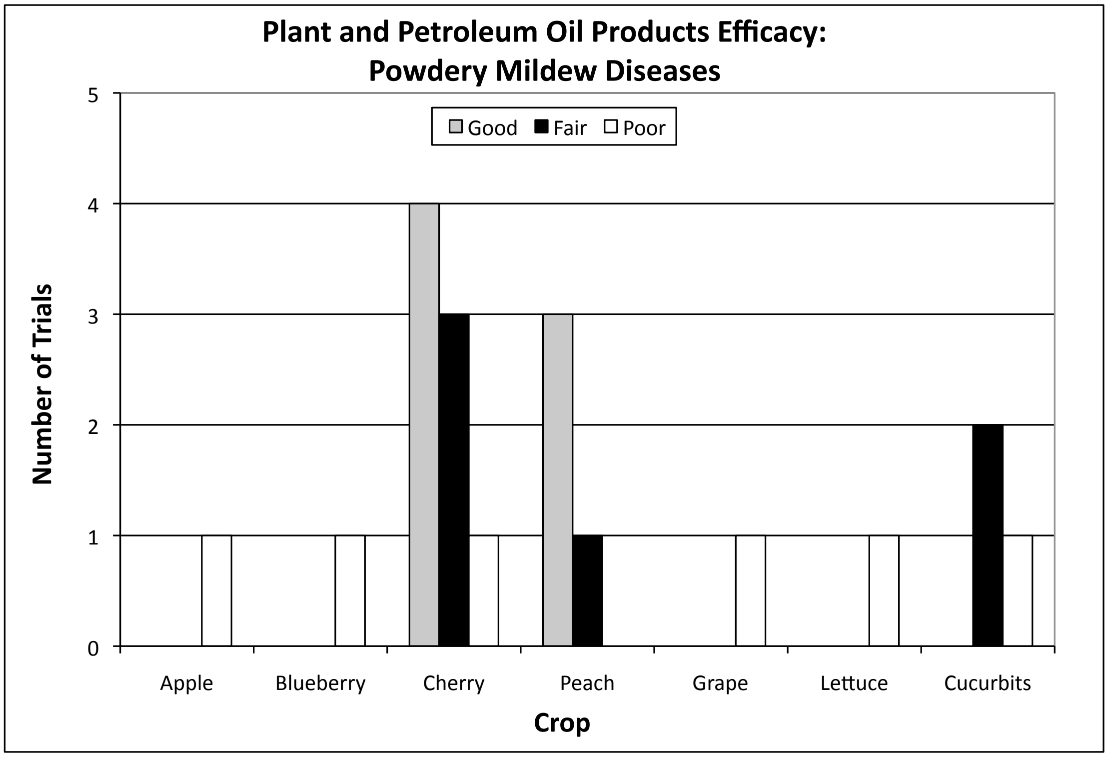

Figure 3. Efficacy of plant and petroleum oil products against powdery mildew in different crops.

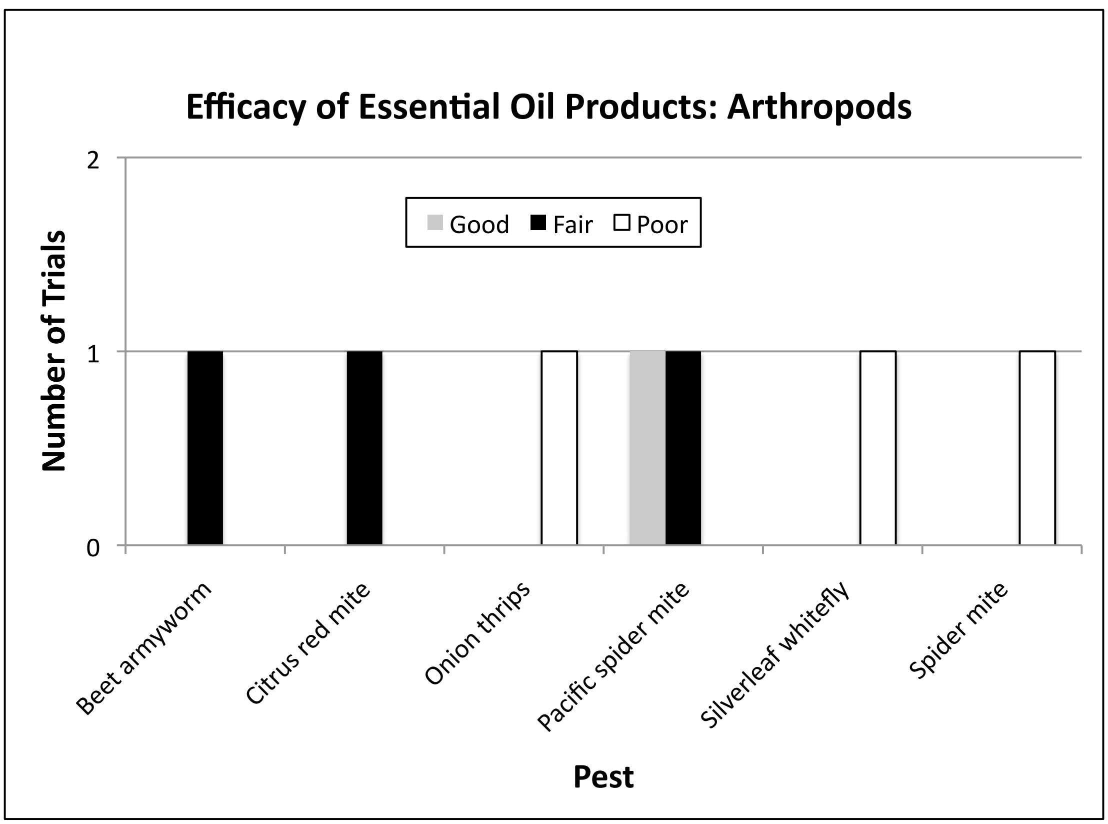

Figure 4. Efficacy of essential oil products against arthropod (insects and mites) pests.

shown some good results against mites, San Jose scale, and spotted tentiform leafminers. They have had fair success against pear psylla and caterpillar pests (Fig. 2), and showed good control of powdery mildew on stone fruit crops (Fig. 3). In general, plant and petroleum oil products were not very effective against powdery mildew diseases on other crops in these trials.

Essential oils

The use of essential oils for insect and disease management is fairly recent, and relatively few efficacy studies have been conducted. For arthropod pests, results have been most promising against Pacific spider mite and citrus red mite (Fig. 4). One trial showed fair efficacy against beet armyworm. Essential oil products have shown fair or good results against powdery mildew on tomato and grape, and one trial showed fair results against early blight on tomato (Fig. 5). The efficacy of an essential oil product was increased by the addition of a petroleum oil product in one trial (not included in Fig. 5). Because the petroleum oil product was not tested separately, determining whether it was a synergist or mostly responsible for the increased effectiveness was not possible in this study.

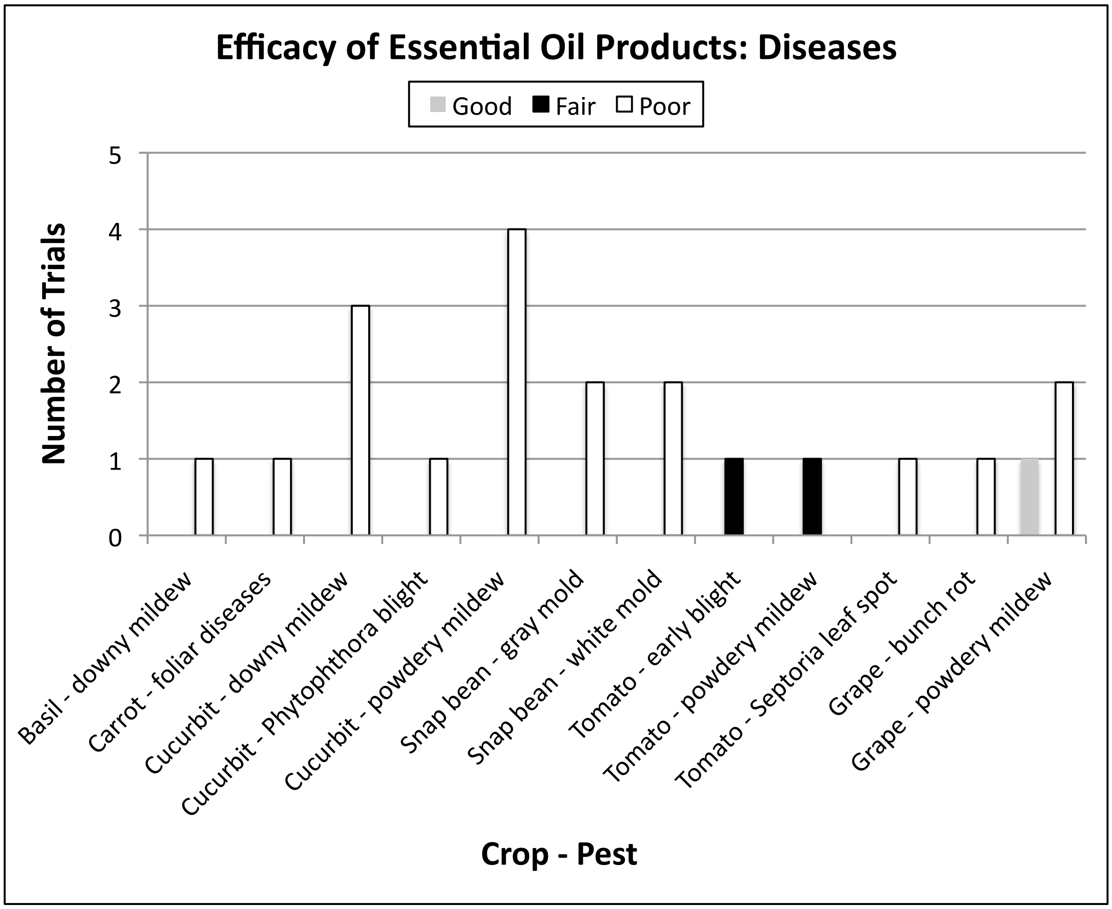

Figure 5. Efficacy of essential oil products against plant diseases.

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MATERIAL FACT SHEET
Pesticidal Soap

MATERIAL NAME: Pesticidal Soap

MATERIAL TYPE: Synthetic

U.S. EPA TOXICITY CATEGORY: IV, "Caution." Potassium and ammonium salts of fatty acids are exempt from tolerance levels on raw agricultural commodities (EPA 1992).

USDA - NOP:
Soap is allowed for use as insecticide, miticide, algaecide, moss killer, and herbicide only for farmstead maintenance such as roadways, ditches, etc. (not permitted on food crops or fallow fields). Ammonium soaps are permitted as animal repellants as long as there is no contact with edible portions of crop or with soil. Soap is also permitted for use as an herbicide, but again, only for farmstead maintenance (i.e., roadways, ditches, building perimeters, non-food crops, etc.); use on any food crop or fallow fields is prohibited (NOP 2000). The USDA-NOP regulation does not describe the type of soaps permitted, though the initial review was for potassium salts of fatty acids. Soaps classed by EPA as "List 4 Inerts" (inerts of minimal concern) may be used as inert ingredients and adjuvants.

MATERIAL DESCRIPTION:
Pesticidal soaps are potassium or ammonium salts of fatty acids. Pesticidal soaps are selected to be relatively non-phytotoxic, unless specifically formulated as herbicides. For information on neem-based soaps, please see the neem products fact sheet of this manual.

HOW IT WORKS:
Insecticidal soap products work by disrupting the cuticle (skin) layer and suffocating soft-bodied insects. To be effective, the spray solution must contact and thoroughly cover the targeted pest. Once the soap dries on the plant surface, insects and mites will not be affected by the residue. Soaps have little efficacy against insect eggs (Lawson & Weires 1991; Liu et al. 1996). Some insecticidal soaps are labeled for powdery mildew suppression. The manner in which soaps suppress plant diseases is not fully understood. Ammonium salts of fatty acids are used as a mammal repellant; they slowly release an ammonia smell that may deter deer and rabbits.

Soaps also function as wetting agents or surfactants, reducing the surface tension of water. Using them can allow spray materials to penetrate into small crevices and cover plant surfaces more effectively with less "beading."

TYPES OF PESTS IT CONTROLS:
Insecticidal soap products are effective against some aphid, mealybug, whitefly, mite, and other soft-bodied species. They do not work against hard-bodied insects, such as beetles. Soaps can also be formulated as herbicides, killing weeds, moss, and algae. Insecticidal soap products can suppress powdery mildew in some crops. Ammonium soaps show some repellency against deer and rabbits. Be sure to check product labels to choose the appropriate soap product.

RELATED PRODUCTS:
Recently, research has been done on sugar esters that are produced by reacting fatty acids with sugars. These kinds of sucrose esters are found naturally in plants and were originally isolated from the hairs on tobacco leaves (EPA 2002). They are relatively nontoxic to mammals and have some efficacy as insecticides (Puterka et al. 2003); however, they are considered synthetic and are not approved for organic production. Other related products include those composed of

plant oils and organic acids, which may also be effective against pests. Products of this type may be marketed as “plant washes” to avoid pesticide labeling requirements. See appendix D for a discussion of pesticide products exempt from EPA registration.

APPLICATION GUIDELINES:
Insecticidal soaps are widely available for use against soft-bodied insects, such as aphids. Some are also labeled against powdery mildew, though such use is not approved under the NOP. Currently, no commercial herbicidal or mammal repellant soap products are approved for organic production.

Mixing water with a high mineral content (hardness >300 or 17.5 grains/gallon) should be tested for compatibility or conditioned using an approved compatibility agent. See the OMRI list (http://www.omri.org/) for allowed adjuvants. Soap products are most effective when they dry slowly, so spraying in the evening or at night is best (Imai et al. 1995).

Phytotoxicity can be a concern with soap products. The M-Pede label lists cucumbers and several species of ornamental plants that are sensitive. For grapes, the label warns that soap applications within 3 days of a sulfur spray can increase the likelihood of injury. Fruit crops may be damaged if heavy spray volume causes soap to accumulate at the base of the fruit. When in doubt, test for phytotoxicity by spraying a portion of a single plant one day in advance of the others, and observe the effects.

Protective eyewear is required when applying ammonium soap products.

OMRI LISTED PRODUCTS: **(**This is a partial list. Check http://www.omri.org for many more**)**

- Concern Insect Killing Soap II (Woodstream Corporation)
- Des-X (Certis USA)
- Final-San-O herbicide (Certis USA)
- M-Pede (Dow Agrosciences/Mycogen)
- M-Pede Insecticide Miticide Fungicide (Gowan Co.)
- SaferBrand Fruit & Vegetable Insect Killer II (Woodstream Corporation)
- Safer Brand Houseplant Insect Killing Soap Concentrate II (Woodstream Corporation)
- Safer Brand Houseplant Insect Killing Soap II (Woodstream Corporation)
- Safer Brand Insect Killing Soap Concentrate II (Woodstream Corporation)
- Safer Brand Moss & Algae Killer & Surface Cleaner Ready to Spray II (Woodstream Corporation)
- Safer Brand Moss & Algae Killer & Surface Cleaner Ready to Use II (Woodstream Corporation)
- Safer Brand Rose & Flower Insect Killer II (Woodstream Corporation)

As adjuvants:

- Green Valley Natural Plant Wash (WTB Technology)
- Green Valley Ultra Guard Plant Wash (WTB Technology)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI)
REI 12 hours, PHI 0 (M-Pede)

EFFECTS ON THE ENVIRONMENT:
Soap products rapidly degrade and wash off of leaf surfaces. The half-life of fatty acids is estimated to be less than one day (EPA 1992). Due to its fleeting nature, presumed low mammalian toxicity, and long history of use, agricultural use of soap is thought to have minimal negative environmental impact. If spilled into water, potassium soaps are highly toxic to invertebrates (EPA 1992).

Soap products have little effect on beneficial species unless they are soft-bodied and directly contacted by the spray. Some predator mite species and ladybeetle larvae are adversely affected (Liu et al. 1996).

EFFECTS ON HUMAN HEALTH:

Potassium salts of fatty acids are generally recognized as safe (GRAS) by the US FDA (EPA 1992). Acute toxicity to rats has been documented as LD 50 > 5000 mg/kg for M-Pede formulated with ethyl alcohol. Insecticidal soaps are presumed to be rapidly broken down in the environment and metabolized when ingested in small amounts. They are thought to have little, if any, long-term health effects. Ammonium soaps can cause permanent eye damage (EPA 1992). Soap salts of fatty acids have caused reproductive and mutagenic effects when fed to test animals at high doses (EPA 1992), but are not reported to be carcinogenic in NTP or IARC databases (Mycogen 1998).

EFFICACY

A summary of university field trials of soap products against pests of fruit and vegetable crops commonly grown in the Northeast is compiled in Figure 1. These university-based trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. On completely treated fields in which a good program of cultural controls has also been implemented, the pest population would be lower and the level of pest control obtainable may be higher than shown.

Insecticidal soaps provide variable control against aphids, mites, whiteflies, mealybugs, psyllids, and some other soft-bodied insects. University-based trials show efficacy was variable against aphids and poor against whiteflies and thrips. In particular, soaps were ineffective against green peach aphid. There have also been unexpectedly positive, though variable, results against caterpillar pests.

In Figure 1, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

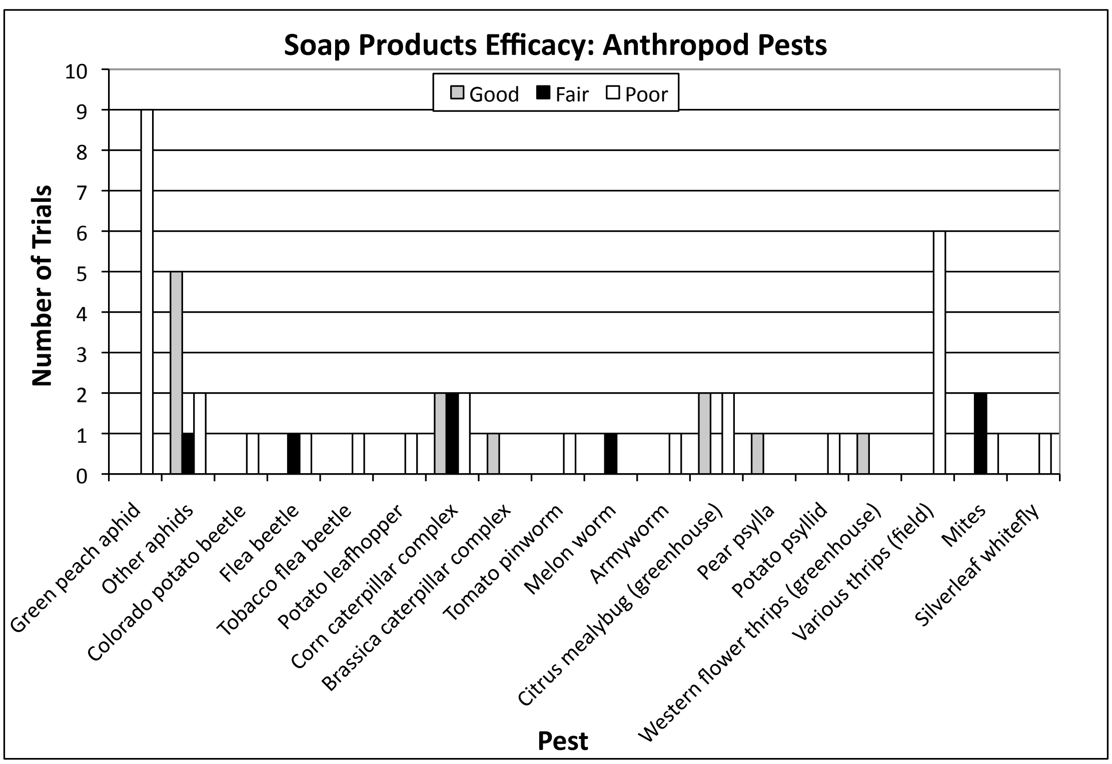

Figure 1. Efficacy of soap products against various pests.

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MATERIAL FACT SHEET
Pyrethrum

MATERIAL NAME: Pyrethrum

MATERIAL TYPE: Botanical

U.S. EPA TOXICITY CATEGORY: III, "Caution"

USDA – NOP:
Considered non-synthetic, allowed. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological or botanical material must be documented in the organic system plan (NOP 2000).

ACTIVE INGREDIENT DESCRIPTION:
Pyrethrum is the generic name given to a plant-based insecticide derived from the powdered, dried flower heads of the pyrethrum daisy, chiefly *Chrysanthemum cinerariaefolium*, but also *C. coccineum* and *C. marshalli*. Pyrethrins are comprised of six constituent compounds with insecticidal properties that occur in these *Chrysanthemum* species. The pyrethrum daisy is native to southwest Asia. Kenya is the leading producer of pyrethrum, followed by Australia.

Pyrethrum is used widely throughout the world to control many human and household pests, such as mosquitoes and houseflies. While it was used widely in agriculture before World War II, cheaper and more effective synthetic products have largely replaced it for farm use (Casida 1973; Casida & Quistad 1995). More recently, new pyrethrum products (often solvent-based and including PBO) have appeared on the agriculture market. Only a few are approved for organic production under the NOP. Because of their widespread use, populations of insects in some areas may be resistant to pyrethroids and pyrethrum.

Note: Pyrethroids are synthetic compounds whose structure and mode of action are similar to pyrethrins, but they are not approved for use in organic production. Pyrethroids are one of the most common and effective classes of insecticides. There are many pyrethoid products, including Ambush, Baythroid, Pounce, and Warrior.

HOW IT WORKS:
Pyrethrum is a fast acting contact poison that "knocks down" susceptible insects. Insects are left paralyzed by the toxic effect of pyrethrum. The normal function of the nervous system is affected, stimulating repetitive nerve discharges and leading to paralysis and death. However, if the dose is too low, some insects are able to recover after the initial knockdown.

SYNERGISTS:
Mortality may be enhanced with the addition of a synergist, a chemical that is not considered strongly insecticidal by itself, but enhances the activity of the material being applied. Piperonyl butoxide (PBO) is a common synthetic synergist that reduces an insect's ability to detoxify pyrethrum. It is added to some pyrethrum products. Piperonyl butoxide is not allowed under the National Organic Program. Care should be taken not to use pyrethrum products that contain prohibited synergists.

TYPES OF PESTS IT CONTROLS:
Pyrethrum is a broad-spectrum insecticide used to control true bugs, caterpillars, beetles, aphids, flies, mites, whiteflies, thrips, and leafhoppers (Casida 1973). Within these groups, pests may have a greater or lesser susceptibility to pyrethrum products. Specific pest species controlled by pyrethrum, as noted in the older literature, include potato leafhopper, beet leafhopper, cabbage looper, celery leaf tier, Say's stink bug, twelve-spotted cucumber beetle, six-

spotted leafhopper, lygus bugs on peaches, grape thrips, flower thrips, grape leafhopper, and cranberry fruitworm. It was not considered particularly effective against flea beetles, imported cabbageworm, diamondback moth, aphids on spinach, or lygus bugs on alfalfa (Casida 1973).

FORMULATIONS AND APPLICATION GUIDELINES:
OMRI listed formulations are emulsifiable concentrates, containing 0.1-5% pyrethrins, some formulated with insecticidal soaps. Because pyrethrins break down quickly after application, frequent applications may be needed against mobile pests that can reinvade fields. A recently registered product, Azera, is a mixture of pyrethrins and azadirachtin, which have been shown to improved control of some pests (Dively, unpublished data).

AVAILABILITY AND SOURCES:
Readily available from garden and farm suppliers.

OMRI LISTED PRODUCTS (This is a partial list. Check http://www.omri.org for many more**):**
- Azera Insecticide (also contains azadirachtin (neem)) (MGK Co.)
- Concern Multi-Purpose Insect Killer Concentrate (contains soap) (Woodstream Co.)
- Pyganic Crop Protection EC 5.0 II (MGK Co.)
- Pyganic Crop Protection EC 1.4 II (MGK Co.)
- Safer Brand Yard & Garden Insect Killer Concentrate II (with soap) (Woodstream Co.)
- Safer Brand Yard & Garden Insect Killer II (with soap) (Woodstream Co.)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL (PHI):
The EPA Workers Protection Standard requires a minimum of 12 hours before reentering a treated field. May be applied up to the day of harvest.

APPLICATION TIPS:
Care should be taken to not mix pyrethrum with lime, sulfur, or soap solutions, since pyrethrum is broken down by both acid and alkaline conditions.

Pyrethrum is rapidly broken down by sunlight. Use of UV-inhibiting adjuvants may allow for a longer period of control. Given that longer control is a concern for its impact on beneficial species, growers must decide whether the advantage of having a longer activity period to protect the crop from reinfestations is appropriate for their management system.

Pyrethrum can be a contact poison, so it is effective when the spray physically lands on an insect. Flighty insects, such as cucumber beetle, should be sprayed early in the morning when they are sluggish and bee pollinators have not yet begun to fly. Pyrethrum can also be effective when the residue on the leaf is ingested by the insect; however, because pyrethrum breaks down so rapidly in sunlight, this residual effectiveness is quickly lost.

EFFECT ON THE ENVIRONMENT:
Leaf persistence. Pyrethrum is quickly degraded in sunlight (Casida & Quistad 1995).

Fate in water. Pyrethrum compounds are broken down to nontoxic products in water (Extoxnet 1994).

Soil persistence. Soil application studies of pyrethrum showed a half-life of only one to two hours (Casida & Quistad 1995). When used indoors, pyrethrum can persist much longer; Cox (2002) found it to last up to two months or more in carpet dust.

Wildlife. Pyrethrum is extremely toxic to fish, such as bluegill and lake trout, while it is slightly to moderately toxic to bird species, such as mallards and bobwhite quail. Natural pyrethrins are highly fat soluble, but are easily metabolized, so they do not accumulate in the body. Because pyrethrin-I and pyrethrin-II have multiple sites in their chemical structures that can be readily attacked in biological systems, they are unlikely to concentrate in the food chain (Extoxnet 1994; Casida & Quistad 1995).

Effect on beneficial arthropods. Pyrethroids are broad-spectrum insecticides that can negatively affect some beneficial arthropods; however, since pyrethrum residues on the plant break down quickly, the effect on natural enemies is reduced. Pyrethrum is highly toxic to bees. The average lethal dose (LD50) for honeybees was measured at .022 micrograms per bee (Casida & Quistad 1995). Direct hits on honeybees and beneficial wasps are likely to be lethal (Cox 2002).

EFFECT ON HUMAN HEALTH:

Acute Toxicity: Compared to many other insecticides, pyrethrum is relatively non-toxic to humans; therefore, it only carries the signal word CAUTION. Care is warranted, however.

Rats and rabbits are not affected by high dermal applications. On broken skin, pyrethrum produces irritation and sensitization, which is further aggravated by sun exposure. Absorption of pyrethrum through the stomach, intestines, and skin is slow; however, humans can absorb pyrethrum more quickly through the lungs during respiration. Response appears to depend on the pyrethrum compound used. Inhaling high levels of pyrethrum may bring about asthmatic breathing, sneezing, nasal stuffiness, headache, nausea, lack of coordination, tremors, convulsions, facial flushing and swelling, and burning and itching sensations (Extoxnet 1994).

The lowest lethal oral dose of pyrethrum is 750 mg/kg for children and 1,000 mg/kg for adults. Oral LD50 values of pyrethrins in rats range from 200 mg/kg to greater than 2,600 mg/kg. Some of this variability is due to the variety of constituents in the formulation. Mice have a pyrethrum oral LD50 of 370 mg/kg. Animals exposed to very high amounts may experience tongue and lip numbness, nausea, diarrhea, lack of coordination, tremors, convulsions, paralysis, respiratory failure, and death. Recovery from serious poisoning in mammals is fairly rapid (Extoxnet 1994).

Organ Toxicity: In mammals, tissue accumulation has not been recorded. At high doses, pyrethrum can be damaging to the central nervous system and the immune system. When the immune system is attacked by pyrethrum, allergies can be worsened. Animals fed large doses of pyrethrins may experience liver damage. Rats fed pyrethrin at high levels for two years showed no significant effect on survival, but slight, definite damage to the liver was observed. Inhalation of high doses of pyrethrum for 30 minutes each day for 31 days caused slight lung irritation in rats and dogs (Extoxnet 1994).

Fate in Humans and Animals: Pyrethrins and their metabolites are not known to be stored in the body or excreted in milk. The urine and feces of people given oral doses of pyrethrum contain chrysanthemumic acid and other metabolites. These metabolites are less toxic to mammals than are the parent compounds. Pyrethrins I and II are excreted unchanged in the feces. Other pyrethrum components undergo rapid destruction and detoxification in the liver and gastrointestinal tract (Extoxnet 1994).

Chronic Toxicity: Overall, pyrethrins have low chronic toxicity to humans, and the most common problems in humans have resulted from the allergenic properties of pyrethrum. Patch tests for allergic reaction are an important tool in determining an individual's sensitivity to these compounds. Pyrethrum can produce skin irritation, itching, pricking sensations, and local burning sensations. These symptoms may last for about two days (Extoxnet 1994). Cox (2002) reports more serious chronic effects, including circulatory and hormonal effects.

Casida and Quistad (1995) performed 90-day feeding tests on animals. They found no effects at 1000 ppm or less on rats, 300 ppm or less on mice, and 600 ppm or less on dogs.

Reproductive Effects: Rabbits that received pyrethrins orally at high doses during the sensitive period of pregnancy had normal litters. A group of rats that were fed very high levels of pyrethrins daily for three weeks prior to first mating had litters with weanling weights much lower than normal. Overall, pyrethrins appear to have low reproductive toxicity (Extoxnet 1994).

Teratogenic Effects: A rabbit reproduction study showed no effect of pyrethrins on development of offspring (Extoxnet 1994). Casida and Quistad (1995) found that in rats, there were no teratogenic effects at feeding doses of up to 600 mg/kg/day. According to the Agency for Toxic Substances and Disease Registry, part of the US Center for Disease Control, "There is no evidence that pyrethrins or pyrethroids cause birth defects in humans or affect the ability of humans to produce children" (ATSDR 2001).

Mutagenic Effects: No mutagenic effects were observed in salmonella, rat primary hepatocyte, or Chinese hamster ovary cell tests (Casida & Quistad 1995).

Carcinogenic Effects: "There is no proof that pyrethrins or pyrethroids cause cancer in people. Pyrethrins and pyrethroids do not appear to cause cancer in animals" (ATSDR 2001). However, Cox (2002) cites several studies indicating the possibility of a connection between pyrethrins and cancer, including one study showing a 3.7-fold increase in leukemia among farmers who had handled pyrethrins compared to those who had not. In 1999, a USEPA memo classified pyrethrins as "likely to be a human carcinogen by the oral route" (Cox 2002). Pyrethrin has recently undergone US EPA reregistration review and remains a registered insecticide.

Table 1. Information on general levels of reduction of agricultural pests by pyrethrum, from Casida (1973).

Pest Reduction Relative to Untreated Control	Crop	Pest
61-100%	Celery	Beet armyworm
	Celery	Black cutworm
	Cabbage	Imported cabbage worm
	Blueberry	Blueberry spanworm
	Tomato	Greenhouse whitefly
	Cucumber	Greenhouse whitefly
	Lettuce	Greenhouse whitefly
	Cabbage	Cabbage aphid
	Apple	Green peach aphid
	Potato	Potato aphid
	Celery	Sunflower aphid
	Grape	Grape leafhopper
	Potato	Potato leafhopper
	Alfalfa	Potato leafhopper
	Grape	Variegated leafhopper
	Blueberry	Blueberry flea beetle
	Potato	Colorado potato beetle
	Potato	Potato flea beetle
	Blueberry	Blueberry thrips
	Onion	Onion thrips
	Blueberry	Blueberry sawfly
41-60%	Tomato	Beet armyworm
	Cabbage	Cabbage looper
	Tomato	Tomato fruitworm
	Apple	Apple aphid
	Potato	Tarnished plant bug
Less than 41%	Tomato	Tomato pinworm
	Sweet corn	Fall armyworm
	Sweet corn	Corn earworm
	Sweet corn	European corn borer
	Tomato	Vegetable leafminer
	Celery	Vegetable leafminer
	Blueberry	Blueberry maggot
	melon	Spider mite

EFFICACY:
Because pyrethrum has such a long history of use in agriculture, there is a great deal of information in older literature on its effectiveness against different insect pests. General information on levels of reduction of different agricultural pests from Casida (1973) is summarized in Table 1.

Recent studies: A summary of university field trials of pyrethrum products on vegetable crops commonly grown in the Northeast is compiled in Figure 1. These university-based trials typically test products with untreated buffer rows and other conditions that create unusually severe pest pressure. The level of pest control is likely to be higher on fields in which a good program of cultural controls has been implemented.

In Figure 1, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74%, and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

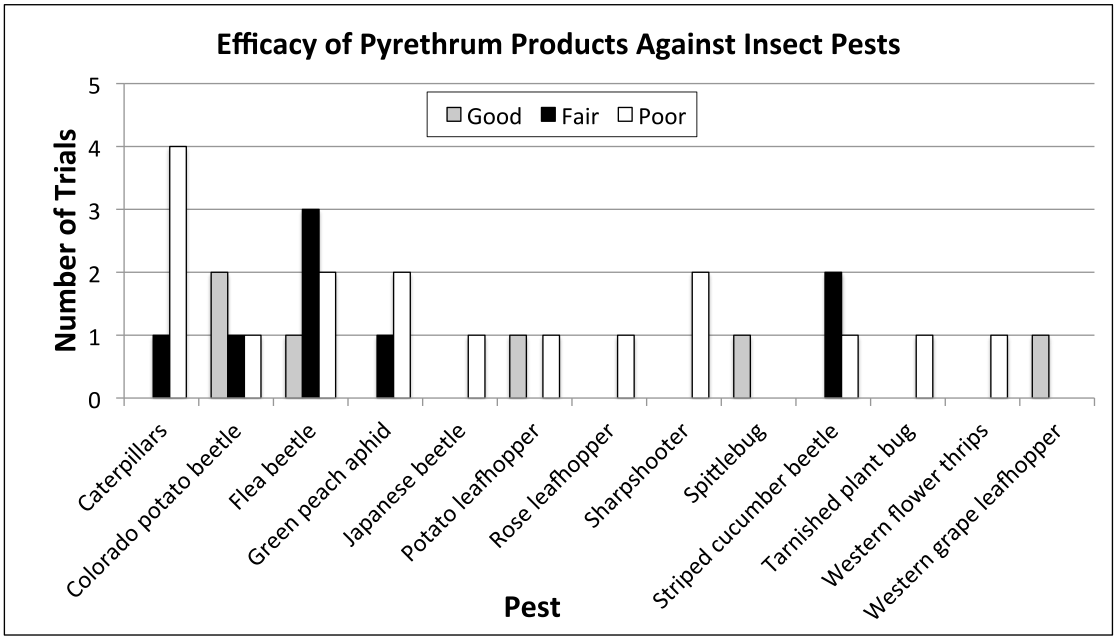

Figure 1. Efficacy of pyrethrin products against various insect pests.

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MATERIAL FACT SHEET
Rotenone

MATERIAL NAME: Rotenone

NOTE: ROTENONE IS NO LONGER AN EPA REGISTERED INSECTICIDE, AND ITS USE IS NOT PERMITTED.

THIS CHAPTER IS FOR INFORMATIONAL PURPOSES ONLY.

MATERIAL TYPE: Botanical

USDA – NOP:
Considered non-synthetic, allowed, but since it is not an EPA registered insecticide, it is not allowed for use on commercial farms. Furthermore, at the time of publication, the NOP is considering adding rotenone to Section 205.602, which is the list of prohibited natural materials.

ACTIVE INGREDIENT DESCRIPTION:
Rotenone is a pesticidal compound found in several subtropical leguminous shrubs of the genera Derris, Lonchocarpus, and Tephrosia.

HOW IT WORKS:
Rotenone is a slow-acting poison that interferes with the electron transport system in the mitochondria. It acts as both a contact and stomach poison.

TYPES OF PESTS IT CONTROLS:
Rotenone is toxic to insects in many different insect orders (caterpillars, beetles, flies, etc.). It also kills fish and ticks.

FORMULATIONS AND APPLICATION GUIDELINES:
In the past, Rotenone was commonly used by organic growers; however, at this time, no rotenone products are listed by OMRI.

AVAILABILITY AND SOURCES:
ROTENONE IS NO LONGER AN EPA REGISTERED INSECTICIDE, AND ITS USE IS NOT PERMITTED.

EFFECT ON THE ENVIRONMENT:
Leaf persistence. Rotenone is quickly degraded in sunlight (Extoxnet 1996).

Fate in water. Rotenone compounds are broken down rapidly in water (Extoxnet 1996).

Soil persistence. Soil application studies of rotenone showed a half-life of only one to three days (Extoxnet 1996).

Wildlife and domestic animals. Rotenone is extremely toxic to fish, such as bluegill and lake trout, and slightly toxic to bird species, such as mallards and pheasants (Extoxnet 1996).

Rotenone acts as a general inhibitor of cellular respiration. The acute oral toxicity of rotenone is moderate for mammals, but there is a wide variation between species. Ingested orally, Rotenone is less toxic to mice and hamsters than rats. Pigs seem to be especially sensitive. The reported oral LD50 values in rats vary considerably, possibly because of differences in the plant extracts used. Studies have shown that, in rats, rotenone is more toxic to females than males. It is highly irritating to the skin in rabbits (WHO 1992).

Effect on beneficial arthropods. Rotenone is relatively nontoxic to bees (Extoxnet 1996); however, it can kill many other beneficial species if they come directly into contact with it.

EFFECT ON HUMAN HEALTH:
In the first half of the 20th century, rotenone was considered a non-toxic alternative to the lead- and arsenic-based pesticides in common use. Later research showed that it was more toxic than originally thought. Rotenone may be absorbed by ingestion and by inhalation. In studies with rabbits, absorption through intact skin was low (WHO 1992).

Fate in humans and animals: Absorption in the stomach and intestines is relatively slow and incomplete, although fats and oils promote its uptake. The liver breaks down the compound fairly effectively. Animal studies indicate that possible metabolites are carbon dioxide and a more water-soluble compound excreted in the urine. Studies indicate that approximately 20% of the applied oral dose (and probably most of the absorbed dose) may be eliminated from animal systems within 24 hours (Extoxnet 1996).

Acute toxicity: Local effects on the body include conjunctivitis, dermatitis, sore throat, and congestion. Ingestion produces effects ranging from mild irritation to vomiting. Inhalation of high doses can cause increased respiration followed by depression and convulsions. The compound can cause a mild rash in humans and is a strong eye irritant to rabbits. The oral LD50 of rotenone ranges from 132 to 1500 mg/kg in rats. The reported LD50 of rotenone in white mice is 350 mg/kg. A spray of 5% rotenone in water was fatal to a 100-pound pig when exposed to 250 cubic centimeters (ml) of the airborne mixture. In rats and dogs exposed to rotenone in dust form, the inhalation fatal dose was uniformly smaller than the oral fatal dose. Rotenone is believed to be moderately toxic to humans, with an oral lethal dose estimated from 300 to 500 mg/kg. Human fatalities are rare, perhaps because rotenone is usually sold in low concentrations (1 to 5% formulation) and its irritating action causes prompt vomiting. The mean particle size of the powder determines the inhalation toxicity. Rotenone may be more toxic when inhaled than when ingested, especially if the mean particle size is very small, and particles can enter the deep regions of the lungs (Extoxnet 1996). Occupational exposure to powdered rotenone-containing plant materials has been reported to induce dermatitis, ulcers in the nose, and irritation of mucous membranes (WHO 1992).

Chronic toxicity: Growth retardation and vomiting resulted from chronic exposures in rats and dogs. No pathological changes could be attributed to rotenone in rats fed diets containing doses up to 2.5 mg/kg for two years. Dogs fed doses of rotenone up to 50 mg/kg/day for 28 days experienced vomiting and excessive salivation, but no decreased weight gain. Dogs fed rotenone for six months at doses up to 10 mg/kg/day had reduced food consumption, and therefore, reduced weight gain. At the highest dose, blood chemistry was adversely affected, possibly due to gastointestinal lesions and chronic bleeding. Examination of 35 tissue types revealed only one type of lesion that might have been associated with exposure to the test chemical: lesions of the GI tract (Extoxnet 1996).
A "no observed adverse effect level" (NOAEL) of 0.4 mg/kg per day has been determined for rats (two-year study) and dogs (six-month study). In short-term studies on rats, dose-dependent bone marrow atrophy and forestomach lesions were observed (WHO 1992).
In 2000, a study was published showing that rats exposed to continuous intravenous rotenone at a rate of 2-3 ppm displayed degenerative neurological symptoms nearly identical to Parkinson's disease (Betarbet et al. 2000). While the goal of this project was to demonstrate a valuable tool for research into the disease, it raised serious questions about whether exposure to rotenone could lead to neurological damage. This question has not been resolved.

Reproductive effects: Pregnant rats fed 10 mg/kg/day on days 6 through 15 of gestation experienced decreased fecundity, increased fetal resorption, and lower birth weight. Very high maternal mortality was seen at this dose. The 2.5 mg/kg/day dose produced no observable maternal toxicity or adverse effect on fetal development. Fetotoxicity and failure of offspring have been reported in guinea pigs at doses of 4.5 and 9.0 mg/kg/day, respectively, for an unspecified period. Thus, reproductive effects seem unlikely in humans at expected exposures (Extoxnet 1996).

Teratogenic effects: Pregnant rats fed 5 mg/kg/day produced a significant number of young with skeletal deformities. The effects were not observed at the 10 mg/kg/day level, so the data do not provide convincing evidence of teratogenicity because the effects do not appear to be dose-related. Thus, the evidence for teratogenicity is inconclusive (Extoxnet 1996). Fetotoxic effects were observed in mice and rats at doses that elicited adverse reactions in the mother. There were no indications of a teratogenic action in rodents below doses that were maternally toxic (WHO 1992).

Mutagenic effects: The compound was determined to be nonmutagenic to bacteria and yeast as well as to treated mice and rats. However, it was shown to cause mutations in some cultured mouse cells. In summary, the data regarding the mutagenicity of rotenone are inconclusive (Extoxnet 1996).

Carcinogenic effects: Studies in rats and hamsters have provided limited evidence for carcinogenic activity of rotenone. No evidence of carcinogenic activity was seen in hamsters at oral doses as high as 120 mg/kg/day for a period of 18 months. Studies of two species of rats evidenced no statistically significant cancerous changes in any organ site, including mammary glands, at oral doses of up to 75 mg/kg/day for 18 months. Significant increases in mammary tumors have been reported in albino rats with intraperitoneal doses of 1.7 mg/kg/day for 42 days, and in Wistar rats at oral doses of approximately 1.5 mg/kg/day for 8 to 12 months. In the latter study, however, higher dose rates (3.75 and 7.5 mg/kg/day) over the same period did not produce increased tumors. Thus, the evidence for carcinogenicity is inconclusive (Extoxnet 1996).

Organ toxicity: Chronic exposure may produce changes in the liver and kidneys as indicated by the animal studies cited above (Extoxnet 1996).

EPA Status:
ROTENONE IS NO LONGER AN EPA REGISTERED INSECTICIDE, AND ITS USE IS NOT PERMITTED.

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MATERIAL FACT SHEET
Spinosad

MATERIAL NAME: *Spinosad*

MATERIAL TYPE: Microbial (Derived from fermentation)

U.S. EPA TOXICITY CATEGORY: III, "Caution"

USDA-NOP:
Considered non-synthetic, allowed. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (7CFR 205.206(e)). The National Organic Standards Board reviewed this substance in May, 2002 and found it to be a permitted non-synthetic substance (USDA 2002).

ACTIVE INGREDIENT DESCRIPTION:
Spinosad is composed of spinosyns A and D, substances produced by aerobic fermentation of the actinomycete species *Saccharopolysora spinosa*. This rare species was found in soil samples from an island in the Caribbean in 1982. Actinomycetes are filamentous bacteria found in the soil that give it a sweet, "healthy" smell.

HOW IT WORKS:
Spinosad is a fast-acting, somewhat broad-spectrum material that acts on insects primarily through ingestion or by direct contact with a spray droplet or a newly treated surface. It affects the nervous system of the insect, causing loss of muscle control. Continuous activation of motor neurons causes insects to die of exhaustion within 1-2 days. Foliar applications of spinosad are not highly systemic in plants, although some movement into leaf tissue has been demonstrated. The addition of a penetrating surfactant increases absorption by tissues and activity on pests that mine leaves (Larson 1997).

AVAILABILITY AND SOURCES:
Spinosad is a patented product developed by Dow AgroSciences (Baker 1993; Boek et al. 1994). Several formulations are widely distributed.

OMRI LISTED PRODUCTS: **(**This is a partial list. Check http://www.omri.org for many more**)**

- Conserve Naturalyte Insect Control (Southern Agricultural Insecticides Inc.)
- Conserve Conserve Fire Ant Bait Fire Ant Bait (Dow AgroSciences)
- Entrust SC Naturalyte Insect Control, (Dow AgroSciences)
- Justice Fire Ant Bait (Dow AgroSciences)
- GF-120 NF Naturalyte Fruit Fly Bait (Dow AgroSciences)
- Seduce Insect Bait (Certis USA)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings.

FORMULATION AND APPLICATION GUIDELINES:
See labels for application guidelines. Entrust SC contains 2 lb. spinosad per gallon (240 g spinosad per liter). Entrust SC is generally applied to plants at the rate of 1.5 to 10 fl oz/acre per application (Entrust product label).

For small plantings or spot sprays, add the required amount of Entrust SC to the specified amount of water, mix thoroughly, and apply uniformly to plant foliage to the point of runoff. To accurately measure the required amount of Entrust SC, a graduated cylinder is required, allowing measurements of volumes to the nearest one-tenth of a milliliter. Alternatively, a scale can be used to measure weights to the nearest one-tenth of a gram. Mixing only as much spray as needed for a single treatment is recommended. Do not use more than 3 gallons of spray per 1000 sq ft of area. Follow all other label instructions for mixing and application.

	milliliters (mL) or grams (g)		
Entrust SC, fl oz/acre	**per gallon of spray**	**per 3 gallons of spray or 1000 sq ft**	**per 5 gallons of spray**
2	0.5	1.4	2.3
3	0.7	2.0	3.4
4	0.9	2.7	4.5
5	1.1	3.4	5.7
6	1.4	4.1	6.8
7	1.6	4.8	7.9
8	1.8	5.4	9.1
9	2.0	6.1	10.2
10	2.3	6.8	11.3

According to the manufacturer, the rate of 7 fluid ounces per acre is equivalent to 1 teaspoon per 1,000 square feet. Dow. (2012)

Studies have shown that some populations of the diamondback moth have developed resistance when Entrust is used intensively (Zhao et al. 2002), so resistance management should be practiced. Avoid applications of Entrust on consecutive pest generations. Alternate sprays with other effective products, and implement cultural controls. The Entrust label has detailed instructions for resistance management.

Many crops have maximum yearly application restrictions. See the label for specific information.

REENTRY INTERVAL (REI): 4 hours.

EFFECTS ON THE ENVIRONMENT

Leaf persistence: Spinosad is partly taken up by leaf tissue, which enhances its effectiveness over time. Dry surface residues do little harm to non-plant feeding insects. Spinosad residues on the leaf surface are broken down by sunlight. Half-lives for spinosyn A are 1.6 to 16 days, depending on the amount of sunlight received (Saunders & Brett 1997).

Fate in water: When spinosad is mixed with water, very little breakdown (hydrolysis) occurs; however, in water exposed to sunlight, photodegradation occurs rapidly (Saunders & Brett 1997). In the absence of sunlight, the half lives of spinosyn A and D are at least 200 days.

Soil Persistence: Soil microbes degrade spinosad into other spinosyns that can persist in the soil for several months and remain biologically active. Repeated applications could lead to some build-up of spinosyns in soil. A 10-month field study in California and Mississippi showed that no degradation products were found in soil below 24 inches (Saunders & Brett 1997). Leaching: Spinosyn A is more water-soluble than spinosyn D; therefore, it was the subject of soil mobility studies. Research showed that spinosyn A and its soil metabolites bind to soil and have low soil mobility.

Wildlife: Spinosad shows slight toxicity to birds, moderate toxicity to fish, and slight to moderate toxicity to aquatic invertebrates. In laboratory tests, it was highly toxic to bees, oysters (US EPA 1997 a,b), and other marine mollusks (Dow 2001).

Beneficial insects: Care must be taken when applying spinosad while honeybees are foraging; after residues dry (a few hours), it is far less toxic to bees (Bret et al. 1997). Direct contact with spray droplets can also harm Trichogramma wasps and other parasitoids (Bret et al. 1997; Suh et al. 2000; Tillman & Mullrooney 2000). However, once the deposits dry, they are generally safe for beneficial insects. Studies in sweet corn have shown spinosad to be very effective against the European corn borer while conserving its natural enemy complex (Musser and Shelton, 2003).

Other non-targets: Effects of spinosad on earthworms and soil microorganisms have been investigated in the laboratory. Results indicated that application rates of 25-150 g/ha should not cause significant effect on soil microflora respiration. Earthworms were not very susceptible to spinosad (LD50 > 970 mg/kg) (Jachetta 2001). There is little research on the impact of spinosad on insect soil detritivores and their predators, including ants and springtails. However, since some spinosad products are targeted against fire ants, a soil dwelling species, it is likely that there would be some impact against other soil fauna.

EFFECTS ON HUMAN HEALTH:

Acute toxicity: Spinosad has very low acute mammalian toxicity. The oral LD50 in rats is 3,738 mg/kg in males and >5,000 mg/kg in females. According to an EPA factsheet (US EPA 1997 b), acute dermal dose in rabbits is >2,000 mg/kg. The rat inhalation LC50 is >5.18 mg/liter (US EPA 1997b; Jachetta 2001; Dow 1997).

Metabolism: Spinosad is rapidly absorbed and extensively metabolized in rats. Within 48 hours of ingestion, 60-80% of spinosad or its metabolites are excreted through urine or feces (US EPA 1997a, b; Dow 1997).

Chronic Toxicity: Thirteen-week dietary studies showed no-effect levels of 4.98 mg/kg/day in dogs, 6 mg/kg/day in mice, and 8.6 mg/kg/day in cats. No dermal or systemic toxicity occurred in a 21-day repeated dose dermal toxicity study in rabbits of 1,000 mg/kg/day. Based on these data, the EPA set the reference dose in humans at 0.0268 mg/kg/day. Presumably, daily doses of this amount would cause no harm (US EPA 1997b).

Cancer and Developmental: There was no evidence of carcinogenicity in two rodent species at any dose tested. Mutagenic studies showed no mutagenic activity. There were no effects on normal development in rats or rabbits, even at the highest dose tested.

Neurotoxicity: Spinosad did not cause neurotoxicity in rats in acute, subchronic, or chronic toxicity studies (EPA 1997b). There may be some effects on the GABA and other nervous systems (Thompson et al. 2000; Salgado 1997; Salgado et al. 1998a, b).

EFFICACY

Spinosad is principally toxic to plant-eating insects in the orders Lepidoptera (caterpillars), Coleoptera (beetles), Thysanoptera (thrips), and Diptera (flies). It is not a plant systemic, but will penetrate leaves to some extent and, therefore, has activity against some leafminers. Spinosad is not effective at controlling mites at normal use rates (Thompson et al. 2000; Cowles et al. 2000; Tjosvold & Chaney 2001), although at high rates or in combination with some adjuvants, it has miticidal activity (Gilrein 2004).

PEST SPECIFIC OBSERVATIONS

Colorado potato beetle

Spinosad shows very good control of all larval stages. Eggs and adults are virtually unaffected.

Flea Beetles

The few published studies show poor to intermediate efficacy; however, replicated lab studies show good control of cabbage flea beetles (Andersen 2006). Since populations tend to reestablish themselves a few days after application, several applications may be needed.

Striped and Spotted Cucumber Beetle
Spinosad has shown poor to intermediate efficacy with very few published studies.

Caterpillars (*Lepidoptera*)
Spinosad shows very good control of most pests.

Thrips (*Thysanoptera*)
The efficacy of spinosad is variable among crops and thrips species. Western flower thrips and onion thrips are susceptible to spinosad.

Aphids, whiteflies, leafhoppers (*Homoptera*):
Spinosad shows variable control of aphids. One study shows good control of whiteflies. One shows poor control of potato leafhopper; more trials are needed.

True bugs (*Hemiptera*)
Spinosad exhibits poor control for true bugs on various crops.
A summary of recent university field trials of spinosad products on vegetable crops commonly grown in the Northeast was compiled. These university-based trials typically test products under unusually severe pest pressure.

In Figure 1, "good control" means statistically significant reductions in either pest numbers or damage of 75% or more, compared to an untreated control. "Fair control" includes those with significant reductions of 50-74% and any non-significant reductions of over 50%. The "poor control" group includes any results with less than 50% reduction.

Species that performed similarly are grouped in Figure 1 below:

1. Green peach and potato aphids.
2. Common armyworm, beet armyworm, fall armyworm, corn earworm, cabbage looper, imported cabbageworm, diamondback moth, European corn borer, tomato hornworm, tomato pinworm, tomato fruitworm, and squash vine borer.
3. Stink bugs, harlequin bug, and lygus bug.
4. One trial demonstrating poor efficacy was found for each of the following: sap beetle, striped cucumber beetle, pepper maggot fly, two spotted spider mite, potato psyllid, and potato leafhopper.

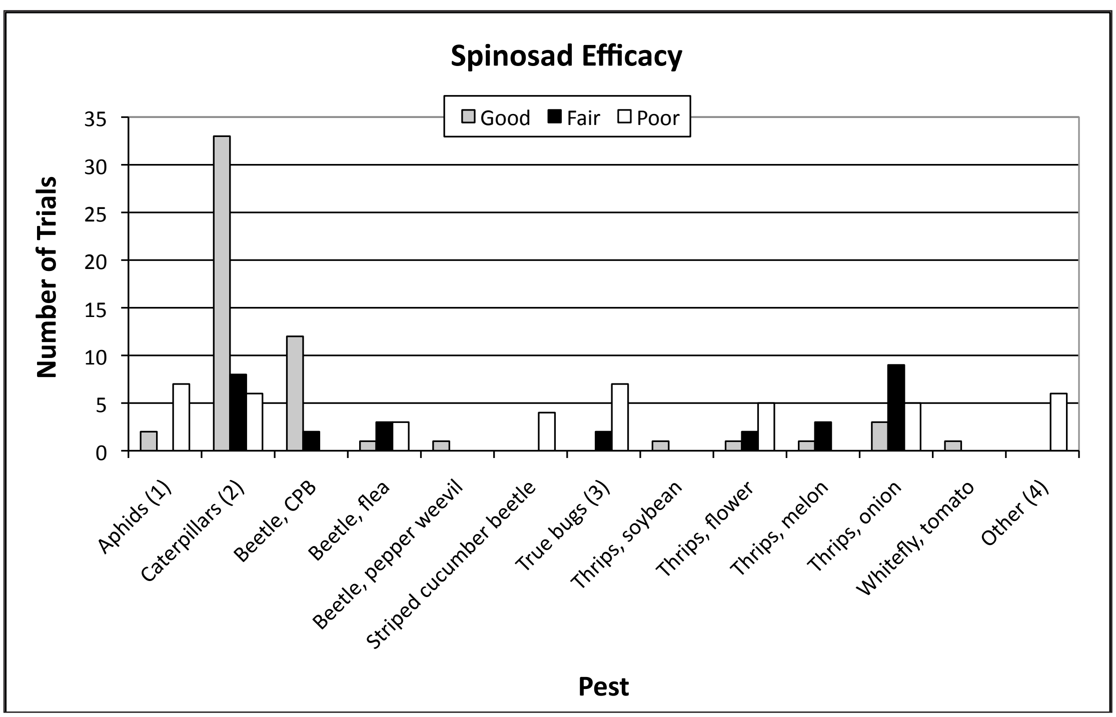

Figure 1. Efficacy of spinosad against insect pests.

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MATERIAL FACT SHEET
Streptomyces lydicus

MATERIAL NAME: *Streptomyces lydicus*

MATERIAL TYPE: Microbial

U.S EPA TOXICITY CATEGORY: IV, "Caution"

USDA-NOP
Considered non-synthetic, allowed. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION
Streptomyces lydicus is a ubiquitous, naturally occurring bacterium that is commonly found in soil. The isolate WYEC 108 has been commercialized as an antifungal agent for greenhouse, nursery, turf, and agricultural uses. It was isolated from a linseed plant growing in a soil that exhibited natural suppression of root pathogens. The commercial product is a soluble powder that contains *S. lydicus* spores and proprietary inert ingredients.

HOW IT WORKS
S. lydicus colonizes plant roots, competing with root pathogens for physical space and nutrients exuded by the roots. Foliar applications result in colonization of aboveground plant parts. It may act as a parasite of fungal plant pathogens. Other possible modes of action include production of antibiotics, antifungal compounds, and enzymes that digest the cell walls of fungi. Root colonization by *S. lydicus* is reported to increase plant vigor through the production of siderophores, compounds that convert iron to a form more easily absorbed by plants. In peas, it has been shown to colonize the surface of developing root nodules and improve the vigor of nitrogen fixing *Rhizobium* bacteria in the nodules by increasing availability of iron (and possibly other minerals) (Tokala et al. 2002).

TYPES OF PESTS IT CONTROLS
Product labels indicate soil drench and seed treatment applications for suppression of root rot and damping-off pathogens, such as *Fusarium, Rhizoctonia, Pythium, Phytophthora, Phymatotrichum omnivorum* (cotton root rot), *Aphanomyces, Monosporascus, Armillaria, Sclerotinia, Gaeumannomyces, Postia, Verticillium,* and *Geotrichum*. Foliar applications are intended to provide suppression or control of powdery and downy mildews, *Botrytis, Monilinia, Anthracnose*, *Mycosphaerella citri* (greasy spot of citrus), *Sclerotinia, Alternaria, and Erwinia*.

FORMULATIONS AND APPLICATION GUIDELINES
Products are formulated as soluble powders and have a shelf life of at least one year. Refrigeration may extend shelf life. They may be applied as soil treatments (e.g., drench, in furrow), foliar applications, and bulb dusting treatments. Seed treatment may be applied as dry hopper-box, mist, or slurry. Soil drenches may be applied through irrigation systems to potting media or field soil. Irrigation systems connected to public water systems must be equipped with a functional back-flow prevention system. Soil applications should begin at an early stage of plant development to optimize root colonization. Foliar applications should begin prior to the onset of disease and repeated every 7-14 days, depending on disease pressure and how favorable environmental conditions are for disease progress. Spreader-stickers are recommended for foliar applications. Actinovate products (currently the only OMRI listed products that contain *S. lydicus)* are completely soluble and do not require tank agitation. They can also be tank mixed with many fungicides, insecticides, and fertilizers unless otherwise restricted. Actinovate is not compatible with sulfur (Fernandez et al. 2011).

OMRI LISTED PRODUCTS

Actinovate for Lawn and Gardens (Natural Industries, Inc.)
Actinovate AG (for agricultural uses) (Natural Industries, Inc.)
Actinovate SP (for greenhouse, nursery, and landscapes) (Natural Industries, Inc.)
Actinovate STP (for seed treatment) (Natural Industries, Inc.)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings." after the product listing.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL

REI is one hour for foliar applications.
Actinovate may be applied up to and including the day of harvest.

AVAILABILITY AND SOURCES

Products are available through commercial agricultural suppliers and online.

EFFECT ON THE ENVIRONMENT

There are no reports of birds, mammals, or insects serving as hosts for *S. lydicus*. Testing of non-target organisms such as birds and mammals was waived by US EPA because *S. lydicus* is ubiquitous in the soil, and applications at label rates are unlikely to significantly increase exposures. *S. lydicus* was determined to pose no risk to aquatic organisms because spore viability was reduced by 80% after 96 hours in rainbow trout exposure studies, and naturally-occurring Streptomyces species have been reported from marine sediments. *S. lydicus* is not a known pathogen on any plant species.

EFFECT ON HUMAN HEALTH

Because *S. lydicus* is a common, well-characterized, naturally occurring soil bacterium, US EPA required limited data for registration of the Actinovate products. *S. lydicus* has no known animal hosts, and rat studies show that the WYEC108 strain is not toxic, infective, or pathogenic to rats via oral ingestion, inhalation, or direct injection exposures. Eye and dermal irritation studies showed that *S. lydicus* is non-irritating. Because repeated exposures to high concentrations of microbial proteins can cause allergic sensitization, applicators must wear a dust/mist filtering respirator that meets NIOSH standards of at least N-95, R-95, or P-95. US EPA has made a determination of reasonable certainty of no harm to the US population and established a permanent tolerance exemption for residues on all agricultural commodities when used in accordance with label directions.

EFFICACY

The trials summarized below are mainly from the online publication *Plant Disease Management Reports* and its predecessor journals. Trials conducted between 2000 and 2011 were included.

Because university trials are often conducted in fields with intentionally high levels of disease inoculum, and untreated control and ineffective treatments may be producing secondary inoculum, the level of pest control obtainable is likely to be higher than shown, especially on completely treated fields in which a good program of cultural controls has also been implemented.

In Figures 1 and 2, "good control" includes studies that showed statistically significant reductions in pest levels of more than 75%. "Fair control" includes any non-significant reductions over 50% and significant reductions between 50 and 75%. "Poor control" includes results with less than 50% control. The Y-axis refers to the number of studies conducted.

S. lydicus has been tested against root and foliar pathogens in numerous vegetable crops (Figure 1). Results have fallen mainly into the "Poor" category of control, with the exception of one "Fair" result against root knot nematode in pumpkin and one "Good" and one "Fair" result against Fusarium surface rot in sweet potato.

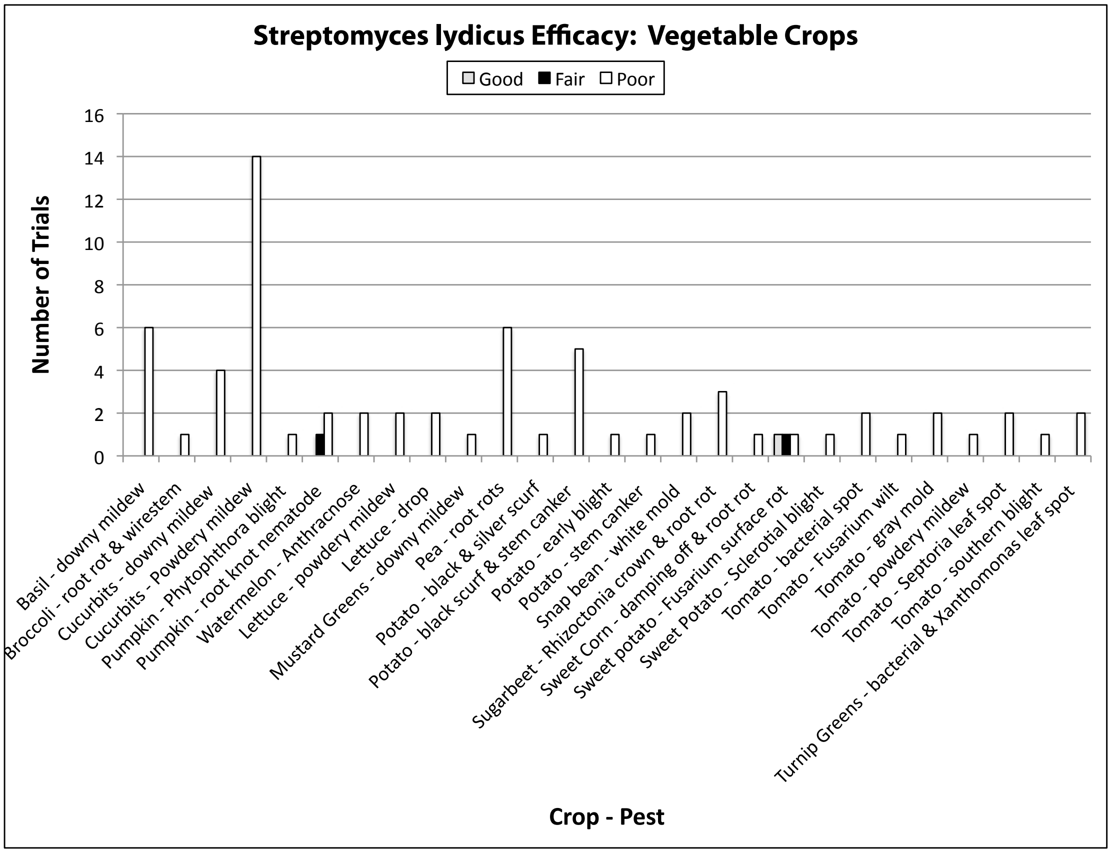

Figure 1. Efficacy of *S. lydicus* against diseases of vegetable crops

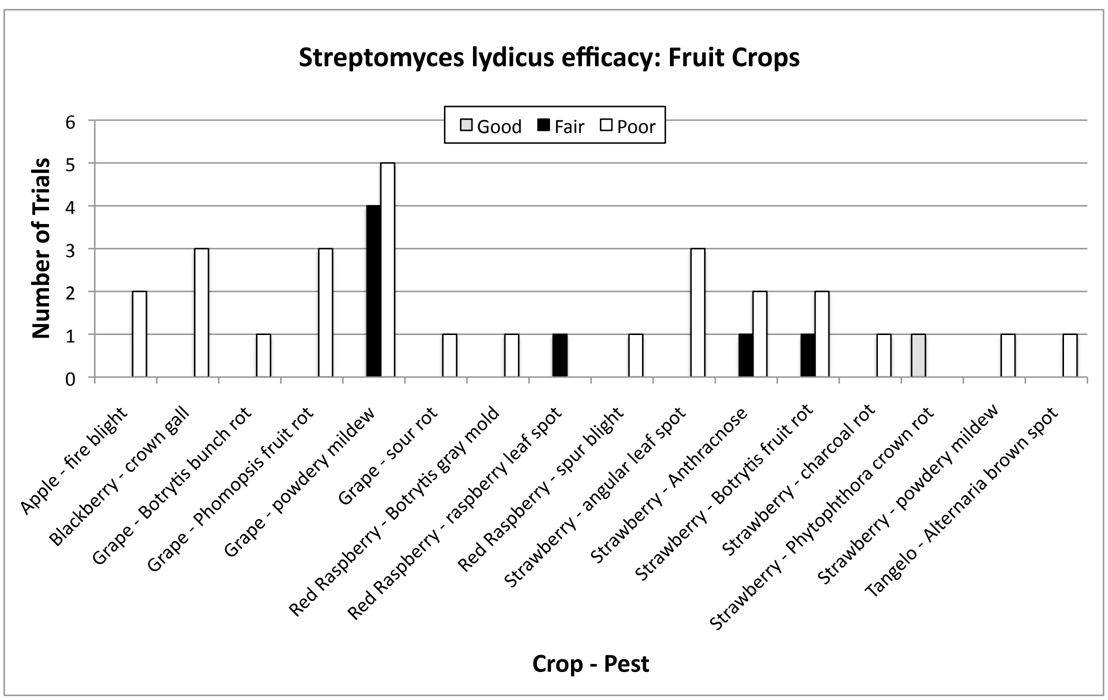

Figure 2. Efficacy of *S. lydicus* against diseases of fruit crops.

Trials in fruit crops have also shown mostly "Poor" results. However, four of nine trials against grape powdery mildew showed "Fair" results. One trial each against raspberry leaf spot and strawberry Anthracnose showed "Fair" results, and one trial against Phytophthora crown rot in strawberry showed "Good" results.

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MATERIAL FACT SHEET
Sulfur

MATERIAL NAME: Elemental sulfur, Lime sulfur

MATERIAL TYPE: Element

U.S EPA TOXICITY CATEGORY: Elemental sulfur: III, "Caution", Lime sulfur: I, "Danger"

USDA-NOP
Both sulfur and lime sulfur (aka calcium polysulfide) are considered to be allowed, synthetic materials; their use is regulated in certified organic production. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological or botanical material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION
Sulfur is one of the oldest known pesticides, cited by the Greek poet Homer in approximately 1000 B.C.E for its "pest averting" properties (Horsfall 1945). In its native state, it is a bright yellow crystalline solid. It was first recommended for control of plant diseases in the early 19th century and was widely used until the introduction of Bordeaux mixture in the 1870's. For a time, Bordeaux was the main fungicide until sulfur regained its position in the early 20th century. It is still widely used against powdery mildews and mites in grapes and other crops.

Lime sulfur is a mixture of calcium polysulfides created by boiling lime and sulfur together. It is an orange liquid with a strong rotting egg odor. It is also one of the earliest known fungicides, used against peach leaf curl in 1888 (Horsfall 1945). Lime sulfur is more toxic to fungi and has more potential for phytotoxicity than elemental sulfur.

HOW IT WORKS
As a fungicide, both sulfur and lime sulfur inhibit spore germination and growth in a number of fungal plant pathogens, likely by permeating the cell wall and interfering with important metabolic processes (Williams & Cooper 2004). Sulfur is a protectant; therefore, it must be applied before the pathogen comes into contact with the leaf in order to be effective. However, lime sulfur has a "kickback" effect against apple scab, providing some control when applied within 72 hours after an infection period. Sulfur has also been identified as a component of the induced defense mechanisms of some plants, accumulating in the xylem at levels toxic to some vascular pathogens. Sulfur fertilization has been associated with increased host resistance in some host/pathogen interactions (Williams & Cooper 2004). Soil application of sulfur, either as ammonium or potassium sulfate or elemental sulfur, has been used to reduce scab (caused by *Streptomyces scabies*) and black scurf (*Rhizoctonia solani*) on potato, Rhizoctonia root rot in beet, and Streptomyces soil rot on sweet potato. The mechanism for control has generally been thought to be the acidifying effect of sulfur and the intolerance of these soil-borne pathogens to low pH (Oswald & Wright 1950). More recent studies suggest that sulfur also increases microbial biodiversity and antibiosis (an association between two organisms that is detrimental to one of them) against *Streptomyces scabies* in the soil (Sturtz et al. 2004) and increases host plant resistance to *Rhizoctonia solani* in potato (Klikocka et al. 2005).

As an acaricide (mite-killer), the mode of action of sulfur is not well understood. Its impact on pest mites is influenced by temperature and relative humidity, with efficacy increasing with higher temperature and relative humidity (Auger et al. 2003).

TYPES OF PESTS IT CONTROLS*

ELEMENTAL SULFUR (Foliar application)
Diseases
Apple scab
Bean rust
Brown rot of stone fruits
Cherry leaf spot
Peanut rust
Pear scab
Powdery mildews of many crops
Rusts
Scab of peach

Mites and Insects
Spider mites on many vegetable and fruit crops
Tomato russet mite
Broad mite
Thrips on citrus

ELEMENTAL SULFUR (Soil application)
Potato scab
Sweet potato scab
Rhizoctonia (potato and beet)

LIME SULFUR DORMANT APPLICATION
Diseases
Coryneum (shothole blight) blight of stone fruits
Peach leaf curl

Mites and Insects
Overwintering aphid eggs
Blister mite
Brown mite
European red mite on pome fruits
Mealy bug
Pear psylla
Rust mite
San Jose scale

LIME SULFUR POST-DORMANT OR FOLIAR APPLICATION
Diseases
Apple scab
Anthracnose cane blight (brambles and grapes)
Sooty blotch on apple
Brooks leaf spot (apple)
Phomopsis cane and twig blight (grape)
Powdery mildew (many crops)

Mites and Insects
Rust mite
Blister mite
Brown mite

*Check individual product labels for specific pests.

FORMULATIONS AND APPLICATION GUIDELINES

Formulations of elemental sulfur include dry flowable, water-dispersible granules, soluble concentrates, and wettable powders. Smaller sulfur particles have been shown to be more toxic to fungi in numerous trials (summarized in Horsfall 1956) and to better adhere to leaf surfaces (Feichtmeyer 1949). Finely ground sulfur for dusting is made flowable by the addition of clay, talc, gypsum, or other materials. Micronized sulfur is ground to especially fine particles (4-5 microns). Colloidal sulfurs are even smaller particles produced by several possible methods, including acidifying lime sulfur solutions. Flowable sulfur is a microfine sulfur formulated in an aqueous suspension.

Elemental sulfur may cause phytotoxicity at high temperatures; it should not be used if temperatures are forecasted to be above 90° F within three days following application. It should not be applied within two weeks of an oil application. It may cause toxicity in sensitive plants, including some varieties of grapes; apples and pears; cranberries; apricots; certain varieties of cucurbits, particularly melons; filberts; and spinach. Test a few plants of each cultivar in sensitive families before applying sulfur to the entire crop.

Sulfur dust suspended in air ignites easily. Keep away from heat, sparks, and flame. Do not smoke while applying.

Elemental sulfur is also formulated with other pest management materials, namely Bt (*Bacillus thuringiensis*) and fixed coppers. These formulations have generally not been tested in university trials and are not included in the efficacy information supplied below.

Lime sulfur is a liquid. It has a strong potential for phytotoxicity. It is used as a dormant application to fruit trees to control fungal and bacterial pathogens, mites, and scale insects. During the growing season, it is also used at lower rates to control several fungal pathogens. It can be used as a spray crop thinner in apples during and shortly after bloom, usually in conjunction with oil. With this usage, lime sulfur's phytotoxic effect reduces photosynthesis and stresses the trees, resulting in the abscission of some fruitlets (Schupp et al. 2006).

CROPS AND VARIETIES THAT MAY BE INJURED BY SULFUR

D'Anjou pears
Comice pears
MacIntosh apple
Jonathan apple
Golden Delicious apple
Concord grape and some other labrusca varieties
cranberries
apricots
certain varieties of cucurbits, particularly melons
certain varieties of beans
filberts
spinach

OMRI LISTED PRODUCTS

Elemental Sulfur

- BT 320 Sulfur 25 Dust (Wilbur-Ellis Company)
- Cosavet DF (Sulfur Mills, Ltd)
- CSC Copper Sulfur Dust Fungicide (Martin Operating Partnerships, LP)
- CSC Dusting Sulfur (Martin Operating Partnerships, LP)
- Dusting sulfur (Wilbur-Ellis Company)
- Dusting Sulfur Fungicide-Insecticide (Loveland Products, Inc.)
- Golden Micronized Sulfur (Wilbur-Ellis Company)
- IAP Dusting Sulfur (Independent Agribusiness Professionals)
- Integro Magnetic Sulfur Dust (Integro, Inc.)
- Kumulus DF (Arysta LifeScience North America Corporation and BASF Sparks, LLC)

Micro Sulf (NuFarm Americas, Inc.)
Microthiol Disperss (United Phosphorus Inc.)
PHT Copper Sulfur Dust (J.R. Simplot Company)
pht Bt 25 Sulfur Dust (Britz-Simplot Grower Solutions LLC)
pht Copper Sulfur 15-25 Dust (Britz-Simplot Grower Solutions LLC)
pht Dryout Dust (Britz-Simplot Grower Solutions LLC)
Proganic Micronized Sulfur (Wilbur-Ellis Company)
ProNatural Micronized Sulfur (Wilbur-Ellis Company)
Safer Brand 3-in-1 Concentrate II (Woodstream Corporation)
Safer Brand 3-in-1 Garden Spray II (Woodstream Corporation)
Special Electric (Wilbur-Ellis Company)
Sulfur DF (Wilbur-Ellis Company)
Wilbur-Ellis Ben-Sul 85 (Wilbur-Ellis Company)

Lime Sulfur
Rex Lime Sulfur Solution (OR-Cal, Inc.)
Tetrasul 4s5 (OR-Cal, Inc.)
References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings." after product list.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL
Elemental sulfur REI 24 hours, PHI 0 days
Lime sulfur REI 48 hours, PHI 0 days

AVAILABILITY AND SOURCES
Sulfur and lime sulfur are widely available from agricultural suppliers and through mail order.

EFFECT ON THE ENVIRONMENT
In its elemental reduced or oxidized forms, sulfur represents approximately 1.9% of the total weight of the earth. Most aquatic and terrestrial environments are high in sulfur (Extoxnet 1995). Sulfur is an essential macronutrient for crop production, and it is allowed by the NOP as a soil amendment for crop fertility. As mentioned above, sulfur fertility status has been associated with increased crop resistance to some pathogens. Since the reduction of sulfur air pollutants, some areas of the world are experiencing soil sulfur deficiencies.

Wildlife
Elemental sulfur is considered non-toxic to birds, aquatic organisms, and honeybees (Extoxnet 1995). The acidifying effects of sulfur on soil have been reported to cause declines in earthworm populations. Carcamo et al. (1998) found an absence of earthworms in sulfur-contaminated soil close to a natural gas processing plant. Earthworms were virtually eliminated at sulfur levels in the soil of 6673 mg/kg (pH 2.85) at a distance of 50 m from the source, increasing only slightly as the pH rose to 5.39 at 250 m. Sulfur is used on turf for decreasing earthworm numbers to manage earthworm castings on golf course fairways. In one study, applications of ammonium or ferrous sulfate over a two-year period lowered pH and reduced castings compared with an untreated control (Backman et al. 2001). Sulfur levels high enough to decrease soil pH are not likely from foliar applications for disease or insect management, but the pH levels associated with soil applications for scab control in potato are in the range reported to reduce earthworm populations.

Natural enemies
While elemental sulfur has generally been thought to be detrimental to natural enemies, especially predaceous mites, an examination of the literature reveals a wide range of impacts. Studies looking at impacts on predaceous mites have found both strong negative (Prischmann et al. 2005) and negligible (Costello 2007; Stavrinides & Mills 2008) impacts on *Galindromus occidentalis*, moderate impacts on *Euseius mesembrinus* (Childers et al. 2001), and negligible impacts on *Typhlodromus pyri* (Zacharda & Hluchy 1991) and *Anystis baccarum* (Laurin & Bostanian 2007).

Bernard et al (2010) found minor detrimental effects against *G. occidentalis* and *Euseius victoriensis* at a rate of 200 g/100 liters, but a high level of toxicity at 400g/100 liters. In other insect orders, Martinson et al. (2001) found sulfur to be highly toxic to *Anagrus* parasitoids of grape leafhopper. Guven and Goven (2002) found low toxicity to green lacewing (*Chrysopa carnea*) in the lab.

Given such variable research results, general statements about the impact of sulfur on natural enemies are not possible. Negative impacts are possible and may depend on the type of natural enemy and level of exposure. The level of impact on natural enemies may be influenced similar to the way that efficacy against pest mites is influenced by temperature and relative humidity.

EFFECT ON HUMAN HEALTH

Elemental sulfur is known to be of low toxicity to humans and poses very little, if any, risk to human and animal health. Short-term studies show that sulfur is of very low acute oral toxicity and does not irritate the skin; however, it can cause some eye irritation, dermal toxicity (toxicity that results from absorption through skin), and inhalation hazards. Acute exposure inhalation of large amounts of the dust may cause catarrhal inflammation of the nasal mucosa, which may lead to hyperplasia with abundant nasal secretions. No known risks of oncogenic, teratogenic, or reproductive effects are associated with the use of sulfur (Extoxnet 1995).

Lime sulfur can be fatal if inhaled, swallowed, or absorbed through the skin. It is extremely caustic and can cause irreversible eye damage and skin burns. If mixed with an acid, it may give off extremely toxic and flammable hydrogen sulfide gas (Meister & Sine 2009).

EFFICACY

Diseases

In Figures 1-4, "good control" includes studies that showed statistically significant reductions in pest levels of more than 75%. "Fair control" includes any non-significant reductions over 50% and significant reductions between 50 and 75%. "Poor control" includes results with less than 50% control. The Y-axis refers to number of studies in each efficacy category.

Elemental sulfur is most effective and widely used against powdery mildews (PM) in a variety of fruit and vegetable crops (Figs. 1 & 2). A review of 30 trials conducted on grapes found 19 resulting in greater than 75% reduction in disease compared with the untreated controls, with 11 of the trials above 90% control. Eleven of 22 trials conducted in cucurbits and 10 of 13 conducted

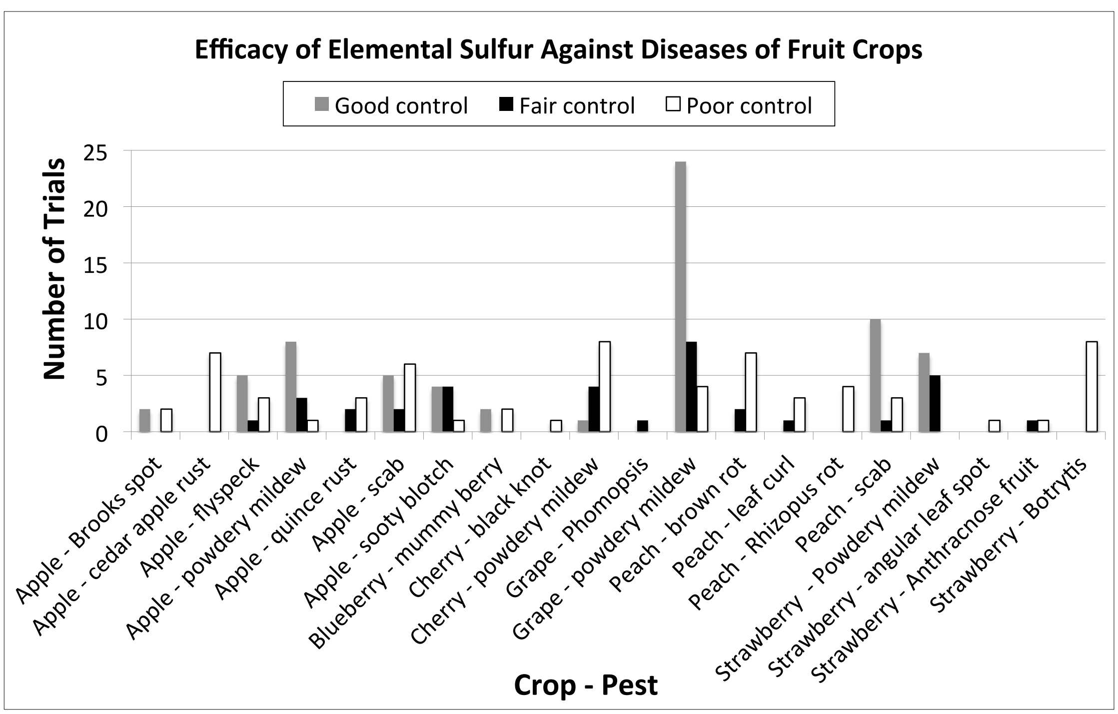

Figure 1. Efficacy of elemental sulfur against diseases of fruit crops.

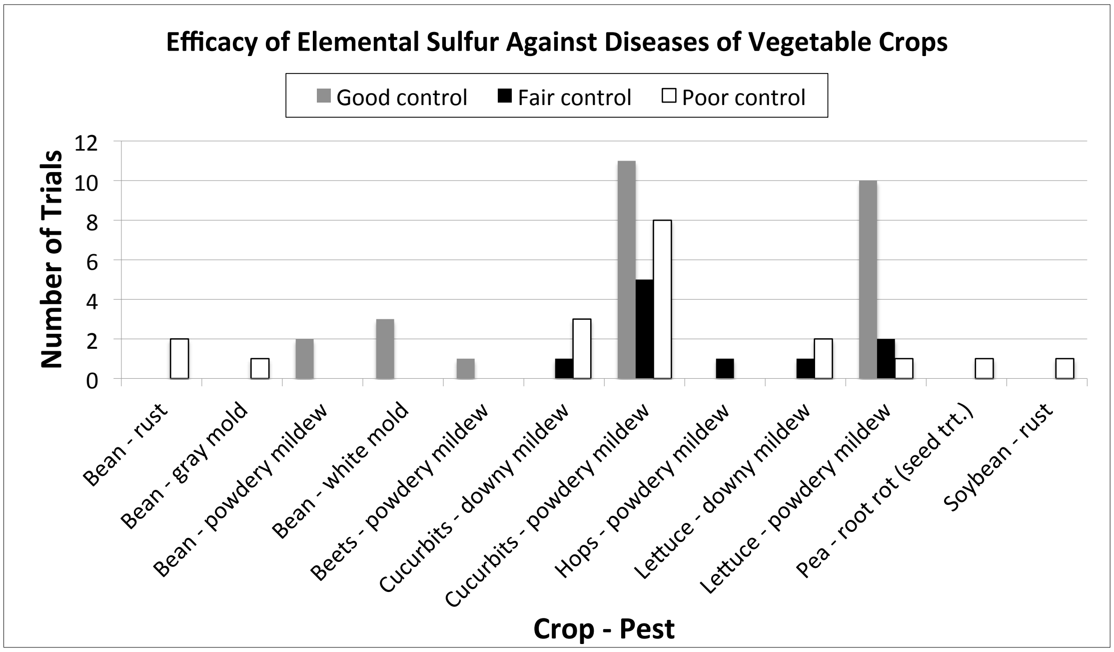

Figure 2. Efficacy of elemental sulfur against diseases of vegetable crops.

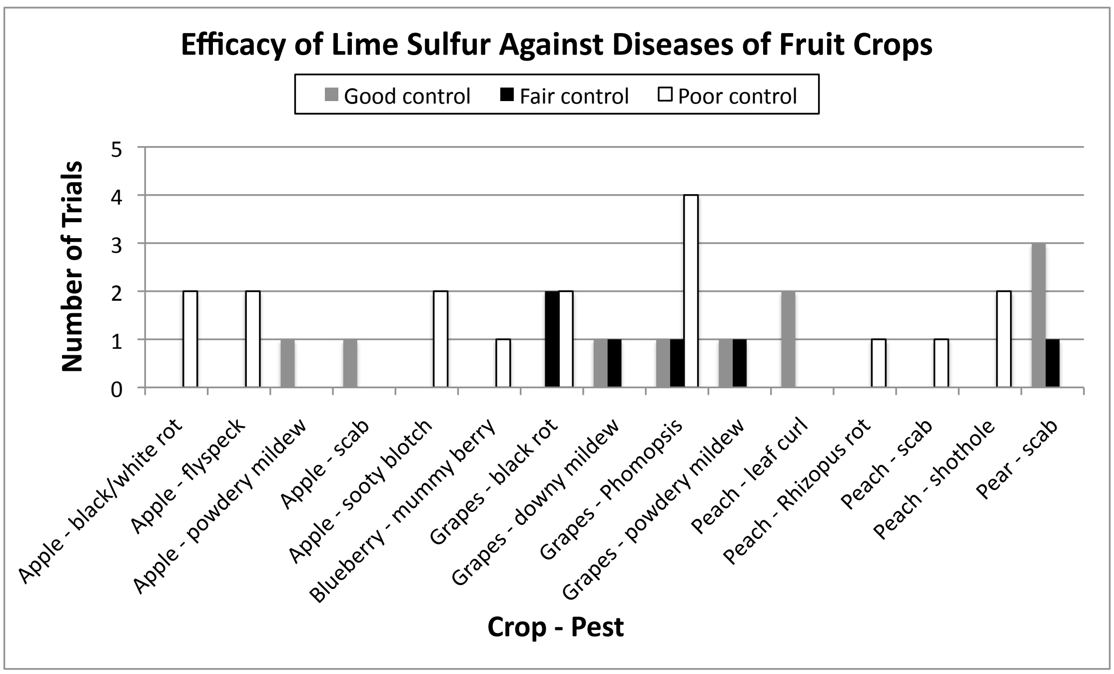

Figure 3. Efficacy of lime sulfur against diseases of fruit crops.

in lettuce had PM reductions of more than 75%. Powdery mildew control was also good in apple and strawberry. Sulfur was less effective against PM in cherry. A review of 12 apple scab trials found 4 with control levels above 75%. Three trials with poor results used a rate of only 1 lb. per acre. Most studies tested higher rates of 3-5 lb. per acre. In most trials, sulfur provided fair to good control of sooty blotch and flyspeck of apple, and good control of peach scab and white mold in beans. Elemental sulfur is ineffective against a variety of other plant pathogens, including peach leaf curl, angular leaf spot in strawberry, and bean rust and gray mold (*Botrytis*) in bean. Levels of Botrytis in strawberry and brown rot in peaches were actually increased by sulfur applications in some trials.

Lime sulfur can be effective against apple scab, pear scab, and peach leaf curl when applied early in the season (i.e., during dormancy or in the early stages of bud break) (Fig. 3). In two trials during the growing season, mixtures of lime sulfur and copper (not included in Figure 3)

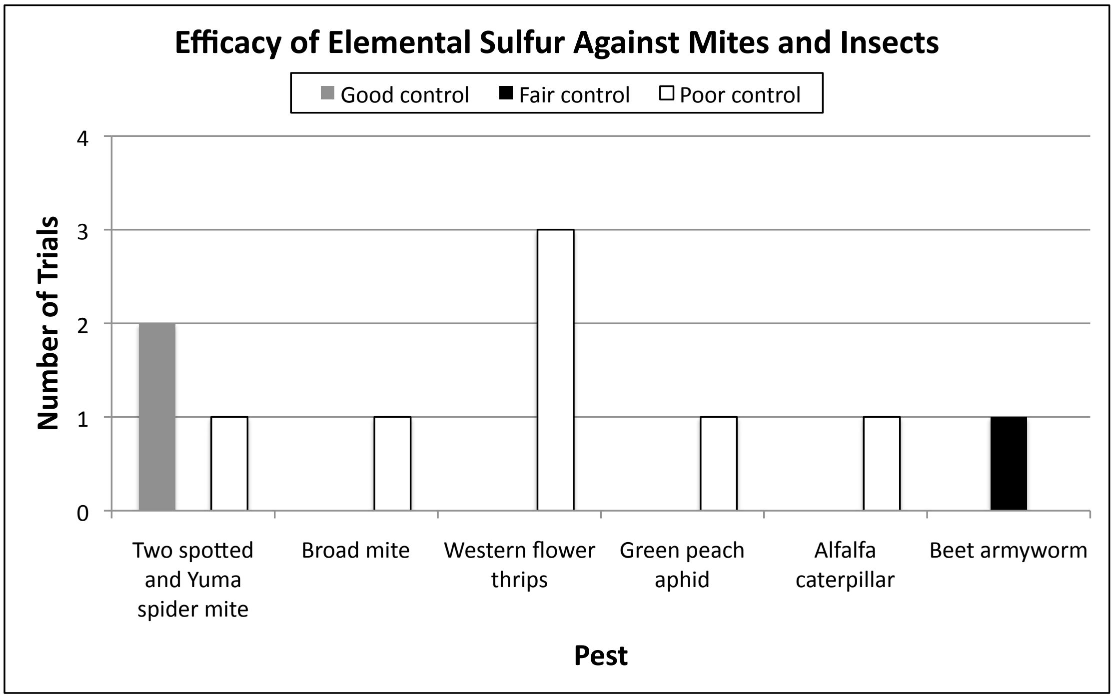

Figure 4. Efficacy of elemental sulfur against mites and insects.

showed good control of sooty blotch and fly speck in apple, but neither was tested separately to determine whether the effect was due to only one of the products.

Mites and Insects

Elemental sulfur showed good efficacy against spider mites in two of three trials, but it increased mite levels in the third (Figure 4). Sulfur applications for pest mite control need to be weighed against potential impact on predaceous mites in some systems. Sulfur was not effective against most other mites and insects tested, with the exception of beet armyworm in one trial.

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MATERIAL FACT SHEET
Trichoderma and related genera of beneficial fungi

MATERIAL NAME: Trichoderma and related genera of beneficial fungi.

MATERIAL TYPE: Microbial

U.S EPA TOXICITY CATEGORY: III, "Caution"

USDA-NOP
Considered non-synthetic, allowed. Preventive, cultural, mechanical, and physical methods must be first choice for pest control, and conditions for use of a biological material must be documented in the organic system plan (NOP 2000).

MATERIAL DESCRIPTION
Fungal species belonging to the genus *Trichoderma* are worldwide in occurrence and easily isolated from soil, decaying wood, and other forms of plant organic matter (Howell 2003). Recent advances in taxonomy have resulted in several name changes within the group. For example, *Gliocladium virens* is now *Trichoderma virens*, although *Gliocladium* is still commonly used to refer to this species, especially in Environmental Protection Agency (EPA) registration documentation. The biocontrol potential for *Trichoderma* species was first recognized in the early 1930's. These fungi grow rapidly in culture, producing thick-walled spores. Several species are produced commercially, formulated as products both to control plant diseases and to promote plant growth. Certain strains within a species are typically isolated for commercial production. Species currently* or formerly available in commercial formulations include:

*T. harzianum**
T. virens (*formerly *Gliocladium virens)*
T. lignorum
T. atroviride
T. polysporum
*T. asperellum and gamsii** mixtures
*Clonostachys roseum var. catenulatum (*formerly *Gliocladium catenulatum)*

HOW IT WORKS
Understanding of the mechanisms of disease suppression by *Trichoderma* species has evolved over the years. The growth of some crops is enhanced when roots are colonized by particular strains of *Trichoderma*, especially under stressful growing conditions. Conversely, crop growth can be inhibited in certain crops by particular strains of *Trichoderma*. The mechanisms for plant growth enhancement and inhibition are still not well understood. One or more mechanisms may be involved in disease suppression by *Trichoderma*. For example, certain species and strains of *Trichoderma* readily colonize the rhizosphere (i.e., root surface) of plants, competing with other organisms for nutrients and physical space. In some situations, *Trichoderma* sp. are able to parasitize other fungi and produce antibiotic compounds that are toxic to them. *Trichoderma* sp. produce some enzymes that compromise the integrity of cell walls in pathogenic fungi and others that disrupt the cell-destroying enzymes produced by pathogenic fungi. Research has demonstrated that none of these mechanisms are completely responsible for the ability of *Trichoderma* sp. to control plant diseases, although all may contribute either individually or synergistically (the combined effect is more than the sum of the individual) (Howell 2003).

Colonization of plant roots by *Trichoderma* sp. has been shown to induce plant defense responses, mobilizing compounds that make plants more resistant to pathogens. The most recent research indicates that this induced resistance response is responsible for most of the biocontrol activity exhibited by these species (Harman 2011). Other benefits of root colonization by *Trichoderma* and related organisms include enhanced plant resistance to stress, such as drought or salt buildup, and enhanced nitrogen use efficiency (Harman 2011).

Biocontrol and plant growth enhancement effects are specific to pathogen, beneficial and strain species, and plant cultivar. Beneficial effects in one pathogen/beneficial/cultivar system should not be expected in another system. In one study, tomato plants receiving *Trichoderma harzianum* soil treatments showed increased disease levels of bacterial speck, possibly as a result of a larger canopy that enhanced the microclimate for the disease. (Lange & Smart 2004). In other studies, tomato plants receiving a *Trichoderma harzianum* soil treatment showed reduced levels of the fungal disease early blight (Seaman 2003).

Some strains of *T. harzianum* are pathogenic on mushrooms, causing serious economic losses in commercial production.

TYPES OF PESTS IT CONTROLS

Most early work on Trichoderma focused on protection from root or tuber pathogens, such as Pythium, Fusarium, and Rhizoctonia, by treating seed, soil, or potting mix with formulations of fungal spores. As other mechanisms for protection from pathogens were discovered, foliar applications were tested for control of aboveground pathogens. As more is learned about the induced resistance response in plants, researchers are also looking at the control of aboveground pathogens by soil-applied treatments.

FORMULATIONS AND APPLICATION GUIDELINES

Spores of Trichoderma and related species are generally formulated in one of two ways: 1) as granules to be mixed with potting media or for in-furrow treatments, or 2) wettable powders to be mixed with water and used as potting media or soil drenches, in-furrow applications, seed treatments, or in irrigation water. Some products are labeled for foliar applications on ornamentals, but not currently for food crops. Optimizing beneficial effects depends on thorough colonization of the root system, so application at an early stage of plant development is important. These products will not be effective as "rescue" treatments in situations where inoculum or disease levels are high, and they work best as part of an overall integrated pest management strategy. Because they are living organisms, products have a shelf life of 6-12 months, depending on temperature, with longer shelf life at lower storage temperatures.

OMRI LISTED PRODUCTS

- BIO-TAM™ (AgraQuest, Inc.)
- Plant Shield® HC Biological Fungicide (BioWorks, Inc.)
- RootShield® Granules (BioWorks, Inc.)
- RootShield® Home & GardenBiological Fungicide (BioWorks, Inc.)
- SoilGard® 12 G Microbial Fungicide (Certis)
- T-22™ HC Biological Fungicide (BioWorks, Inc.)
- T-22™ Planter Box Biological Fungicide (BioWorks, Inc.)
- Tenet™ WP (Isagro USA)

References to OMRI listed products in this Guide are based on the 2012 edition of the OMRI Product List. Please consult www.omri.org for changes and updates in the brand name product listings." after product list.

REENTRY INTERVAL (REI) AND PRE-HARVEST INTERVAL

When used in enclosed environments, such as glasshouses and greenhouses, reentry interval is 0 hours. Such treatments include soil application via soil drench,
in-furrow spray, transplant starter solution, dip, soak, or chemigation.

For field applications: Keep unprotected persons out of treated areas until sprays have dried or dusts have settled. Pre-harvest interval is 0 days.

AVAILABILITY AND SOURCES

Products vary in their availability. Some are available online from seed or agricultural supply companies or directly from producers.

EFFECT ON THE ENVIRONMENT

Trichoderma and related species are ubiquitous in the environment, and their use in agriculture is not thought to pose a risk to the environment. They are not capable of growing in water so do not pose a risk to water systems. They are non-pathogenic to birds, mammals, fish, honeybees, or other beneficial insects.

EFFECT ON HUMAN HEALTH

Trichoderma species have low toxicity to humans through dermal or oral routes of exposure. The potential for inhalation and possible allergic response with long-term exposure does exist and is mitigated by requirements for personal protective equipment on product labels. Applicators and other handlers must wear protective eyewear, long sleeved shirts, long pants, waterproof gloves, shoes, and socks. Mixers/loaders and applicators must wear a dust/mist filtering respirator meeting NIOSH standards of at least N-95, R-95 or P-95. Repeated exposure to high concentrations of microbial proteins can cause allergic sensitization.

EFFICACY

The trials summarized below are mainly from the online publication *Plant Disease Management Reports* and its predecessor journals. Trials conducted between 2000 and 2011 were included.

Because university trials are often conducted in fields with intentionally high levels of disease inoculum, and untreated control and ineffective treatments may be producing secondary inoculum, the level of pest control obtainable is likely to be higher than shown, especially on completely treated fields in which a good program of cultural controls has also been implemented. In the case of Trichoderma products, applications that did not occur early enough in the plant/pathogen interaction may not provide maximum effectiveness.

In the figures below, "good control" includes studies that showed statistically significant reductions in pest levels of more than 75%. "Fair control" includes any non-significant

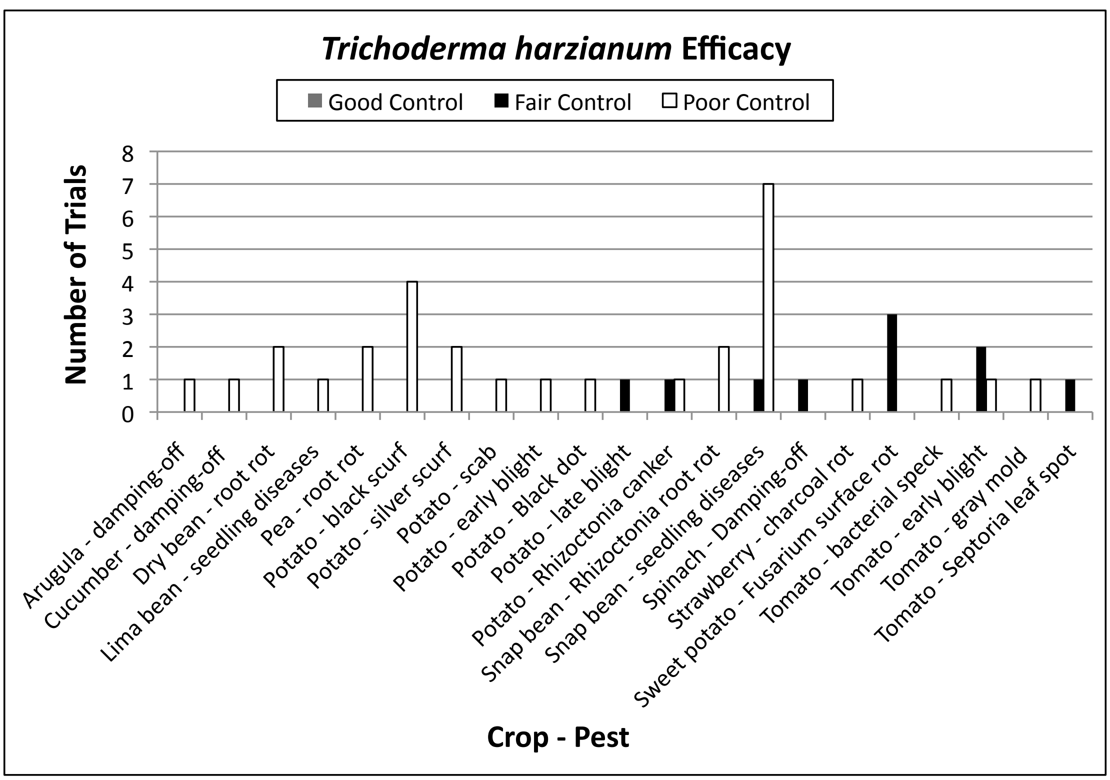

Figure 1. Efficacy of *T. harzianum.*

reductions over 50% and significant reductions between 50% and 75%. "Poor control" includes results with less than 50% control. The number of trials (Y-axis) refers to studies conducted between 2000-2010.

Soil and seed treatments with *T. harzianum* have been tested against a number of soil-borne pathogens, and foliar applications have been tested against late blight on potato and bacterial speck and gray mold on tomato with fair to poor results (Figure 1). Diseases for which fair control was observed include *Rhizoctonia* canker on potato with in-furrow application,

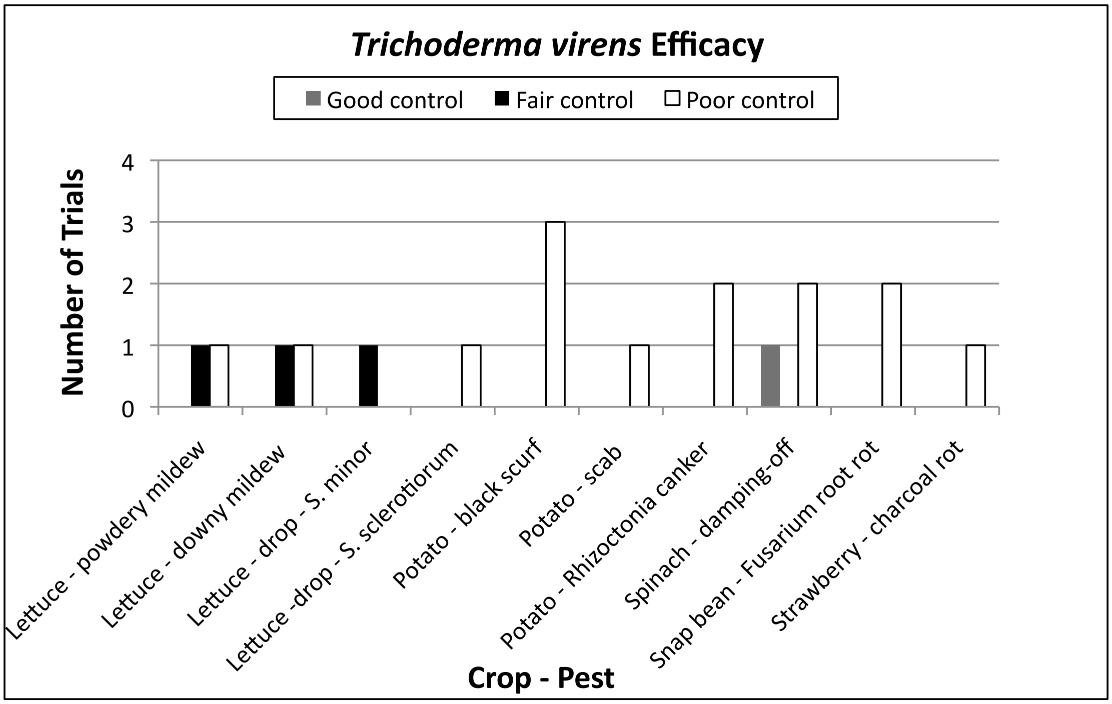

Figure 2. Efficacy of *T. virens*.

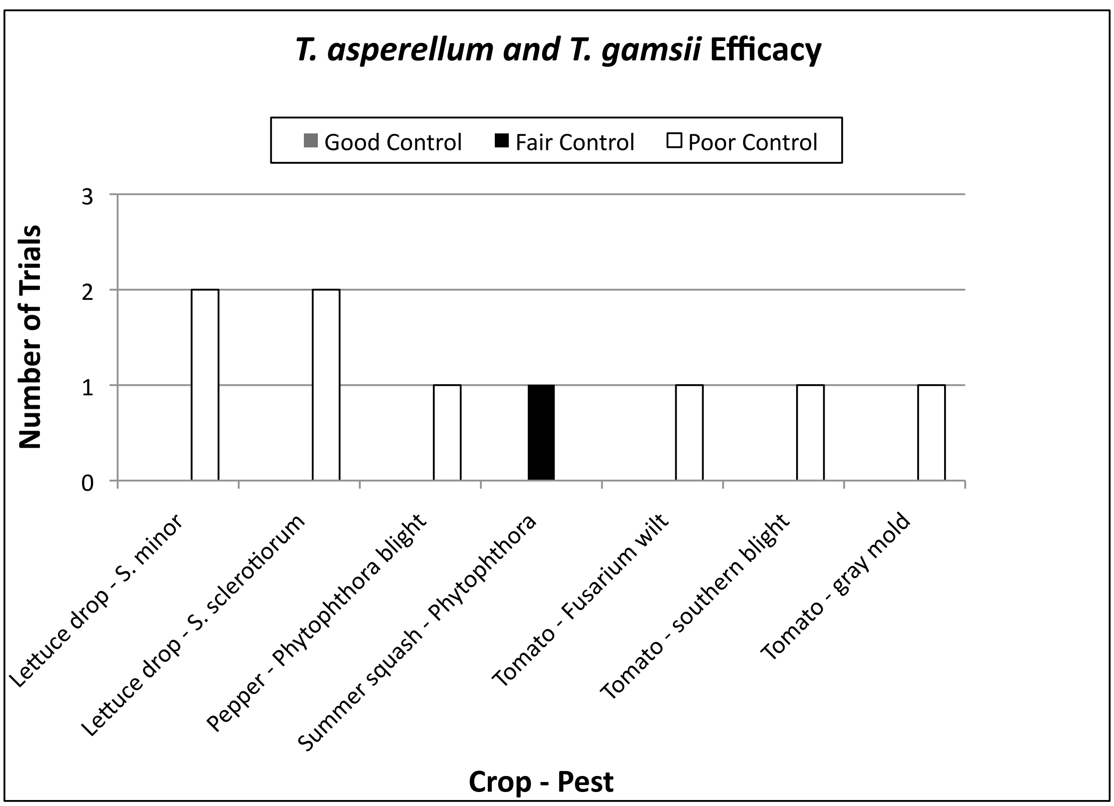

Figure 3. Efficacy of *T. asperellum* and *T. gamsii* mixtures.

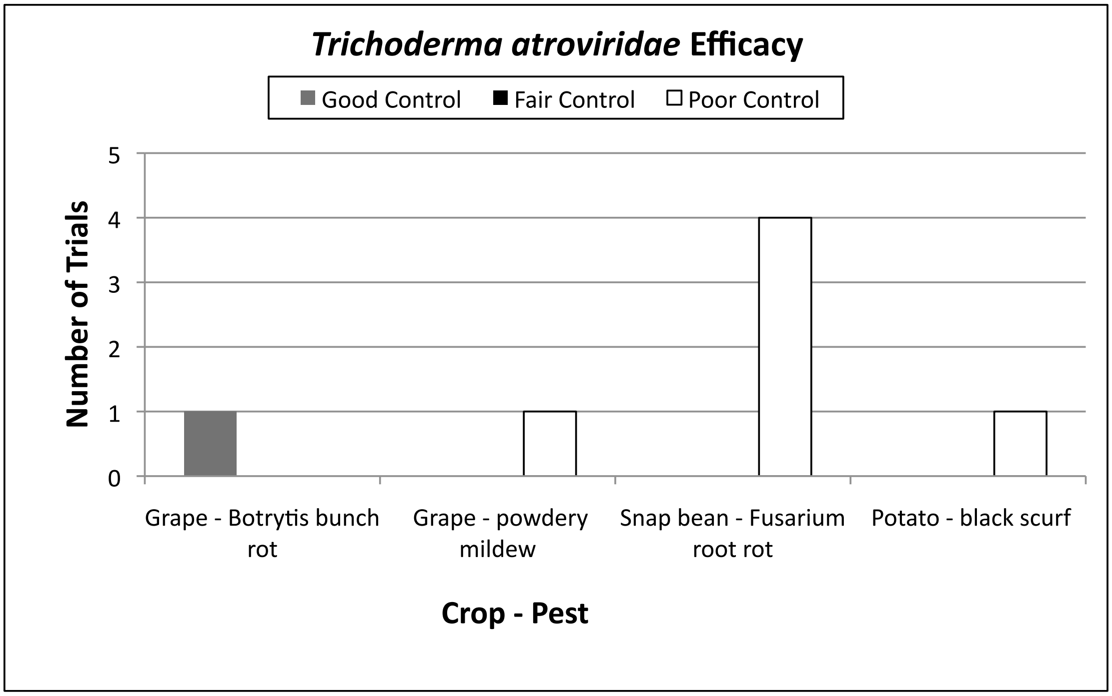

Figure 4. Efficacy of *T. atroviridae.*

Fusarium surface rot of sweet potato with post-harvest treatment, and late blight of potato with foliar application.

Seed and soil treatments with *Trichoderma virens* have been tested against soil-borne pathogens with mostly poor results; one exception was a "good" trial against damping-off in spinach. Foliar applications have been tested against powdery mildew, downy mildew, and Sclerotinia drop in lettuce with fair to poor results (Figure 2).

Products containing of mixtures of *Trichoderma asperellum* and *T. gamsii* have showed mostly poor results in soil and foliar applications against a number of pathogens, with the exception of one "fair" result against Phytophthora blight in summer squash (Figure 3).

Trichoderma atroviride has been tested as foliar applications against Botrytis bunch rot (good results) and downy mildew of grape (poor results). Results have been poor in soil applications and seed treatments against Fusarium root rot of snap beans and black scurf of potato (Figure 4).

Foliar applications of *Trichoderma lignorum* showed poor results against late blight in potato (one trial only). A soil drench of *Clonostachys roseum var. catenulatum* gave "fair" control in one trial against Fusarium root and stem rot in cucumber.

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APPENDIX A
Plant Resistance to Insects and Diseases

PLANT RESISTANCE TO INSECTS AND DISEASES

Selecting a plant variety with resistance or tolerance to insects or diseases may allow producers to avoid or reduce the use of pesticides and other management tactics. Seed catalogues and Cooperative Extension publications should be carefully examined to find varieties of plants that have resistance, or at least some level of tolerance, to the important pests in a given area. Field experience also helps one decide which varieties to grow and which ones are susceptible to insect and disease pests. Plant resistance should be considered a cornerstone for pest management for organic growers.

Commercial varieties of plants are rarely, if ever, resistant to all insects and diseases in a specific area, so identifying the pests that are most damaging and finding suitable, resistant varieties are important steps in pest control.

Successful breeding for insect and disease resistance has occurred in many different crop types, including vegetables, fruits, field crops, and ornamentals. Because field crops are considered low value crops in comparison with fruits and vegetables, control costs must be minimized; in these crops, host plant resistance breeding has had the most attention and success. As far back as the late 1700's, wheat varieties resistant to the Hessian fly were used in commercial plantings, and host plant resistance remains a major tactic for insect control in field crops today. Disease resistance has also become the standard method for controlling fungal and viral pathogens in corn, wheat, and other field crops, as well as many important vegetable crops.

There are many similarities in breeding for disease and insect resistance, including the ability of pests to overcome the resistance. Plants and pests interact on a physical, chemical, and molecular level, and changes in the genetics of either the plant or the pest may affect their interaction; thus, there is a constant battle in which the pest evolves to overcome whatever resistance the plant may have. Depending upon the complexity of the interaction between the pest and the plant, plant resistance may either break down rapidly or be long-lived.

Plant resistance to pests is based on plant genetics and the consequential molecular interactions that occur between host and pest organism (Gebhardt & Valkonen 2001; Pedley & Martin 2003). Based on how the pest and plant interact, there are three general types of mechanisms for resistance: antibiosis, antixenosis, and tolerance.

Antibiosis is defined as the adverse effect that a plant may have on a pest because of chemicals or structures that the plant possesses. Plants contain chemicals that may be toxic to a pest or cause it to grow more slowly. For example, the chemical commonly referred to as "DIMBOA" is antibiotic to the European corn borer and occurs in corn, rye, and wheat varieties. There are dozens of plant chemicals that have an antibiotic effect on insects, including botanical pesticides, such as rotenone and pyrethrum. Some chemicals (e.g., jasmonic acid) may be produced by plants when first attacked by insects or pathogens; however, their levels are usually too low to provide adequate protection. Likewise, plants may possess structures, such as hairs or trichomes, that impede insects or secrete chemicals that ensnarl them and thus, have an antibiotic effect.

Antixenosis resistance involves behavioral factors that cause an insect to avoid the plant for feeding or laying its eggs. This lack of selection could be the result of chemicals, colors, or even the presence of structures on the plant. An example of antixenosis is the chemical, coumarin, which is produced by sweet clover and deters feeding by the vegetable weevil and several other insect pests.

Tolerance is a characteristic of some plants that enables them to withstand or recover from insect or disease damage. An example of breeding for tolerance is the development of corn plants with vigorous root systems that can compensate when they are attacked by corn rootworms. Another example is breeding sweet corn with husks that inhibit the ability of insects to damage the ear. Tolerance to disease is commonly found against plant viruses, where a plant can be infected with a virus but show few symptoms, and the infection has little, if any, effect on yield.

RESISTANCE TO PESTS CAN BE INHERITED IN TWO WAYS:

Vertical resistance is more commonly a form of disease resistance and is generally controlled by a single gene, referred to as an R-gene. These R-genes can be remarkably effective in controlling disease and can confer complete resistance; however, each R-gene provides resistance to only one race of the pathogen. Thus, depending on the race of the pathogen present in a given area, a variety may appear strongly resistant or completely susceptible. Many varieties contain multiple R-genes against the same pathogen; for example, many bell pepper varieties have resistance known as X3R, which confers resistance to three races of *Xanthomonas* (the pathogen that causes bacterial leaf spot).

Horizontal resistance is also known as multi-gene resistance because it is controlled by many genes. Because of the large number of genes involved, breeding varieties with horizontal resistance is much more difficult than varieties with vertical resistance. Unlike vertical resistance, horizontal resistance generally does not completely prevent a plant from becoming damaged. For pathogens, this type of resistance may slow the infection process so much that the pathogen does not grow well or spread to other plants. Additionally, horizontal resistance is generally effective against all races of a pathogen.

In 1965, 65 of 300 crop cultivars registered in the US contained some disease resistance, while only 6% contained significant levels of insect resistance (Smith 1989). This difference can be attributed to the general tendency for multiple plant genes to be involved in insect resistance and the increased difficulty that breeding polygenic resistance requires.

Plant breeders, and the plant pathologists and entomologists with whom they collaborate, constantly seek new sources for developing resistant plants. Sources of plant material that can be utilized for resistant germplasm include the USDA, international research centers, foreign seed banks, private individuals, and seed companies.

Genetic engineering (GE) is used to produce some pest-resistant crop varieties. Genetically engineered crops are not permitted under USDA organic standards, so growers must verify that seeds they purchase have not been developed using GE techniques.

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APPENDIX B
Habitats for Beneficial Insects

HABITATS FOR BENEFICIAL INSECTS

Beneficial insects, such as predators and parasites, are fundamentally important to preventing outbreaks of pest insect populations. Key tenets of insect pest management include:

- Sustain natural enemies through the use of habitat manipulation.
- Avoid pests by using cultural practices.
- When necessary, use rescue insecticide treatments or other practices to control the pests, but choose products and practices that have minimal effects on beneficial insects

Plant diversity in agricultural settings generally adds stability to the system and helps to encourage the presence of beneficial insects. There are different options for providing plant diversity, depending on whether the main crops are annuals or perennials. Generally, crop diversity can be achieved using crop mixtures, crop rotations, border crops or windbreaks, or plants known to be attractive to beneficial insects. Landscape complexity commonly favors populations of beneficial insects, while lack of complexity generally increases insect pest outbreaks. Adding plant complexity to a system can be achieved by providing sites that beneficial insects may use to: obtain nectar or pollen, survive on alternate insect hosts, find habitats in which to increase their numbers, or overwinter. However, since interactions in agricultural systems are complex, potential detrimental interactions are also a concern.

Habitat manipulation to increase biological control requires knowledge about plant biology, potential interactions with other components of the system (i.e., plant diseases), and a general understanding of the life cycle and habits of insect pests and their natural enemies. For example, if plants are added to the system to encourage the build up of beneficial insects, those same plants may also harbor diseases or host insect pests that could affect the cash crop. Some ecologists caution that the potential benefits of habitat manipulation to increase natural enemy populations may be outweighed by the potential liabilities, but a better understanding of the components of the particular system should help to avoid such situations. As a general guideline, rather than trying to incorporate as much diversity into agricultural systems as one sees in natural settings, selecting a specific tactic that will provide the sought-after benefits may be more appropriate. For example, if the goal is to encourage the early buildup of ladybird beetles that will feed on pests of sweet corn, planting some corn early may provide a suitable habitat for ladybird beetles, which may move to later plantings of corn. Another example is to incorporate plants that flower for long periods of time and are attractive to natural enemies, but do not harbor pests that might spill over to the cash crop. Also, when a pest species feeds on a wide variety of native plants (e.g., the tarnished plant bug), manipulating the habitat to encourage natural enemies is difficult.

Flowering plants may provide nectar that can increase the life span and number of eggs produced by a beneficial species. In addition to providing necessary landscape diversification, these flowering plants can be used as part of the farm's saleable crops. When choosing plants to add diversity, a good rule of thumb is to avoid plants in the same family as the cash crop because they may also serve as hosts for insects and diseases of the cash crop. Weeds may also play a significant role in adding plant diversity. Flowering weeds in the families Compositae (e.g., daisy), Labiatae (e.g., mint), and Umbelliferae (e.g, dill, Queen Anne's Lace) are often cited in the literature as being able to support stable populations of natural enemies.

The spatial layout of the planting is also an important consideration, and the goal is to use a spatial scale for planting habitats for beneficial insects that encourages them to easily find their pest hosts. For example, planting flowers around smaller blocks of the cash crop is likely more beneficial than having large blocks of the cash crop planted at a longer distance from the flowers. Likewise, planting "corridors" of the flowers may allow natural enemies to move freely and rapidly between the cash crop and the flowers. Harvesting plants in such a manner as to retain populations of natural enemies can be important. Strip planting, rather than planting large blocks at different times, may allow natural enemies to move easily from one planting to another. However, one should also take care that such practices do not encourage pest populations to also move more readily between plantings.

The vegetation surrounding the crop field is an important refuge and habitat for many beneficials. Typically not intensively managed, it usually contains a high diversity of plant species. In order for beneficials to readily move into the crops, the distance to the center of crop fields should not be too large. Weeds are also hosts for many species of beneficials. While low levels of weeds can be tolerated for this purpose, the ability of weeds to reduce yields makes this option very limited.

Since each farming operation is different and has different constraints, there are no hard and fast rules regarding how to design the farm landscape to increase populations of natural enemies. Some farming operations specialize in very few annual crops on a relatively small area, while others may have annual and perennial crops grown on widely separated patches of land. The goal is clear for either situation: try to add diversity to the landscape in order to provide more stability for the natural enemies that control pest insects. First consider the cash crops, and then consider how to add diversity. Experiment and be observant. Start on a small scale, and work to encourage the buildup of beneficial insects through habitat manipulation over time.

For more information about this subject, see the publications listed below:

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APPENDIX C
Trap Cropping and Insect Control

TRAP CROPPING AND INSECT CONTROL

Traditional farming practices, such as the production of crop mixtures, can help to reduce the risk of crop failure due to weather and may reduce pest damage to some plants. The reasons for changes in the levels of pest damage in such diversified habitats are not always clear; however, crop diversification and its potential for insect pest management is of growing interest with some farming operations. One method of diversification is trap cropping, a technique used specifically for pest management.

Insects demonstrate preferences for particular plant species, cultivars, or crop stages by responding to certain cues. These cues may be visual, tactile, olfactory, or a combination of stimuli. Plant breeders have been able to exploit some of these preferences by developing plants that pest insects avoid (Smith 1989). Alternatively, insect preferences can be exploited for pest management practices using trap crops.

Trap crops are composed of one or more plant species that are grown to attract insect pests in order to protect the cash crop (Hokkanen 1991; Shelton & Badenes-Perez 2006). Protection may be achieved either by preventing the pest from reaching the crop or by concentrating the pests in a certain part of the field, where they can be managed. Trap crops can be manipulated in time or space, so they attract insects at a critical period in the pest's and/or the crop's life cycle. Depending on the insect's biology and the available management practices, the population on the trap crop can be managed in several ways. In some cases, the plants can simply withstand the damage, and no further action is necessary. Additionally, the trap crop can maintain the pest population to serve as a resource on which natural enemies can increase. Natural enemies may suppress the pest population, preventing it from spilling over onto the cash crop, or the trap crop may serve as an initial source of natural enemies that move to the cash crop. Similarly, if there is concern that pests will move onto the cash crop, they can be handled with insecticides or cultural practices, such as destroying the trap crop and the insects on it.

KEY FACTORS

Trap cropping is a knowledge intensive practice and requires an understanding of several factors:

1. **The feeding and/or egg laying habits of the pest**: The trap crop must be far more attractive to the pest as either a food source or egg-laying site than the cash crop. Alternatively, it may simply become attractive earlier than the cash crop
2. **Movement patterns of the insect**: In most instances, trap cropping is focused on attracting and arresting the movement of adult insects, thus keeping them from moving to the cash crop. If adults are strong fliers, and the trap crop is not overly attractive, insects may simply not be captured by the trap crop.
3. **Spatial layout of the trap crop**: Whether best practice is to plant the trap crop around the field or intersperse it within the cash crop depends upon the movement patterns of the insect, and there are no general rules for planting the trap crop that will cover all situations. For example, Colorado potato beetles move from their overwintering sites into new plantings using relatively short-range movements, so planting borders around the field may arrest the beetles. However, European corn borer moths flying into a field may not be so easily arrested by borders of trap crops. The layout for the trap crop may be different depending on whether the field is long and narrow or square.
4. **Proportion of trap crops needed**: There should be a balance in the proportion of the trap crop to the cash crop that is both economically feasible and effective for pest

management. In some recent trials with the diamondback moth on cabbage, results indicated that about 20% of the field is required when using a trap crop (ESA 2003).

5. **Fate of insects on trap crops**: Unless the immature stages of the insect pest die before reaching the adult stage, insect pest movement from the trap crop to the cash crop is likely to occur later in the season; therefore, monitoring the trap crop regularly is important. Recent work has focused on finding what are termed "dead-end trap crops." These plants are highly attractive for egg-laying, but larvae are not able to survive on them. For example, yellow rocket has been used as a trap crop for diamondback moth (Shelton & Nault 2004). In greenhouse trials, the egg laying preference for yellow rocket varied between 24-66 fold over cabbage, but no larvae were able to develop on yellow rocket. Trials are underway to determine the optimal spatial arrangement of the trap crop.

RECENT STUDIES

The number of practical trials of trap cropping has increased rapidly in recent years. Studies have analyzed different trap-cropping situations, such as early planting of single rows of trap crop potatoes between current and previous year fields for Colorado potato beetle control (Mishanec 2003) and perimeter trap cropping against pepper and cucurbit pests (Boucher 2003; Boucher & Durgy 2003). Results have been good on these crops in both university and grower trials, but these methods should be tested on commercial fields in order to assess any limitations.

The cucurbit work for control of the striped cucumber beetle (SCB) is of particular interest. Trap crops of Blue Hubbard squash established around the full perimeter of either summer squash or cucumber fields have shown some success. Blue Hubbard squash is the preferred trap crop for SCB because it does not contribute to the spread of bacterial wilt. These highly attractive perimeter trap crops are then sprayed when SCB arrives, but interior crop plants are not. Crop plants have shown low pest damage even with no spray (Boucher 2003). These trials were carried out with conventional insecticides that are highly toxic to SCB, so the results may not fully transfer to organic management.

While trap cropping has generated considerable interest in recent years, there have also been many disappointments. The use of trap crops may be limited in some crops because of the complexity of attempting to manage multiple pests with different behaviors. For example, the use of yellow rocket may provide good control of the diamondback moth but not the imported cabbageworm. Trap cropping should be investigated, however, as a component of an overall pest management program.

A symposium at the annual meeting of the Entomology Society of America in 2003 highlighted some applications and provided new ideas about trap cropping that may be helpful to growers Although there are no hard and fast guidelines on how to use trap cropping effectively, growers should consider the five points mentioned above and then examine their particular farming situation carefully to determine whether trap cropping should be tested on their farm. Sharing experiences on trap cropping with other farmers should be part of an overall effort to increase the collective knowledge about the potential for trap cropping as part of an overall management plan.

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APPENDIX D
Understanding Pesticide Regulations

UNDERSTANDING PESTICIDE REGULATIONS

Terms used in the Material Fact Sheets

REENTRY INTERVAL (REI)

The REI is the period of time, designated by the federal Worker Protection Standard (WPS), between the application of certain hazardous pesticides to crops and the allowed entrance of workers into the field without protective clothing. Each product label indicates what type of protective clothing is needed to enter the field prior to completion of the REI. The Environmental Protection Agency (EPA) implemented the WPS as part of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). It can be found at 40 CFR Part 170. Products without WPS information on the label should not be used for commercial crop production.

PRE-HARVEST INTERVAL (PHI):

The PHI is the minimum number of days permitted by law (FIFRA) between the final application of a particular pesticide and the harvest of the crop. The PHI is indicated on product labels.

EPA SIGNAL WORD:

Pesticides are labeled with a signal word based on their levels of toxicity.

Class	Toxicity	Signal Word
Class I	highly toxic	"Danger" or "Danger – Poison"
Class II	moderately toxic	"Warning"
Class III	slightly toxic	"Caution"
Class IV	relatively non-toxic	"Caution"

PESTICIDE FORMULATIONS PERMITTED IN ORGANIC PRODUCTION

The USDA-NOP (National Organic Program) regulation requires that pesticides must have active ingredients that are either considered natural, or if they are synthetic, they must appear on the National List (7CFR 205.600-607). Inert ingredients (substances other than the active ingredients) must also meet the USDA-NOP regulations. When the regulations were written, the EPA classified inert ingredients into four lists:

- List 1 (Inert Ingredients of Toxicological Concern)
- List 2 (Potentially Toxic Other Ingredients/High Priority for Testing Inert Ingredients)
- List 3 (Inert Ingredients of Unknown Toxicity)
- List 4 (List 4A- Inert Ingredients of Minimal Concern, and List 4B- Other ingredients for which EPA has sufficient information to reasonably conclude that the current use pattern in pesticide products will not adversely affect public health or the environment).

At that time, all inert ingredients allowed for organic production had to be classified as List 4 by the EPA. However, the EPA no longer uses this List system. Presently, the National Organic Standards Board (NOSB) is working on a recommendation, and the NOP will be modifying this reference at some point in the future. Until the aforementioned modifications are put in place, inert ingredients used in pesticides allowed for organic production must be included on the U.S. EPA's former list 4 (List 4A or 4B), available at: http://www.epa.gov/opprd001/inerts/oldlists.html). Inert ingredients on the EPA former List 3 are permitted if individually reviewed and added to the NOP's National List.

Inert ingredients are not necessarily harmless; some may be quite toxic and make up a large percentage of the product. FIFRA does not require inert ingredients to be identified by name and percentage on product labels; however, the total percentage of inert ingredients must be declared.

In general, nearly all synthetics are prohibited unless they appear on the National List, and all naturals are allowed unless they appear on the list as prohibited. Listed synthetics must be used only as indicated (e.g., for disease or insect control) and may have further restrictions on crop type or method of application. For instance, boric acid is limited to use in structural pest control, with no crop contact.

REGISTERED OR EXEMPT PESTICIDES

Under FIFRA, any product making a pesticidal claim must be registered with EPA, so it can be reviewed to evaluate potential risks to human health and environmental safety. Registration is indicated by the presence of an EPA registration number in small print on the label. FIFRA rules generally require that farmers use only pesticides that are approved by EPA and labeled for the food crop in question.

An exception to this rule exists for products based on certain active ingredients that are considered minimum risk products (the "25b list," named for that section of FIFRA). These products do not have EPA registration numbers and usually have a statement to the effect that "the manufacturer represents that this product qualifies for exemption from FIFRA." For exempt pesticides, until the NOP modifies the regulations to agree with the change in the way EPA classifies inerts, all inert ingredients must be on EPA List 4A and must be disclosed on the label. In addition, all active and inert ingredients must have a residue tolerance (or tolerance exemption) established for any food or animal feed crop that is listed on the label. Tolerances are the maximum, legally permissible levels of pesticide residues, including active and inert ingredients, that may be found in foods. Some states require that the 25b exempt pesticides be registered with the state pesticide agency in order to be permitted in that state.

Many exempt products, but not all, meet the requirements of the USDA National Organic Program.

ACTIVE INGREDIENTS THAT MAY BE IN MINIMUM RISK PESTICIDE PRODUCTS
Exempted from EPA Registration under section 25(b) of FIFRA

1. Castor Oil (U.S.P. or equivalent)
2. Cedar Oil
3. Cinnamon* and Cinnamon Oil *
4. Citric Acid*
5. Citronella and Citronella Oil
6. Cloves* and Clove Oil*
7. Corn Gluten Meal*
8. Corn Oil*
9. Cottonseed Oil*
10. Dried Blood
11. Eugenol
12. Garlic* and Garlic Oil*
13. Geraniol
14. Geranium Oil
15. Lauryl Sulfate
16. Lemon grass Oil*
17. Linseed Oil
18. Malic Acid*
19. Mint* and Mint Oil*
20. Peppermint* and Peppermint Oil*
21. 2-Phenethyl Propionate (2- phenylethyl propionate)
22. Potassium Sorbate
23. Putrescent Whole Egg Solids (See 180.1071)
24. Rosemary * and Rosemary Oil*
25. Sesame* (includes ground Sesame plant stalks) (See 180.1087) and Sesame Oil*
26. Sodium Chloride (common salt)*
27. Sodium Lauryl Sulfate
28. Soybean Oil
29. Thyme* and Thyme Oil*
30. White Pepper*
31. Zinc Metal Strips (consisting solely of zinc metal and impurities)

* These active ingredients are exempt from the requirement of a tolerance on all raw agricultural commodities at 40 CFR 180.1164(d). Note that the remaining substances may not have tolerance for all food crops.

ISSUES OF CONCERN

In some cases, certain products may be marketed as EPA-exempt by listing an active ingredient that appears on the "25b" list, while claiming all other ingredients are non-active (inert ingredient). This claim could cause confusion as to the organic status of the product because the NOP regulations are different for active and inert ingredients. For instance, vinegar is permitted in exempt products only as a non-active ingredient at less than 8% concentrations. Acetic acid at levels over 8% is considered to be a List 4B inert, which is not permitted in 25b exempt products. A number of herbicides based on acetic acid are on the market, some registered and others claiming to be exempt, with citric acid or some other ingredient listed as the active.

Producers should carefully examine the list of ingredients in all exempt products to assess compliance with NOP requirements and to make sure they are aware of all ingredients, both active and inert. Exempt products are entitled to make an organic production claim, but such claims are not verified by the EPA.

Making either a verbal or a written pesticidal claim for a specific product that is not registered by the EPA or legally exempt from EPA registration may be considered a violation of federal law. Farmers who use unregistered pesticides may be in violation of FIFRA if their use of such pesticides results in illegal residues on crops. Although some unregistered or non-exempt products may be on the market, they cannot be researched or recommended by university Extension personnel, making it difficult to assess efficacy for unregistered products.

EPA ORGANIC LABEL PROGRAM

The EPA established a voluntary labeling program in 2003 that permits the use of the phrase "for organic production" on pesticide labels for products that are compliant with NOP regulations. The EPA reviews product formulations to verify that the active and inert ingredients are, in fact, compliant. They do not permit this phrase to be used if other (alternate), non-compliant formulations are marketed under the same registration number. The EPA also requires that all label instructions are consistent with organic standards.
Organic growers may continue to use pesticide products that do not display the EPA approval if these products comply with the NOP rules. Some pesticide formulators may not want to limit pesticide instructions to only organic uses, so these products will not have the EPA organic label. For instance, soaps are currently on the NOP list as an insecticide but not as a fungicide, so reformulating products labeled for both uses to remove the unlisted/unapproved use would be undesirable for pesticide producers. Products approved under this program may bear the logo and words: **For Organic Production.**

Pesticide products that are exempt from EPA registration may make an organic claim but are not subject to EPA review. They are, however, subject to enforcement actions if their claims are fraudulent. A number of the permitted active ingredients for 25b-exempt products are synthetic and not permitted as active ingredients according to the NOP National List, including sodium lauryl sulfate, lauryl sulfate, 2-Phenethyl Propionate, potassium sorbate.

EPA registered products that carry the "for organic production" label have been verified as meeting the NOP requirements. Unregistered products that claim EPA exemption and "for organic production" should be reviewed carefully by users to make sure they do, in fact, meet NOP requirements. Growers are encouraged to check with their certifier before using a product.

RESOURCES

EPA FIFRA regulations. (1996). Retrieved from: http://www.epa.gov/lawsregs/laws/fifra.html.

EPA Lists of Inert Ingredients. (1989). Retrieved from: http://www.epa.gov/opprd001/inerts/oldlists.html.

EPA Pesticide Registration Notice: Labeling of Pesticide Products under the National Organic Program. (2003). Retrieved from: http://www.epa.gov/oppbppd1/biopesticides/regtools/organic-pr-notice.htm.

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USDA-NOP National List. (2012). Retrieved from: http://www.ams.usda.gov/nop/NationalList/ListHome.html .

APPENDIX E

Organic Research Needs: Some Important Vegetable Pests and Possible Organic Controls that Lack Efficacy Data

ORGANIC RESEARCH NEEDS: Some Important Vegetable Pests and Possible Organic Controls that Lack Efficacy Data

Crop	Pest	Occurrence 1=sporadic, 3=yearly	Cultural controls effective?	Possible rescue control
Brassica	Flea beetle	3	Y	Spinosad
	Cabbage aphid	2	?	Soap, oil, neem, Beauveria
	Cabbage maggot	2	Y	Neem, spinosad baits
	Onion thrips	2	?	Kaolin, pyrethrum, spinosad
	Alternaria	2	Y	Microbial products*
	Black leg	1	Y	Microbial products*
	Clubroot	1	Y	Microbial products*
	Swede midge	1	Y	Kaolin
	Downy mildew	1	Y	
	Head rot	2	?	
Cucurbit	Striped cucumber beetle/ Bacterial wilt	3	Y	Microbial products*,Pyrethrum/neem mixtures kaolin, Beauveria
	Squash bug	2	N	Beauveria, kaolin, pyrethrum, spinosad, plant oils, pyrethrum/neem mix
	Black rot	2	N	Microbial products*
	Phytophthora	1	N	Microbial products*
	Powdery mildew	3	N	Several good controls, comparative trials needed
	Downy mildew	3	N	Copper, microbial products*
Lettuce	Tarnished plant bug	2	?	Beauveria, kaolin, neem, pyrethrum, spinosad
	Aster leafhopper/ Aster yellows	2	Y	Neem, kaolin, repellents, pyrethrum
	Sclerotinia	1	Y	Contans
	Powdery mildew	2	Y	Bicarbonate, B. subtilis, microbial products, oils, soap
	Downy mildew	2	Y	Bicarbonate, B. subtilis, microbial products, oils, soap
Onion	Onion thrips	3	Y	Beauveria, kaolin, pyrethrum, spinosad , neem
	Botrytis	2	Y	Oils, microbial products*
	Purple blotch	1	Y	Oils, microbial products*
	Onion and seedcorn maggot	1	Y	Spinosad seed treatment, spinosad baits
	Leek moth	1	Y	Spinosad
Pepper	Downy mildew	1	Y	Oils, microbial products*
	Aphids/CMV	1	Y	Neem, repellents
	Tarnished plant bug	1	?	Beauveria, kaolin, neem, pyrethrum, spinosad
	European corn borer	2	?	Control available, improve timing/application

Crop	Pest	Occurrence 1=sporadic, 3=yearly	Cultural controls effective?	Possible rescue control
Potato	Potato leafhopper	2	N	Neem, kaolin, repellents, pyrethrum, soaps, oils
	Colorado potato beetle	2	Y	Alternate controls needed to avoid resistance to spinosad
	Rhizoctonia	2	Y	Microbial products*
	Scab	3	Y	Microbial products*
	Late blight	1	N	Microbial products*, hydrogen peroxide
Spinach	Seedcorn maggot	1	Y	Spinosad seed treatment, spinosad baits
Sweet corn	Seed corn maggot	1	Y	Microbial products*
	Damping off	2	Y	Microbial products*
	European corn borer	3	N	Bt
Tomato	Early blight	3	Y	Oils, copper, microbial products
	Late blight	1	N	Microbial products*, hydrogen peroxide
	Anthracnose	2	?	Microbial products*
	Stink bug	1	?	Neem, pyrethrum

* Microbial products include plant growth-promoting rhizobacteria, Gliocladium catenulatum, Trichoderma harzianum, Ampelmyces quisqualis, Myrothecia, Pseudomonas flourescens, Streptomyces griseoviridis, and others.

APPENDIX F
Additional Resources

ATTRA- Appropriate Technology Transfer for Rural America, National Center for Appropriate Technology. Call ATTRA at 1-800-346-9140 for free information packets, or visit http://www.attra.ncat.org, a website containing downloadable factsheets and guides for organic production and pest management. "Farmscaping to Enhance Biological Control," information packet available at http://attra.ncat.org/attra-pub/farmscape.html.

Caldwell, B. (2004). *Vegetable Crop Health: Helping Nature Control Pests and Diseases Organically*. NOFA Interstate Council, Barre, MA.

Davidson, R. H., & William F. L. (1987). *Insect Pests of Farm, Garden, and Orchard*. Wiley.

Diagnostic/Compendia from The American Phytopathological Society. Available from APS Press at: http://www.shopapspress.org.

eXtension.org. Available from: http://www.extension.org/organic_production.

Grubinger, V. (1999). *Sustainable Vegetable Production from Start-Up to Market*. NRAES - 104. NRAES, Cooperative Extension, Ithaca, NY 14852-4557. Available from: http://palspublishing.cals.cornell.edu.

Howard, R. J., Garland, J. A. & Seaman, W. L. (Eds.). (1994). *Diseases and Pests of Vegetable Crops in Canada*, a joint publication by the Canadian Phytopathological Society and the Entomological Society of Canada.

Cornell Integrated Crop and Pest Management Guidelines, Cornell Cooperative Extension. These publications provide weed, insect, and disease management information, both chemical and non-chemical, for commercial crop producers, facilities managers, and homeowners. Appropriate integrated pest management (IPM) guidelines are included as well as chemical control tables. Most are updated yearly with regulatory information. Available from: http://www.nysipm.cornell.edu/guidelines.

Wilsey, W., Weeden, C. R., & Shelton, A. M. *Pests in the Northeast*
A website that contains pictures and descriptions of insect pests and damage. Entomology Department at the NY State Agricultural Experiment Station of Cornell University and the New York State Integrated Pest Management Program. Available from: http://web.entomology.cornell.edu/shelton/veg-insects-ne/.

New England Vegetable Management Guide. Published by the Cooperative Extension of the Universities of Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont: http://www.umext.maine.edu, http://www.umassvegetable.org, http://www.ceinfo.unh.edu, http://www.uvm.edu/vtvegandberry.

Organic Materials Review Institute (OMRI)
http://www.omri.org is a website that contains a brand name list of products reviewed and listed for organic production.

Organic Production Guides. These guides provide an overall approach for organic production with a focus on biological, mechanical, and cultural controls. Sections on cover crops, resistant varieties, crop rotation, field selection, soil quality, and nutrient management all highlight their interrelated qualities and precede specifics on pest management options. Available from: http://www.nysipm.cornell.edu/organic_guide.

Plant Management Network. A non-profit, online publishing effort that is jointly managed by the American Phytopathological Society, American Society of Agronomy, and the Crop Science Society of America. This website includes university reports of efficacy trials of pesticides in the Arthropod Management Tests and Plant Disease Management Reports (which is a merger of the *Fungicide and Nematicide Tests* and the *Biological and Cultural Tests for the Control of Plant Diseases*). Available from: http://www.plantmanagementnetwork.org/sub/welcome.asp

RESOURCES

Seaman, A. (Ed.). (2004). *Organic Vegetable Production*. NRAES - 165. NRAES, Cooperative Extension, Ithaca, NY 14852-4557. Available from: http://palspublishing.cals.cornell.edu.

Shelton, A. M. Natural Enemies: A Guide to Biological Control Agents in North America. Available from: http://www.biocontrol.entomology.cornell.edu/index.php.

Stoner, K. (Ed.). (1999). *Alternatives to Insecticides for Managing Vegetable Insects*. NRAES - 165 or NRAES - 152. NRAES, Cooperative Extension, Ithaca, NY 14852-4557. Available from: http://palspublishing.cals.cornell.edu.

USDA National Organic Program. http://www.ams.usda.gov/nop. This website includes the regulations and policy statements regarding the National Organic Program.

APPENDIX G
List of Trademarks and Registered Trademarks Mentioned in this Publication

LIST OF TRADEMARKS AND REGISTERED TRADEMARKS MENTIONED IN THIS PUBLICATION*:

New products are becoming available from several companies that specialize in organic products. However, we did not have sufficient information at the time of publication (Dec. 2012) to provide a comprehensive evaluation of such products (e.g Azera, Grandevo, Melocon). However, we encourage growers to do their own testing and provide us with feedback.

Actinovate®

Align®

Ambush®

Aza-Direct®

Azatin®

Azatrol®

Azera®

Badge® X2

Basic Copper 53®

Baythroid®

BIO-TAM™

Camelot O® Fungicide/Bactericide

Champ™ WG

Chem Copp 50™

Concern® Garden Defense Multi-Purpose Spray

Conserve® Fire Ant Bait

Conserve® Naturalyte Insect Control

Contans®

Cosavet®

Cueva® Fungicide Concentrate

Cueva® Fungicide Ready to Use

Des-X™

DiPel®

Entrust®

Epic®

Final-San™-O herbicide

GF-120 NF Naturalyte® Fruit Fly Bait

HiStick®

Justice® Fire Ant Bait

Kaligreen®

Kodiak®

Kumulus®

M-Pede®

Micro Sulf®

Microthiol®

MilStop®

Monterey® Bi-Carb Old Fashioned Fungicide

Mycostop®

Mycotrol®

NeemAzal® T/S

Neemix®

Nordox® 30/30 WG

Nordox® 75WG

Nu Cop® 50 DF

Nu Cop® 50 WP

Ortho® elementals™ Garden Disease Control

PHT Copper Sulfur Dust

PlantShield® HC

Pounce®

ProGanic® Micronized Sulfur

ProNatural®

Proteknet

PyGanic®

Rex Lime Sulfur Solution

Rhapsody®

RootShield®

Safer® Brand BioNEEM Multi-Purpose Insecticide and Repellent Concentrate

Safer® Brand End All Insect Killer

Seduce®

Serenade®

Sluggo®

SoilGard®

Sonata®

Special Electric®

SpinTor®

Surround®

T-22™ HC

Tenet™

Tetrasul 4s5

Triact® 70 Fungicide/Miticide/Insecticide

Trilogy®

Warrior®

Ready-To-Use Worry Free® Brand Ready to Use Copper Soap Fungicide

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