Organic Vegetable IPM Guide

Interest in nonchemical pest control has increased over the past several years. To some people, this means the same as "organic farming," which implies nature's way. But in this publication, we talk about controlling pests without chemicals, or at least fewer chemicals. This approach does have some limitations. Here are some of them:

1. The problem area needs more personal attention.
2. Nonchemical control is hard work, so it may be better for small areas. This depends on the available labor supply.
3. In some years, you may suffer more damage than you thought you would, including more loss of produce or plants.
4. There are some pests (insects, weeds, or pathogens) for which effective nonchemical management methods are not available.

When planning a nonchemical management program, keep in mind that the climate that allows crops to grow also benefits insects, weeds, and pathogens. Mississippi's climate ranges from semitropical on the Gulf Coast to temperate for the rest of the state. This gives the state a range of 200 to 250 growing days per year. These conditions, along with high humidity, are ideal for the development of a wide range of insects, weeds, and pathogens. For these reasons, be cautious about using information developed in northern states or in the hot, dry climate of the Southwest.

During the planning stages, be careful about information on nonchemical control in popular magazines and newspapers. Writers often report on only a few observations. For example, if a grower reports having one tomato plant where he successfully used wood ashes to control aphids, question whether aphids would have been a problem without using ashes. Personal experiences are good, but respected tests in your farming area mean more.

Mississippi organic growers who wish to sell their produce with the word "organic" on it must be certified. Commercial growers who wish to be certified as organic should read Extension Publication 2454 *Becoming a Certified Organic Grower* at ***http://extension.msstate.edu/publications/becoming-certified-organic-grower***. For more information on organic resources, see the MSU Extension Service Organic Fruit and Vegetable website at ***http://extension.msstate.edu/crops/commercial-horticulture/organic-fruit-and-vegetables***.

Fertilizer for Organic Vegetable Production

Organic matter is important to soil structure and, therefore, to the health of a vegetable crop. Here are some advantages of organic matter in the soil:

- The physical condition of the soil is improved.
- Organic matter is a source of food for microorganisms that break down the organic matter, releasing nutrients that can be taken up by the plant. Acids released during decomposition help release nutrients used in plant growth.
- Plants that receive proper and adequate nutrition are less stressed and less likely to be attacked by insects and pathogens.
- Organic matter helps the soil hold minerals, so leaching is reduced.
- Bacteria growing on organic matter release complex carbohydrates, which help cement soil particles into aggregates.
- Erosion is reduced since water can enter and percolate through the soil better with organic matter present.
- Root penetration is enhanced.
- The water-holding capacity of sandy soils is improved.
- Aggregation in heavy soils improves drainage.

The organic matter content of soil varies over time, depending on the amounts added and environmental conditions. In southern latitudes, organic matter breaks down fairly quickly and needs to be added each year to replenish it.

One of the benefits of organic matter is the fertilizer value. While generally low-grade compared to chemical fertilizers, organic fertilizers in adequate supply can provide enough nutrients for vegetable crops.

One big advantage of organic fertilizers is that nitrogen becomes available to plants gradually through the growing season. This "slow-release" effect is important, because nutrients become available on a continual basis, and the likelihood of fertilizer burn is reduced or eliminated.

Table 1 shows the typical composition of various organic fertilizers. There is much variation among samples of these materials, so these numbers should be used only as a guide. This is especially true of animal manures. Manure nutrient content will vary according to factors such as the feed used, percentage and type of litter or bedding, moisture content, age, and degree of decomposition. With the commercially prepared, bagged manure, some nitrogen content is lost in the drying process.

The main disadvantages of organic fertilizers are supply and cost. Some of the materials may be hard to find commercially. This limited supply often leads to high prices. One other disadvantage is bulk. Since most organic fertilizers are relatively low in nutrient values (e.g., manures tend to be 1 to 4 percent nitrogen), large amounts are needed to obtain enough fertilizer for the crop. While this works well for growers who maintain their own animals or live near farms, it can be challenging for others to find enough manure for their farms. If you have any question about which fertilizers are allowed under organic rules, go to the Organic Materials Review Institute (OMRI) website at ***http://www.omri.org***.

Table 1. Nutrient value of various organic fertilizer materials.

Organic Material	N (nitrogen)	P_2O_5 (phosphate)	K_2O (potash)
Bat guano	10.0	4.0	2.0
Blood, dried	13.0	2.0	1.0
Bone meal, raw	3.0	22.0	—
Bone meal, steamed	1.0	15.0	—
Castor bean meal (pomace)	5.5	2.0	1.0
Cocoa shell meal	2.5	1.0	2.5
Compost	1.5–3.5	0.5–1.0	1.0–2.0
Cottonseed meal	6.0	3.0	1.5
Fish meal (dry)	10.0	6.0	—
Fish scrap (dry)	3.5–12.0	1.0–12.0	0.08–1.6
Garbage tankage (dry)	2.5	2.0	1.0
Granite meal*	0	0	3.0–5.0
Greensand*	0	1.35	4.0–9.5
Kainite*	0	0	12.0
Kelp	0.9	0.5	4.0–13.0
Manure, dairy	0.6–2.1	0.7–1.1	2.4–3.6
Manure, duck	0.6	1.4	0.5
Manure, feedlot	1.0–2.5	0.9–1.6	2.4–3.6
Manure, horse	1.7–3.0	0.7–1.2	1.2–2.2
Manure, poultry	2.0–4.5	4.5–6.0	2.1–2.4
Manure, rabbit	2.4	1.4	0.6
Manure, sheep	3.0–4.0	1.2–1.6	3.0–4.0
Manure, swine	3.0–4.0	0.4–0.6	0.5–1.0
Peanut meal	7.0	1.5	1.2
Rock phosphate*	0	20.0–32.0	0
Sewage sludge	1.5	1.3	0.4
Sewage sludge, activated	6.0	3.0	0.2
Soybean meal	7.0	1.2	1.5
Tankage	7.0	10.0	1.5

*These materials are natural mineral deposits, not organic materials, but they are commonly used as organic fertilizers.

Organic Management Practices for Vegetable Diseases

Organic disease management protects plants from many vegetable diseases that commonly occur in Mississippi each season. Organic disease management is based on sanitation; cultural, physical, and biological practices; and the use of approved organic chemicals.

Used in an integrated program, these practices reduce populations of plant pathogens, such as fungi, bacteria, nematodes, and viruses, that can cause disease. A combination of practices is necessary, since no one practice works for all diseases that threaten a given crop. Some organic disease management practices should be carried out before the crop is planted, while others may be carried out after the crop is planted.

Before Planting

Sanitation

Destroy and bury crop debris. Many plant pathogens survive through the winter in old plants, cull piles, or plant stubble left in the field. Destroying crop debris is an important sanitation step that can reduce the amount of disease inoculum (any part of or an entire pathogen that can cause disease) in the production site at the beginning of the season. If you eliminate overwintering sites of fungi, bacteria, viruses, and nematodes, you will reduce disease problems the next season.

As part of an early-season sanitation program, remove and destroy stalks (with root systems, when possible), stems, vines, and other debris as soon as possible after the last harvest. When root-knot nematodes are a problem, destroying old root systems removes thousands of nematodes and eggs from the field site. Do not add debris from diseased plants to compost piles, since temperatures do not always get high enough to kill nematode eggs and other plant pathogens.

Plow under remaining stubble and surface litter at least 6 inches before planting. This works because, as debris decays, disease-causing microorganisms deteriorate, which reduces the amount of fungal and bacterial inoculum that could cause disease in future crops. Deep plowing is most effective in the South when done 3 or more months prior to planting of the next crop. Plowing to bury debris reduces southern blight on tomatoes, peppers, and other susceptible vegetables.

Disinfect plant-support structures. Some plant pathogens survive during the off season on stakes, poles, cages, and other plant-support structures. These support structures should, therefore, be disinfected before use. Wash support structures to remove soil, then dip in or spray with an OMRI-approved sanitizing product. Thorough washing is a major part of disinfestation. As little as 0.5 percent organic matter can ruin a disinfestant's ability to work.

Use disease-free seeds and transplants. Clean seeds and transplants are a must in vegetable production. To avoid problems next season, do not save seeds from fields or areas where there are diseases. Examples of seed-borne diseases are anthracnose of lima beans, mosaic virus of southern peas, bacterial blight of snap beans, black rot of cabbage, and leaf spots of turnip and mustard greens. Buy certified seeds that come from dry regions, such as the western United States, where diseases are less common.

If you produce your own transplants, follow strict guidelines to ensure quality planting material. Sow disease-free seed in a sterile growth medium. If you use growth flats that were used previously in transplant production, disinfect them with an approved disinfectant or put them in hot water (at least 180°F) for 15 to 20 minutes. Buy a steam-sterilized growth medium, or sterilize growth medium by baking at 160°F for 1 hour. Baking destroys most plant pathogens.

Perform a hot water treatment of seeds. Hot water treatment may be used to reduce or eliminate populations of some bacterial and fungal pathogens in seeds. Since seeds may be damaged by hot water treatment, a sample of the seed you intend to treat should be treated and tested for germination before treating the entire lot. Recommended temperatures and times for disinfestation of various vegetable seeds as well as additional information about treating seeds may be found in the most recent edition of the *Southeastern U.S. Vegetable Crop Handbook*.

Control weeds. Some insects carry viruses from infected plants to healthy plants. Destroy perennial weeds (including milkweed, horse nettle, and pokeweed) in and around fields before planting, since these plants often act as overwintering hosts for harmful viruses. In the spring, aphids, thrips, and other insects feed on weeds, pick up virus particles, and carry them to healthy plants. Weeds should also be controlled throughout the growing season.

Cultural Practices

Choose a good planting site. To reduce chances of damping-off, root rot, and other problems with wet soils, choose a well-drained site. If drainage is a problem, plant on raised beds to promote drainage and faster warming of soil. These conditions encourage faster seed germination and seedling emergence. Also, young, established plants are more resistant to seedling disease infection, and transplants are less susceptible to root disease problems when grown in raised beds.

Test the soil to determine fertility needs. Have the soil tested and then fertilize plants according to the test recommendations. Healthy, properly fertilized plants are less susceptible to diseases than are plants that are low in nutrition or that do not get a good balance of nutrients. Too much nitrogen is related to some foliage diseases and some seedling diseases of peas, beans, and other vegetables. We do not know how much each nutrient influences disease development, but we do think fertilizers are important in an organic disease management program. Information and instructions on how to properly collect and submit a soil sample can be found in Extension Information Sheet 346 *Soil Testing for the Farmer* or Information Sheet 1294 *Soil Testing for the Homeowner*.

Test the soil to determine if parasitic nematodes are present. Collecting soil samples for nematode analysis should be a routine part of a vegetable production program. Collect at least 20 cores from 6 to 8 inches deep per 5,000 square feet of production area in fall or winter. Mix this soil thoroughly, and place about 1 pint in a nematode soil sample bag or in a plastic freezer bag, and seal. Mark the sample number on the collection container, and complete the Nematode Soil Sample form (Form 448), which must be sent to the testing lab with your soil samples.

At all times, keep the soil samples cool and away from direct sunlight. The number of live nematodes present in a soil sample can be reduced by exposure to high temperatures (over 100°F) or direct sunlight for even short periods of time. Take the samples and completed form to your county Extension office for mailing to the Extension Plant Diagnostic Lab. There is a fee for nematode analysis. Expect to receive sample results in about 2 weeks.

Rotate crops. Since some pathogens infect one type of vegetable or a group of related vegetables but may not infect another type or group of vegetables, rotating fields to different crops is a good way to manage several plant pathogens.

Several vegetables of the same family (such as squash, cucumbers, watermelons, and cantaloupes) may be affected by the same disease, so it is not good to grow plants of the same family in rotation. We suggest at least a 3-year rotation for vegetable crops. For example, if you grew tomatoes or peppers this season, switch to vegetables listed in other groups for 3 more years, switching groups each of the 3 years, before returning to tomatoes or peppers.

Table 2 lists vegetables susceptible to similar diseases. You can use it as a basis for setting up a rotation program. *Remember, rotation does not work against all plant pathogens.*

Follow recommendations for seeding rates. Dense plantings stay wet longer because of reduced air circulation and poor sunlight. Also, it is more difficult to get good spray coverage.

Physical Practices

Use plastic or organic mulch. Plastic mulch is a widely used ground cover in vegetable production. It serves as a physical barrier between soil and plant surfaces and reduces the amount of disease inoculum that may be splashed onto foliage, stems, and fruits during watering or rains. The amount of cucumber belly rot and buckeye rot of tomato may be reduced this way. You can also use organic mulches, such as pine needles, oat straw, bark, composted sawdust, and similar materials, as physical barriers.

Light-reflective mulch helps to manage several important virus diseases of vegetable crops. Watermelon mosaic virus causes a serious disease in squash. It causes yellow squash to turn green or develop green streaks and also reduces yield. A 30-inch-wide silver-colored mulch (aluminum foil also works) can help reduce the occurence of this virus. Light reflected from the mulch surface repels aphids that transmit the virus, thereby reducing the number of virus-infected squash plants. This same management strategy reduces the number of tomato spotted wilt virus-infected tomato and pepper plants. Thrips, which transmit the spotted wilt virus, are also repelled by reflective mulches.

Cage, stake, or trellis plants. One of the main reasons for supporting tomatoes and other vegetables by staking,

Table 2. Vegetable groups based on susceptibility to similar diseases.

Group A	Group B	Group C	Group D	Group E	Group F	Group G
Cantaloupes Cucumbers Gourds Pumpkins Squash Watermelons	Broccoli Brussels sprouts Cabbage Cauliflower Collards Kohlrabi Mustard Turnips	Eggplant Irish potatoes Peppers (all types) Tomatoes	Beets Spinach Swiss chard	Beans (all types) English peas Snow peas Southern peas	Garlic Leeks Onions Shallots	Sweet corn

caging, or trellising is to keep plants and fruit off the ground. This reduces losses from fruit rots when fruit touch the ground and from sunburn when fruit are not shaded by foliage.

Wrap stems to help manage southern blight. You can wrap aluminum foil around the base of the stems of tomato and pepper plants to help protect plants from the southern blight pathogen. The stem should be wrapped so that the foil wrap extends 2 inches above and 2 inches below the soil surface. The aluminum foil provides a physical barrier between the plant and the southern blight fungus.

Try solarization. Solarization is another nonchemical way to reduce damaging populations of root-knot nematodes. Solarization also aids in the management of many soil-borne fungal pathogens, as well as many damaging insects and weeds. The process is most effective for reducing nematode populations in the top 8 to 10 inches of soil.

Solarization is a process by which the sun's energy is trapped in the soil in the form of heat. This is accomplished by covering the soil surface with polyethylene tarps. Several procedures must be followed closely to ensure the soil temperature is high enough to control nematodes.

First, the soil should be moist and well-tilled before laying and securing the tarp. Also, solarization should be attempted during the late spring months or, ideally, at the hottest time of the year when the sun is brightest. Normally, 4 to 6 weeks is enough time for solarization to be effective. Six weeks is the preferred period if you use this technique in late spring.

Selecting a plastic or polyethylene cover is probably the most important step in the process. The cover must be clear, no more than 2 millimeters thick, and strong and durable enough to stretch and remain intact over the solarization period. Solarization works best when performed in rows made into hills. Make sure that the top of the row is smoothly domed and that no depressions exist. Depressions may hold water and prevent the underlying soil from reaching an adequate temperature.

Placement of the cover is also important. Stretch the cover tight and make sure it is in direct contact with the soil. Carefully bury the edges of the cover in the soil at least 6 inches deep so the wind will not lift the tarp during the solarization period. The tarp should stay in place for 4 to 6 weeks. When removing the tarp, be careful not to contaminate the treated area with untreated soil. Remember this at planting, too. The best results are achieved when beds are prepared for planting before solarization and when planting occurs immediately after removing the tarp.

Biological Practices

Take advantage of resistant varieties. Make every effort to buy disease-resistant or disease-tolerant varieties. Consult lists of recommended varieties, seed catalog variety descriptions, and other sources of information. Unfortunately, resistant or tolerant varieties are not available for many vegetable diseases. A list of selected vegetables with varieties that have resistance/tolerance to various diseases and pathogens and that are recommended for planting in Mississippi is provided in **Table 3**.

Use marigolds for nematode management. Marigolds give off a substance from their roots that is toxic to nematodes, making them valuable in nematode management when planted in solid beds. For best results, use one or more of the French marigold varieties (such as Tangerine or Petite Harmony), and space plants 7 inches apart in 7-inch rows.

Use biological products. A number of products that use various microorganisms or biological agents, such as bacteria or various products produced by microorganims, have been shown to be effective in managing some diseases. Many of these products are approved for use in organic production. Some of these products are listed in **Table 4**. A list of products approved for use in organic production by the Organic Materials Review Institute (described in more detail on page 7) can be found at ***www.omri.org***.

After Planting

Sanitation

Remove diseased plants or plant parts. Examine plants at least twice per week for signs (the physical presence of pathogens; e.g., fungal mycelium or sclerotia) and symptoms (the plant's reaction to infection by a pathogen) of disease. Look for fungal growth, leaf spots, wilting, stunting, fruit rots, misshapen leaves, cankers, and stem blights. If you detect only a small amount of disease, removing infected foliage or fruit helps reduce inoculum that may be spread to disease-free foliage and fruit on the same or nearby plants. Remove and destroy heavily diseased plants, including the roots, since later treatment of such plants is not effective. In some cases, you may have to remove surrounding soil. For example, remove 3 or 4 inches of soil with plants affected by southern blight to ensure removal of the seed-like sclerotia (compact masses of fungal growth) associated with this disease. Do not place diseased plants and plant parts in cull piles. Whenever possible, place this material in landfills or bury it away from production sites. Be sure to contain infected plants at their location in the field or greenhouse so that infested soil or infected tissue is not dropped throughout

Table 3. Selected vegetable varieties and their tolerance or resistance to important diseases and pathogens.	
Vegetable and Variety	**Disease or Pathogen Tolerance/Resistance[1]**
Beans (bush, lima)	
Nemagreen	root-knot nematodes
Cabbage	
Blue Vantage	black rot, bacterial speck, fusarium yellows
Bravo	black rot, fusarium yellows
Cheers	black rot, bacterial speck, fusarium yellows
Platinum Dynasty	black rot, fusarium yellows
Solid Blue 780	black rot, fusarium yellows
Cucumbers (fresh market)	
Dasher II	anthracnose, angular leaf spot, cucumber mosaic virus (CMV), downy mildew, powdery mildew, scab and gummosis
General Lee	CMV, downy mildew, powdery mildew, scab and gummosis
Rockingham	anthracnose, angular leaf spot, CMV, powdery mildew, scab and gummosis
Talladega	anthracnose, angular leaf spot, powdery mildew, scab and gummosis, watermelon mosaic virus (WMV)
Thunder	angular leaf spot, CMV, downy mildew, powdery mildew, scab and gummosis, zucchini yellows mosaic virus (ZYMV)
Cucumbers (greenhouse, English types)	
Bologna	powdery mildew, scab and gummosis, target spot
Camaro	powdery mildew
Cumlaude	angular leaf spot, powdery mildew, scab and gummosis
Discover	angular leaf spot, powdery mildew, scab and gummosis
Verden	CMV, cucumber vein yellowing virus (CVYV), powdery mildew, scab and gummosis, target spot
Pepper (bell, hybrid)	
Camelot X3R	bacterial leaf spot (races 1, 2, and 3)
King Arthur	potato virus Y (PVY), tobacco etch virus (TEV), bacterial leaf spot (race 2), tobacco mosaic virus (TMV)
Orobelle	PVY and TMV
Revolution	Phytophthora root rot, bacterial leaf spot (races 1, 2, 3, and 5), CMV
Tequila	TMV
Valencia	TMV
Pepper (jalapeno type, hybrid)	
El Rey	bacterial leaf spot (races 1, 2, and 3)
Grande	PVY, TEV
Ixtapa	PVY, bacterial leaf spot (races 1, 2, and 3)
Milta	PVY
Squash (summer)	
Supersett	WMV, ZYMV
Squash (winter, acorn)	
Taybell PM	powdery mildew
Southern Peas	
Magnolia Blackeye	blackeye cowpea mosaic virus (BlCMV), Fusarium wilt, root-knot nematodes
Mississippi Purple	Fusarium wilt, root-knot nematodes; several viruses, including BlCMV
Mississippi Shipper	Fusarium wilt, root-knot nematodes; several viruses, including BlCMV
Mississippi Silver	Fusarium wilt, root-knot nematodes; several viruses, including BlCMV
Pinkeye Purple Hull – BVR	BlCMV
Tomatoes (fresh market)	
Amelia VR	Fusarium wilt (races 1, 2, and 3), tomato spotted wilt virus (TSWV), Verticillium wilt
Applause	Alternaria stem canker, Fusarium wilt (races 1 and 2), gray leaf spot
Bella Rosa	Alternaria stem canker, Fusarium wilt (races 1 and 2), gray leaf spot, TSWV, Verticillium wilt

BHN 589	Fusarium wilt (races 1 and 2), tomato mosaic virus (ToMV), Verticillium wilt
BHN 602	Fusarium wilt (races 1, 2, and 3), TSWV, Verticillium wilt
BHN 640	Fusarium wilt (races 1, 2, and 3), TSWV, Verticillium wilt
Big Beef	Alternaria stem canker, Fusarium wilt (races 1 and 2), gray leaf spot, nematodes, Verticillium wilt
Carolina Gold	Fusarium wilt (races 1 and 2), Verticillium wilt
Crista	Fusarium wilt (races 1, 2, and 3), nematodes, TSWV, Verticillium wilt
Florida 47R	Alternaria stem canker, Fusarium wilt (races 1 and 2), gray leaf spot, Verticillium wilt
Florida 91	Alternaria stem canker, Fusarium wilt (races 1 and 2), gray leaf spot, Verticillium wilt
Mountain Magic	early blight (tolerance), Fusarium wilt (races 1 and 2), late blight, Verticillium wilt
Mountain Spring	Fusarium wilt (races 1 and 2), Verticillium wilt, gray leaf spot
Plus	early blight (tolerance), Fusarium wilt (races 1 and 2), nematodes, Verticillium wilt
Rocky Top	Fusarium wilt (races 1, 2, and 3), gray leaf spot, Verticillium wilt
Tomatoes (greenhouse, beefsteak)	
Big Dena	Fusarium wilt (races 1 and 2), Fusarium crown root rot, TMV, Verticillium wilt
Geronimo	Fusarium wilt (race 2), Fusarium crown root rot, leaf mold[2] (races A, B, C, D, and E), powdery mildew, TMV, Verticillium wilt
Starbuck	Fusarium wilt (race 1), Fusarium crown root rot, leaf mold[2] (races A, B, C, D, and E), ToMV, Verticillium wilt
Torero	Fusarium wilt (race 2), Fusarium crown root rot, leaf mold[2] (races A, B, C, D, and E), powdery mildew, TMV, Verticillium wilt
Trust	Fusarium wilt (race 2), Fusarium crown root rot, leaf mold[2] (races A, B, C, D, and E), TMV, Verticillium wilt
Zucchini	
Payroll	CMV, papaya ringspot virus (PRSV), WMV, ZYMV
Tigress	PRSV, WMV, ZYMV

This is a partial list of selected vegetables and varieties with some level of disease tolerance or resistance that are recommended for planting in Mississippi according to the latest edition of the *Southeastern U.S. Vegetable Crop Handbook*. Additional varieties, some with and without tolerance or resistance to various diseases and pathogens, are also recommended for Mississippi or neighboring states and are listed in the *Southeastern U.S. Vegetable Crop Handbook*.

[1]Disease tolerance/resistance of diseases indicated may be "tolerance/resistance," "resistance" only, "tolerance" only, or some level of disease resistance. Additional information may be provided in the latest edition of the *Southeastern U.S. Vegetable Crop Handbook*.

[2]Leaf mold is caused by the fungus *Passalora fulva*. Former names of this pathogen, including *Fulvia fulva* and *Cladosporium fulvum*, may still be used in various publications.

the production area. This may be done by placing soil and rogued plants in garbage bags immediately upon removal.

Do not use tobacco. Tobacco products can carry tobacco mosaic virus. The virus is easily transmitted to susceptible tomatoes and peppers. Avoid using tobacco while working with these crops. Workers should wash their hands thoroughly in soap and water after handling tobacco and before working with tobacco mosaic-susceptible plants. Workers may disinfect their hands by washing them in reconstituted nonfat dry milk (20% wt/vol). This solution can be very effective in reducing tobacco mosaic virus on surfaces, including plants, tools, and clothing. The length of soaking time needed to be effective depends on the item being disinfected, but a 10-minute soak works best.

Clean equipment. Remove plant debris and wash soil from farm equipment before moving it from one field to another. This can help prevent the movement of pathogens from infected fields into uninfected fields.

Avoid working with plants when wet. Delay cultivation and walking or moving through a crop with equipment until rain or dew has dried and plant surfaces are no longer wet. This reduces the chances of moving bacteria and fungi from diseased to healthy plants.

Avoid "dirtying" plants during cultivation. Piling soil around the base of plants creates an environment that favors stem rots and fungal growth.

Chemical Practices

The Organic Materials Review Institute (OMRI) is a national nonprofit organization that determines which products are suitable for use in organic production. The OMRI lists approved products that can be used in USDA-certified organic farming systems. The list includes biological, biorational, and inorganic products labeled for pest management. A partial list of some OMRI-approved products labeled for use on various crops against certain diseases is included in **Table 4**.

Alternatives to using synthetic products to manage vegetable diseases include using fungicides that contain sulfur and copper. Spraying or dusting with sulfur is an old remedy that still works on rusts, powdery mildews, and leaf spots on tomato and other vegetable crops. Mix finely ground sulfur with water at the rate of 3 ounces per 3 gallons

Table 4. Various OMRI-approved products[1] for vegetables.

Trade Name (Company)	Active Ingredient(s)	Diseases Managed	Labeled Crops	Labeled for Greenhouse Use?
Actinovate AG (Novozymes BioAg)	*Streptomyces lydicus* strain WYEC 108	soil-borne diseases, powdery mildew, *Alternaria*, *Botrytis*, gray mold, and others	many vegetables	yes
Cease (BioWorks Inc.)	*Bacillus subtilis* strain QST 713	bacterial and fungal foliar diseases and fungal soil-borne diseases	many vegetables	yes
Contans WG (Sipcam Agro USA Inc.)	*Coniothyrium minitans* strain CON/M/91-08	*Sclerotinia* diseases	many vegetables[2]	yes
MilStop (BioWorks Inc.)	Potassium bicarbonate	powdery mildews and foliar fungal diseases	many vegetables	yes
Mycostop (Verdera Oy)	*Streptomyces griseoviridis* strain K61	seed, root, and stem rots	any vegetable	yes
OxiDate 2.0 (BioSafe Systems, LLC)	Hydrogen dioxide Peroxyacetic acid	many root and foliar fungal diseases	many vegetables	yes
RootShield[3] (BioWorks Inc.)	*Trichoderma harzianum* various strains	soil-borne plant diseases	many vegetables	yes
Serenade (Bayer CropScience LP)	*Bacillus subtilis* strain QST 713	bacterial and foliar fungal diseases and soil-borne fungal diseases	many vegetables	not prohibited

[1]This is a partial list of OMRI-approved products that have been widely researched. There are many more OMRI-approved products on the market. Product labels change; always check the product label and read and follow all label instructions before use. Also, check to make sure that a product is approved for organic production and is approved for use in Mississippi.
[2]Tomatoes are not included in the list of fruiting vegetables on this label.
[3]Many, but not all, RootShield products are approved for use in Mississippi.

of water, or dust an even coat over plant surfaces. Rain easily removes sulfur from plants, so you may have to make frequent applications to get adequate disease protection. To avoid plant injury, do not use sulfur when the temperature is 90°F or above.

Bordeaux mixture is a fungicide that works on a number of fungal and bacterial pathogens that cause blights and leaf spots on vegetables. Bordeaux mixture can be made at home by combining hydrated lime or any type of finely ground lime with powdered copper sulfate (sometimes referred to as "bluestone"). Both materials should be available at farm and garden supply stores, but you may have to do some searching.

Bordeaux mixture can be made in several strengths, but the most popular and effective strength for general field and orchard use is the 4-4-50 formulation. The numbers are the ratio of copper sulfate and lime in 50 gallons of water. For example, 4 pounds each of these materials would be combined in 50 gallons of water.

Since this amount is much more than most growers need, the ratio can be reduced to a more useable amount. To prepare a gallon of a 4-4-50 Bordeaux mixture spray, measure out 2 tablespoons of copper sulfate and 3 tablespoons of hydrated lime. Mix the lime with a pint of water to make a "milk of lime" suspension. Dissolve the copper sulfate in a pint of water. It may take several minutes for the copper sulfate to dissolve. Strain each container of these materials through a cheesecloth filter. This is very important. If cheesecloth is not available, use cloth of a similar loose weave. The filtering is necessary to remove small pieces of lime or copper sulfate that will not dissolve and to prevent these pieces from clogging up your garden sprayer. To make the filter, place the cheesecloth loosely over the top of another container and fix securely in place with a string or rubber band.

Add the filtered copper sulfate solution to a 1-gallon container. Then add the filtered lime solution. Add enough water (about 3 quarts) to the container to bring the total volume up to 1 gallon. You now have 1 gallon of Bordeaux mixture ready to use. For 2 gallons, simply double the proportion of materials and prepare as before.

For best results, use Bordeaux mixture the same day you make it, and keep the sprayer agitated. Do not add insecticides to the Bordeaux mixture without first checking the insecticide label for possible compatibility problems.

Bordeaux mixture may be used to manage early and late blight on tomatoes and Irish potatoes. On leafy greens, this fungicide helps to manage most of the leaf spots that commonly occur on mustard and turnips.

Additional Resources

Southeastern U.S. Vegetable Crop Handbook. Available online (http://www.thepacker.com/guides/Pest-production-guides) or by contacting your local county Extension Office.

Organic Materials Review Institute website (www.omri.org).

Soil Testing for the Farmer (Information Sheet 346). http://extension.msstate.edu/publications/information-sheets/soil-testing-for-the-farmer.

Soil Testing for the Homeowner (Information Sheet 1294). http://extension.msstate.edu/publications/information-sheets/soil-testing-for-the-homeowner.

How to Collect and Package Plant Disease Specimens for Diagnosis (Publication M1562). http://extension.msstate.edu/publications/miscellaneous/how-collect-and-package-plant-disease-specimens-for-diagnosis.

Plant Disease Sample Submission Form (Form 1139). http://extension.msstate.edu/publications/forms/plant-disease-sample-submission-form.

Nematode Soil Sample Bag (Form 591). Available from your local county MSU Extension office.

Nematode Soil Sample Form (Form 448). http://extension.msstate.edu/publications/forms/nematode-soil-sample-form.

Organic Insect Control for Commercial Vegetable Production

Controlling insect pests on commercial vegetables organically is difficult, especially in the South, but it is not impossible. The key to success is to choose your crops and planting times wisely and rely more on noninsecticidal management methods than on insecticide sprays. There are only a few organic insecticides available for use in commercial vegetables, and organic insecticides are generally less effective than their nonorganic counterparts. If you rely on organic insecticides as your primary means of insect control, you will spend a lot of time and money spraying and may still have disappointing results.

Following are some of the more important non-insecticidal management tools. These tools are available to both conventional and organic vegetable producers, but they are a lot more important for organic growers. It is much more difficult to "spray your way out of trouble" in organic production.

Choose crops that have relatively few insect pests. Sweet corn for fresh market is a lot easier to grow organically than tomatoes are. This does not mean you cannot grow tomatoes organically, but it does take more planning, management, effort, and luck. Sweet corn for commercial canning is a different situation altogether. Because of the extremely low tolerance for caterpillar contamination, it is probably not possible to grow organic sweet corn successfully in Mississippi for commercial canning, especially if transgenic seed is not an option.

Grow crops at a time of year when the insect pests they do have are least abundant. Usually, early-planted crops experience less insect pressure than late-planted crops, but this is not always the case. Most vegetable insect pests have several generations per year, with populations increasing each generation. By late summer and fall, populations of pests like stink bugs, whiteflies, and tomato fruitworms can be extremely high. If you have large acreages of agricultural crops growing nearby that generate large numbers of pests, such as stink bugs, loopers, armyworms, or tomato fruitworms, time planting of susceptible vegetable crops so that they will be harvested before the agricultural crops mature and insects begin leaving the fields in search of other hosts. There are some situations where it is helpful to delay planting until overwintered pests have left their overwintering sites and moved to other crops. This is true for bean leaf beetles on beans and peas and for cucumber beetles on melons and squash.

When possible, choose varieties that are resistant to key pests. Sometimes choosing a variety that is resistant to a particular disease can aid in insect management, as well. For example, thrips control is less important on tomatoes resistant to tomato spotted wilt virus than on nonresistant varieties. Of course, there are no resistant varieties for many pests, and varieties that are resistant don't always have other traits needed to produce a marketable, profitable crop. Consider the big picture when choosing varieties. See **Table 5** for a partial listing of vegetable varieties with insect tolerance or resistance.

Practice crop rotation. Repeatedly growing the same crop in the same field can result in increased insect pressure. Cowpea curculios on southern peas is a good example. This pest overwinters as an adult in crop residue and nearby ground litter and rarely flies. Rotating the pea patch to a different location each year can help manage this important pest. Likewise, rotating the location of the turnip patch can help reduce numbers of vegetable weevils. Crop rotation is also important in controlling many diseases.

Avoid growing successive plantings of the same crop near each other, especially if the crop is attacked by serious insect pests that have multiple generations per year. For example, if you grow three successive plantings of organic peas in close proximity, each planted 2 or 3 weeks apart, there will probably be a lot of stink bugs in that last planting!

Think about where you plant a crop in relation to other crops, including crops on neighboring farms. If you are trying to produce organic tomatoes in late summer or early fall, locate them as far as possible from crops such as corn, sorghum, soybeans, or peas that generate large numbers of stink bugs and tomato fruitworms. A tomato patch surrounded by timber will probably have less stink bug and tomato fruitworm pressure than a patch near annual row crops.

Destroy old crop residue as soon as possible after the final harvest. This is an extremely important insect management tool! It destroys large numbers of immature insect pests before they have a chance to become adults and move to nearby crops, destroys adult insects before they have a chance to lay eggs or enter overwintering sites, removes the crop as a breeding site for future generations of pests, and destroys overwintering pests. Prompt crop destruction also helps control disease and weeds.

Know when to quit on a crop. Because pest populations usually increase as a crop ages, fruit produced earlier in a crop's growth cycle are more likely to be blemish-free and pest-free than fruit produced later. Depending on the overall situation, it may be worth growing a crop just to get those few early weeks of production and then stopping when insect pressure increases. Then, remember to destroy old crop residue promptly!

Plant into weed-free fields and maintain good weed control. Mechanical tillage is the main method of weed control in organic production. It also helps control insect pests such as cutworms, false chinch bugs, vegetable weevils, spider mites, slugs, and crickets that often begin developing on weeds growing in the field before planting and then move to seedling vegetables. Avoid these early insect problems by planting into a weed-free field. For cutworm control, till the field to destroy all weeds and cover crops at least 3 weeks before planting. Thorough

Table 5. Vegetable varieties with tolerance or resistance to specific insect pests.

Vegetable	Variety	Insect Tolerance
Broccoli	De Cicco	striped flea beetle
Cabbage	Early Globe	cabbage looper, imported cabbageworm
	Red Acre	cabbage looper, imported cabbageworm
	Round Dutch	cabbage looper, imported cabbageworm
Chinese cabbage	Michihli	diamondback moth
Collard	Georgia	striped flea beetle, harlequin bug
Corn	Merit	corn earworm (good shuck extension)
	Golden Security	corn earworm
	Transgenic Bt varieties[1]	European corn borer, corn earworm
Cucumber	Poinsett	spotted cucumber beetle
	Ashley	pickleworm, spotted cucumber beetle
Kale	Yates	diamondback moth
Mustard	Florida Broadleaf	diamondback moth, striped flea beetle
Radish	Cherry Belle	diamondback moth, harlequin bug
	White Icicle	harlequin bug
Rutabaga	American Purple Top	diamondback moth, striped flea beetle
Squash	Early Prolific (SN)	pickleworm, striped cucumber beetle
	Straight Neck	pickleworm, striped cucumber beetle
	White Bush Scallop	pickleworm, striped cucumber beetle
	Zucchini	striped cucumber beetle, squash vine borer[2]
Sweetpotato	Centennial	sweetpotato flea beetle, southern potato wireworm
	Jewel	sweetpotato flea beetle, southern potato wireworm
	Beauregard	soil insects (except susceptible to flea beetles)
Tomato	TSWV-resistant varieties[3]	TSWV is vectored by thrips. Thrips control is less important on TSWV-resistant varieties.
Turnip	Seven	diamondback moth, striped flea beetle
Watermelon	Crimson Sweet	pickleworm, spotted cucumber beetle

[1]Transgenic Bt sweet corn varieties are not approved for certified organic production. Because of their cost and the licensing and resistance management practices required for their use, they are only suitable for large-scale commercial production. Use transgenic Bt varieties only if you are sure they are acceptable for your particular market. These varieties provide excellent control of European corn borers, good control of corn earworms, and suppression of fall armyworms.

[2]A general rule for squash and pumpkin varieties and their susceptibility to squash vine borers is that *Cucurbita moschata* and *C. mixta* species are more susceptible than *C. pepos* species, and *C. maxima* species are less susceptible than *C. pepos*. Within the *C. pepos*, zucchinis tend to be less susceptible than yellow summer squash.

[3]Tomato varieties resistant to tomato spotted wilt virus (TSWV) include Amelia VR, Bella Rose, BHN 640, BHN 602, Quincy, Taladega, Crista, Muriel (roma), BHN 685 (roma), and Picus (roma).

tilling helps control insect pests that overwinter in the soil or under crop debris. It also helps reduce the number of in-field fire ant mounds.

Know which pests are likely to occur on the crops you are growing and understand the biology of these pests. Often you can use your knowledge of a pest's biology to help manage that pest. Know how to identify insect pests and be able to distinguish between insects that are pests and those that are not. See Extension Publication 2347 *Insect Pests of the Home Vegetable Garden* for information on identification and biology of common vegetable pests.

Use trap crops when feasible. Trap crops are crops planted to attract pests away from the main crop. Around cabbage, border plantings of collards can trap diamondback moths. Trap crops can also work for stink bugs, leaffooted bugs, and bean leaf beetles. Plant some southern peas near your tomato patch, and most of the stink bugs will go to the peas. Similarly, sunflowers can be used as a trap crop for leaffooted bugs.

But there is an important pitfall to using trap crops: you have to be able to kill the pests that are attracted to the trap crop before they move to the main crop. Otherwise, you have a nursery crop! The problem is there are no really effective organic insecticides to control stink bugs and leaffooted bugs. You will have to use conventional insecticides like Baythroid, ProAxis, or Mustang Max. Depending on the organic production goals for your particular farm, this may or may not present a problem. Potentially, you could use a trap crop of southern peas to help keep stink bug numbers down in your organic tomato patch, spray the peas with an effective nonorganic stink bug treatment, and sell organic tomatoes and conventionally grown peas. But this will not work if your organic certification program does not allow any nonorganic products to be used on the farm.

Use metalized reflective plastic mulches to reduce early-season infestations of pests such as thrips, aphids, and whiteflies. Research has shown that reflective mulches can greatly reduce the number of thrips and aphids attracted to seedling crops. The increased light reflection prevents the insects from recognizing and landing on seedling plants. This is especially helpful in reducing incidence of serious insect-vectored diseases, such as tomato spotted wilt virus. In fact, some studies have shown reflective mulches to be more effective than weekly insecticide sprays for reducing TSWV incidence in tomatoes and peppers. Reflective mulches do not provide the same degree of early-season soil warming as black mulches do, but they do help cool the soil on later crops.

Use physical exclusion methods when feasible. Physical exclusion methods are not available for most crops, but there are some specific situations where they may be useful. One is in the production of seedling transplants. Transplants grown in a "bug-tight" greenhouse, in isolation from other plants, are more likely to be free of insects and insect-vectored diseases. Home gardeners sometimes protect newly set transplants from cutworms with "cutworm collars." Cutworm collars are made of wax paper or aluminum foil and extend from about 1 inch below the soil line to 2 to 3 inches above. This is usually too labor-intensive for commercial production but may still be worthwhile if you have to plant into fields where weeds were destroyed fewer than 3 weeks before planting.

Some growers use floating or hoop-supported spun-bond fabric row covers for early frost protection and to help protect against early-season pests such as cucumber beetles on melons or squash. Row covers are costly and labor-intensive to install, but they are an effective way to protect many vegetable crops from early pest infestations. Agribon Row Covers and Dewitts Row Covers are examples of floating row covers available in commercial quantities.

Rely on naturally occurring biological control. This is our most important means of controlling insect pests, and it is much more important to organic growers than to conventional growers. Pest insect populations are normally kept in check by naturally occurring populations of the three Ps: predators, parasites, and pathogens. For any given insect pest, there are usually many different species of predators that feed on that pest; several species of parasitic wasps or flies that attack it; and fungi, bacteria, and viruses that cause fatal diseases. Collectively, these naturally occurring beneficial organisms are our most important defense against pest insects. Without this free natural control, the pests would definitely have the advantage.

Still, it is normal for there to be more pests than predators and parasites—there are usually more rabbits than foxes. When severe pest outbreaks occur, it is usually because the pest population has gotten ahead of the beneficials. The beneficials will usually eventually catch up and bring the pest population under control, but this does not always happen in time to prevent excessive damage.

What can you do to take advantage of this free natural insect control? The main thing is to try to avoid messing it up! Insecticide applications kill more than just the target pests; they also kill beneficial insect predators and parasites. This can trigger outbreaks of other pests, or allow the population of the target pest to rebound to even higher levels. Don't spray unless you are sure you really need to spray. On the other hand, don't let concern over preserving beneficials prevent you from spraying when you really need to. When you do have to spray, try to choose an insecticide that works well on the target pest but

has minimal impact on beneficial insects. Organic growers usually benefit much more from biological control than conventional growers do because organic insecticides tend to harm beneficial insect populations less.

Growing a diversity of plants, especially plants with large numbers of blooms, can also promote beneficial insects. Many adult predators and parasites rely on nectar from blooming plants as food. Some organic producers maintain "nursery strips," planted with a variety of plants that bloom at various times, to provide habitat and nectar sources for beneficial insects. Just be sure to avoid using plants that are a host to a major pest of one of the crops you are growing.

What about buying and releasing beneficial insects into your crop? Artificial releases of laboratory-reared parasites and predators can work quite well in enclosed greenhouse situations where the environment is carefully controlled, but such releases are usually less successful in annual outdoor crops. The released insects either fly away, die because they are not adapted to the environment, or fail to find suitable hosts because the timing is wrong. This does not mean that there are no situations where artificial releases of predators or parasites will work outdoors. There are special cases where such releases can be helpful. Success with artificial releases in outdoor annual crops requires knowing exactly which pests you are trying to control; which beneficial insects you need to release; when and how to make the releases; and where to purchase healthy, vigorous beneficial insects.

Educate your market. Organically produced vegetables usually cost more to produce and have more insect blemishes and infestations than conventionally produced vegetables. Consumers who purchase organic vegetables usually understand this, but it is still wise to be sure the customer understands what they are buying. Explanations such as the following can be helpful: "This is organic sweet corn. Most ears are probably going to have some caterpillar damage, or even live caterpillars, at the end of the ear." Or: "I can supply organic tomatoes, but they are more expensive to produce and they will probably have superficial insect damage on some fruit."

Grow healthy, vigorous plants. This is a goal of every farmer and gardener, but it also helps with insect control. Healthy plants are less susceptible to insect attack and better able to tolerate low to moderate insect infestations and still produce. For example, plants stressed by drought or potassium deficiency are more susceptible to spider mites. On the other hand, excessive nitrogen can make plants more susceptible to spider mites and aphids.

Monitor pest populations. Good scouting can help assess effectiveness of noninsecticide management tactics and help you better time insecticide treatments. Scout crops at least once or twice weekly by making a special trip through the crop specifically to check for insects and diseases. Know what pests are present and how abundant they are. Use a hand lens to check for small pests like thrips and spider mites. Use pheromone traps and other survey tools as appropriate for the particular pests you need to monitor. Yellow sticky traps can help monitor pests like thrips and whiteflies. Pheromone traps are available for moths of many caterpillar pests and a few other types of pests.

Use mating disruption when available and appropriate. The goal of mating disruption is to confuse male moths and reduce their ability to find mates by flooding the field with synthetic pheromone. As a result, many of the female moths lay unfertilized eggs. Mating disruption pheromones are species specific and are available for only a few vegetable insect pests. CheckMate TPW and CheckMate DBM are commercially available products that work against tomato pinworm and diamondback moth, respectively. Note that while the TPW lure is OMRI-approved, the DBM lure is not.

Use mechanical controls where feasible. Some organic growers use specially designed vacuums or blowers to remove insects from plants. A forceful spray of water can be used to dislodge pests such as aphids. Though too labor-intensive for large-scale use, hand-picking insects and egg masses can help delay pest population buildup on small plantings.

Use organic insecticides when necessary. Sometimes you have to use insecticides to avoid excessive crop damage. Scout regularly and begin treating before pests reach damaging levels. Choose approved organic insecticides that are effective against the pest or pests you are trying to control. Use rates that are adequate but not excessive. Apply sprays in a manner that achieves thorough coverage, especially to undersides of leaves. Target treatments against the most susceptible pest stage. For example, when treating caterpillar pests, target small, newly hatched caterpillars. Re-treat at appropriate intervals when necessary to obtain or maintain control. Comply with the preharvest interval for the specific insecticide and crop.

Be aware of the limitations of organic insecticides. Organic insecticides vary greatly in relative efficacy against various pests. Spinosad and Bts are effective against most caterpillar pests if they are applied when caterpillars are small, but they don't work at all on stink bugs and most beetles. If good spray coverage is achieved, products like azadirachtin, botanical and horticultural oils, and insecticidal soaps can be effective against aphids and whiteflies. There are no highly effective organic insecticides for most beetles and stink bugs, but products

like pyrethrins and rotenone + pyrethrins can provide limited, short-term control.

Use integrated pest management. Don't rely on a single control tactic to control any pest. The more different methods you use, the greater your chances for success. Consider all pests likely to occur in your crop, including insects, diseases, and weeds, and develop a pest management plan that addresses all of these.

Keep records, keep learning, and use what you learn in the next crop. Every farm situation is different. By keeping records, you can learn which pests are particular problems on your farm and at what time of year they are most abundant. You can also learn which pests are least likely to cause problems and what management tactics work best for you.

Organic Insecticides for Commercial Vegetable Production

Following is a listing and brief review of many of the insecticides currently approved for organic vegetable production. Note that some of these active ingredients are also sold as formulations that are not approved for organic production. For example, Spintor is a liquid formulation of spinosad that is widely used in commercial vegetable production, but Spintor contains inert ingredients that are not organic. Entrust also contains spinosad, but Entrust is a wettable powder formulation that is specially formulated for organic production.

Also note some of these products are extremely target specific. Spod-X is only active against beet armyworms! Other products, such as Pyganic, have activity against a wide range of insect pests, but only provide very short-term control and are generally much less effective than conventional inorganic insecticides. Consequently, sprays may need to be applied more frequently than with conventional insecticides. Because most organic insect control products only work by direct contact, good spray coverage is especially important when using organic insecticides. Neemix and Aza-Direct are effective against whiteflies. Vegetable oils, such as Vegol, and soaps, such as M-pede, will control spider mites, aphids, and other soft-bodied insects. All these products work only on pests they contact.

Always read the product label at least twice, once before you buy it and again just before you use it. Be sure the product is suitable for your organic production goals. Follow label directions.

Spinosad: Spinosad is a biopesticide that is very effective against thrips, leaf miners, and most caterpillar pests. It is produced through commercial culture of a soil-borne microbe that makes the toxic metabolites known as spinosad. These metabolites are harvested and formulated into insecticide, so the final product contains no living microbes. Spinosad is organic, but most formulations contain inorganic inert ingredients that disqualify them as "organic insecticides." Some products are formulated to comply with organic guidelines. Entrust is an organic formulation of spinosad formulated for commercial use. Justice and Greenlight Fire Ant Bait with Conserve are granular baits containing spinosad that are approved for fire ant control in organic crops.

Bts: "Bt" stands for *Bacillus thuringienisis*. Bts are naturally occurring soil bacteria that produce toxins that have insecticidal activity. There are many different strains of Bts. Some only control caterpillar pests (*Bt kurstaki* and *Bt aizawai*), while others only work on mosquito larvae (*Bt israelensis*) or beetles (*Bt tenebrionis*). Bts are generally slow-acting and have to be eaten by the caterpillar in order to work, but they are useful organic insecticides when used properly. Javelin, Dipel, Delfin, Deliver, Biobit, and Agree are examples of Bt products used in commercial organic vegetable production. Because of their relatively slow activity, Bts are best used when caterpillars are small.

Transgenic Bt Crops: Some varieties of sweet corn have been biologically engineered to produce toxins found in some of the *Bacillus thruingienisis* bacteria used to control caterpillar pests. These transgenic crops inherently provide high levels of control of caterpillar pests such as corn earworms and European corn borers. Be aware, however, that these transgenic crops are not approved for certified organic production. Use transgenic varieties only if you are sure they are suitable for your market.

Azadirachtin: Azadirachtin is a natural insect-growth disruptor derived from the seed of the neem tree. It is especially effective against sucking insect pests, such as whiteflies and aphids. Because it is a growth disruptor, it is slow-acting and must be applied when low populations of immature pests are present. Neemix, Aza-Direct, and Azatrol are examples of azadirachtin products labeled for commercial organic vegetable production. Azadirachtin is one of the better options for organic control of whiteflies.

Neem Oil: Neem oil, obtained from the seed of the neem tree, controls soft-bodied insects such as aphids, whiteflies, and mites. It also helps control certain fungal diseases. Products containing "clarified hydrophobic extract of neem" do not contain azadirachtin; they usually contain 70 percent neem oil. Trilogy 70 percent neem oil is marketed for commercial organic vegetable production, and Monterey 70 percent neem oil is sold for small-scale production.

Beauvaria bassiana: *Beauvaria bassiana* is a fungal disease that infects certain insect pests, especially

whiteflies, thrips, aphids, mealybugs, and certain beetles and caterpillars. It is marketed for organic crop production under the brand names Mycotrol-O, BotaniGard, and Naturalis L. These products are slow-acting, so begin treatments when pest populations are low. Do not tank-mix with fungicides.

Viruses: Virus diseases of insects attack only very specific species. A few insect viruses are formulated and sold commercially. Spod-X LC is a sprayable formulation containing polyhedra of a viral disease that attacks only beet armyworms. Gemstar LC is a similar product that controls only corn earworms/tomato fruitworms and tobacco budworms. Proper pest identification and spray timing are critical when using these products.

Parasitic Nematodes: Some nematodes attack only insects, and some of these species of nematodes are formulated and marketed for use in organic crop protection. There are several species, but most are *Heterorhabditis* or *Steinernema* species. Parasitic nematodes are usually used to control soil-dwelling pests such as cutworms, squash vine borers, mole crickets, and white grubs. Do your homework before purchasing parasitic nematodes. Be sure that the species you purchase is active on the pest you need to control, and be sure you know how to handle and apply the nematodes properly.

Pyrethrin: Pyrethrin, also known as pyrethrum, is a natural extract from the flowers of the pyrethrum daisy. Pyrethrin is a broad-spectrum insecticide that affects most insect pests through contact activity. However, it is short-lived, and many pests may be ''knocked down" but recover later. Inorganic synergists, such as pipronyl butoxide (PBO), are often mixed with pyrethrin to enhance activity. Although the addition of PBO greatly enhances short-term control, it does not greatly increase residual control. Pyrethrin products that contain the inorganic synergist PBO cannot be considered organic. Pyganic is an example of a totally organic formulation of pyrethrin. This product can be used to control a wide range of insect pests, but repeated treatments may be necessary because it only provides very short-term control.

Rotenone + Pyrethrin: Rotenone is an older botanical insecticide that is effective against aphids, stink bugs, beetles, and other pests, but it is difficult to find products that contain only rotenone. Pyrellin is a commercial insecticide that contains a combination of rotenone and pyrethrins. Pyrellin is labeled for use on commercial vegetables to control pests such as stink bugs, squash bugs, cucumber beetles, vegetable weevils, and others. Note that Pyrellin is not currently approved by OMRI (Organic Materials Review Institute).

Plant Extract Products: Several companies market, or are developing, products based on extracts from various plants for insect control. Quite a few companies market "garlic spray" products that have pest repellent properties. Garlic Barrier is one example. Be aware that such products may not be approved for certified organic production. Cinnamite is a commercial miticide based on extracts from cinnamon oil. It is not currently OMRI-approved and can be phytotoxic to tomatoes and certain other plants.

Iron Phosphate: Several companies make slug baits that contain iron phosphate and are approved for organic production. Sluggo is an example of an iron phosphate-based slug bait. This product is only useful to control snails and slugs.

Horticultural Oils: Petroleum-based horticultural oils are useful for control of soft-bodied pests such as aphids, spider mites, and whiteflies. However, most petroleum-based horticultural oils are not approved for organic production. Although the oils themselves are classified as organic, many of the secondary ingredients added as emulsifiers are inorganic. Only a few companies formulate petroleum oils using organic emulsifiers. BVA Spray 10 and Organic JMS Stylet-Oil are two examples. Stylet oil is most often used to help prevent sucking insects like aphids from transmitting certain virus diseases. Stylet oil does not necessarily kill insects. Instead, it forms a fine coat on the leaf and cleans the virus particles off the insects' mouthparts as they feed, preventing them from getting into the plant.

Vegetable Oils and Fish Oils: There are a number of organic oils made from various plant seed or fish extracts. These are effective against soft-bodied insects such as aphids, mites, and whiteflies. Golden Pest Spray Oil is an example of an oil derived from soybeans. Vegol Year-Round Spray Oil is derived from canola seed, and Organocide is a combination of fish oil and sesame oil. Such oils may or may not be approved for certified organic production. Some products contain a combination of vegetable oil and pyrethrins. Pyola, a combination of canola oil and pyrethrins, is one example.

Insecticidal Soaps: Insecticidal soaps are potassium salts of fatty acids. They help control soft-bodied insects such as aphids, spider mites, and whiteflies, but they require direct contact to work. Be sure to read and follow label directions; insecticidal soaps can cause foliage injury. Be aware that chain length has a big effect on the phytotoxicity of fatty acids. Some short-chain fatty acids are actually used as herbicides. This is one reason it is not a good idea to use commercial soaps as insecticides. Another good reason is that they are not labeled for use as insecticides. If you want to use soaps to control insect pests, stick with labeled insecticidal soaps. M-Pede and Safer Insect Killing Soap Concentrate are two examples.

Sulfur: Elemental sulfur has long been used to control spider mites and certain plant diseases and is approved

for organic production. Organic gardeners primarily use microfine sulfur dust formulated for application as a liquid spray. Sulfur can cause skin and eye irritation and can cause plant injury if improperly used, especially if applied in combination with oils or if applied within several weeks of an oil treatment. Thiolux, Microsul, and Sulfur DF are examples.

Kaolin Clay: Finely ground kaolin clay is sometimes applied to crops to help reduce heat stress or prevent sunburn on fruit of crops like tomatoes and peppers. It is applied as a foliar spray at relatively high rates, around 25 pounds per acre, and dries to form a fine coating of clay particles that reflect sunlight. This coating of clay also helps suppress feeding by certain insect pests, such as cucumber beetles, flea beetles, thrips, and grasshoppers. Surround WP is one example of a commercially available product (95 percent kaolin clay) that is OMRI-approved.

Table 6. Insect management options for organic vegetable production.

Pest	Management and Control Options
Aphids	Use reflective mulch. If they are available, consider varieties resistant to aphids or to important aphid-vectored viruses. Use a strong water spray to wash aphids from plants. Where appropriate, use stylet oil to help reduce virus transmission. Destroy crop residue promptly after final harvest. This is especially helpful for root aphids. Foliar sprays: azadirachtin, neem oil, oil sprays, insecticidal soaps
Whiteflies	Grow transplants in isolation from other plants. Use reflective mulch. Avoid growing whitefly-susceptible crops near greenhouses or nurseries. Destroy crop residue promptly after final harvest. Foliar sprays: azadirachtin, *Beauvaria bassiana*, neem oil, insecticidal soaps
Thrips	Grow tomato varieties resistant to tomato spotted wilt virus. Use reflective mulch. Promptly remove tomato spotted wilt virus-infected plants. Avoid mowing or tilling field borders and adjacent fallow fields after transplants are set. Foliar sprays: spinosad, azadirachtin, neem oil, insecticidal soaps, pyrethrins
Spider mites	Plant into a weed-free field. Avoid mowing field borders after midsummer or during drought. Avoid potassium deficiency, drought stress, or excessive nitrogen. Avoid water stress. Mist leaves with water spray to encourage outbreak of natural fungal disease. Foliar sprays: neem oil, oil sprays, insecticidal soaps, sulfur
Cutworms	Be sure field is tilled and free of all weeds and cover crops at least 3 weeks before planting. Use "cutworm collars" when planting small numbers of transplants into cutworm-prone situations.
Seed corn maggots Root maggots	Work manure and other organic fertilizers into the soil in the fall before you plan to plant, or well before planting. Till field at least 4 weeks before planting to allow weeds and cover crops time to decompose.
Mole crickets	Preventive treatment with parasitic nematodes *Steinernema scapterisci*.
Leaf miners	Use floating row covers where appropriate. Foliar sprays: spinosad, neem oil
Bean leaf beetles	Plant crop after beetles have left overwintering sites and moved to other crops, such as soybeans. Grow varieties with resistance or tolerance to key beetle-vectored virus diseases. Foliar sprays: pyrethrins, rotenone + pyrethrins
Flea beetles	Maintain good weed control. Many weeds, especially solanaceous weeds, are hosts to flea beetles. Destroy crop residue promptly following harvest. Grow insect-resistant sweetpotato varieties. Parasitic nematodes can help control larvae in soil. Foliar sprays: pyrethrins, rotenone + pyrethrins, insecticidal soap
Colorado potato beetles	Avoid planting Irish potatoes following another solanaceous crop. Mulching with straw can help reduce populations. Destroy crop residue promptly following harvest. Foliar sprays: spinosad (target larvae), rotenone + pyrethrins
Blister beetles	These insects often occur in clusters. Dislodge from plants and crush them. Foliar sprays: pyrethrins, rotenone + pyrethrins
Cucumber beetles	Avoid early planting to avoid the heavy early flush of overwintered beetles. Use floating or hoop-supported row covers to protect young plants. Foliar sprays: pyrethrins, rotenone + pyrethrins
Cowpea curculios (southern peas)	Rotate planting locations. Avoid locating successive crops near earlier crops. Destroy crop residue promptly after final picking. Foliar sprays: pyrethrins, rotenone + pyrethrins

Vegetable weevils (turnips & greens)	Rotate planting location. Avoid locating successive susceptible crops near earlier host crops. Destroy crop residue promptly after final harvest. Foliar sprays: rotenone + pyrethrins
Sweetpotato weevils	Plant only certified weevil-free slips. Do not transport sweetpotatoes from weevil-infested areas to noninfested areas. Destroy crop residue promptly after harvest. Avoid storing potatoes through the winter, especially in weevil-infested areas of the state.
Harlequin bugs	Plant mustard as a trap to protect less favored hosts, but destroy the trap before bugs move to main crop. Destroy crop debris promptly after harvest. Foliar sprays: rotenone + pyrethrins, insecticidal soap
Wireworms White grubs	Till field deeply in the previous fall. Avoid planting recently tilled pastures or fallow fields. Grow insect-resistant sweetpotato varieties.
Squash bugs	Use floating or hoop-supported row covers to delay infestations. Destroy crop residue promptly after harvest. Foliar sprays: pyrethrins, rotenone + pyrethrins
Stink bugs Leaffooted bugs	Grow early crops. Stink bug populations are highest from midsummer through fall. Avoid growing successive crops near earlier crops. Time vegetable crops to be finished before nearby agricultural crops mature. Destroy crop residue promptly after final harvest. Foliar sprays: pyrethrins, rotenone + pyrethrins
Tomato fruitworms Corn earworms	Grow an early crop. Fruitworm numbers are highest from midsummer through fall. Grow corn varieties with long, tight-fitting shucks. Foliar sprays: spinosad, Bts, Gem Star (NPV virus).
Armyworms	Grow early crops. Populations increase as season progresses. Control weeds, especially pig weeds and amaranth. Foliar sprays: spinosad, Bts, Spod-X (for beet armyworms only)
Loopers Diamondback moths	Use trap crop of collards to reduce diamondback moth infestation on cabbage and other cole crops. Use mating disruption pheromone (for diamondback moths only). Foliar sprays: spinosad, Bts
Squash vine borers	Grow resistant varieties when feasible. Mechanically removing borers from stems may be helpful in small plantings. Destroy crop residue promptly following last picking. Foliar sprays: spinosad (to control newly hatched larvae before they bore into plant)
Pickleworms Melonworms	Grow early crops. Populations are much higher in late season. Foliar sprays: spinosad, Bts
Slugs	Till weeds and old crop residue before planting. Use iron phosphate slug bait. "Beer traps" can be effective in small plantings.
Fire ants	Tillage helps reduce number of fire ant mounds in field. Use granular fire ant baits containing spinosad. Baits are slow-acting; use preventively. Apply granular fire ant bait around field borders, too.

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