

Organic Gardening

Kentucky Master Gardener Manual Chapter 18

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Organic farming and gardening have grown in popularity in recent years as consumers and producers have sought alternatives to synthetic fertilizers and pesticides in favor of biologically-based management. A 2008 survey by the National Gardening Association found that 12% of American household gardens (12 million households) use all-natural management techniques, an increase of 7% from 2004. This number is anticipated to grow by as much as 42%, to 17 million, if other households follow through on their plans to switch to all-natural methods.

The U.S. Department of Agriculture (USDA) National Organic Program (NOP) defines the rules for USDA Certified Organic production practices. (The label used to designate certified organic products is shown in Figure 1. See the USDA-NOP website at <http://www.ams.usda.gov/AMSv1.0/nop> for additional details). This publication provides an overview of the principles and practices of organic agriculture for the home gardener, whether he or she wants to grow a completely organic garden or adopt select practices to lower input costs and build soil fertility. The fertilizer and pest control strategies in this publication are consistent with spirit of the USDA-NOP guidelines. However, gardeners who want to meet the “letter” of those guidelines should explore the Organic Materials Review Institute (OMRI) list of NOP-approved materials at www.omri.org or look for the OMRI label when purchasing garden supplies (Figure 2).

Organic gardening offers the gardener many benefits—a safe, low-chemical gardening environment, produce free from synthetic pesticide residues, and gardens that can increase in fertility and natural pest control over time. However, reaping the benefits of organic management requires planning, observation, and thinking about the garden as an interconnected system of soils, plants, pests, and beneficial organisms. Principles and practices include:

- Building long-term soil fertility with composts, manures, and mulches
- Rotating crops
- Using good planning practices to avoid insect, disease, and weed pests and using biological or mechanical controls when necessary



Figure 1. USDA Certified Organic label.



Figure 2. OMRI label.

Planning Your Organic Garden

Crop Rotation

Crop rotation is alternating crops grown in a particular bed or field between growing seasons. By rotating crops, you can avoid buildup of certain pests and also enable nutrients in the soil to be used more efficiently.

The most popular type of rotation is alternating crops by botanical family. For example, diseases that affect tomatoes can also affect other members of the Solanaceae family, including peppers, potatoes, and eggplants.

Rotating crops in the Solanaceae family with crops in other families can minimize losses from these diseases. Similarly, rotating among crops that have different growth habits can help deter pests. For example, if root crops such as sweet potatoes or carrots are planted in the same location year after year, soil-dwelling insect pests, such as white grubs, wireworms, and some nematodes, may proliferate. Rotating among plants with different root architecture may prevent proliferation or help break these pest cycles.

One common rotation method is based on the fertility requirements for each crop. With this method, you categorize crops by whether they “feed” or “give” nutrients to the soil over the course of the growing season. Crops with high fertility

(primarily nitrogen) requirements have been described as heavy feeders, those with moderate fertility requirements as medium or light feeders, and crops that contribute nutrients are “givers.” (See Jeavons’ book in Additional Resources.) Crops are rotated in a cycle from heavy givers to light feeders to heavy feeders and back to heavy givers. Examples of crops in these categories are:

- **Heavy givers:** Beans (snap, pole, bush), peas, green manure crops such as clovers, and field peas
- **Light feeders:** Beets, carrots, garlic, onions, sweet potatoes, turnips
- **Heavy feeders:** Broccoli, cabbage, corn, cucumbers, squash, tomatoes

If you plan to practice rotation, it’s important to keep records and a year-by-year map of your garden. Flashcards also can be useful in the garden planning process. Using this technique, flashcards are made for each crop, with a copy of the flashcard for that crop for every year in the rotation (e.g., three potato flashcards for three years of potatoes). You can then manipulate the cards for a three-to-five-year timeline for the entire garden. This exercise, using the botanical family as the guide to the rotation, is outlined in *The New Organic Grower* by Eliot Coleman (see Additional Resources).

Common vegetables and their botanical families are listed in Table 1.

Table 1. Common garden vegetables and their botanical families.

Botanical Family	Common Family Name	Crop
<i>Solanaceae</i>	Nightshade	Tomato, pepper, potato, eggplant, tomatillo
<i>Brassicaceae</i>	Cole crop	Broccoli, cauliflower, cabbage, kale, Brussels sprouts, radish, rutabaga, turnip
<i>Cucurbitaceae</i>	Gourd	Winter squash, summer squash, melons, cucumber, pumpkin
<i>Apiaceae</i>	Carrot	Carrot, parsley, celery, parsnip
<i>Chenopodiaceae</i>	Goosefoot	Beet, chard, spinach
<i>Fabaceae</i>	Legume	Pea, bean
<i>Asteraceae</i>	Sunflower	Lettuce
<i>Liliaceae</i>	Lily	Onion, garlic, shallot, leek
<i>Poaceae</i>	Grass	Corn

Soil Fertility and Organic Fertilizers

A central tenet in sustainable and organic agriculture is to “feed the soil to feed the crop”—restoring and maintaining the soil organic matter that ultimately feeds crop plants. Soil organic matter accumulates through use of organic amendments such as composts, manures, cover crops, and mulches. Over time, these amendments sustain fertility, relieve compaction, improve both drainage and water holding capacity, and improve nutrient retention. However, organic amendments are delivered more slowly and less consistently than standard synthetic fertilizers because they become available as microbes and other soil organisms decompose.

Table 2 shows the nutrient contents (N-P-K) of several common sources of fertility in organic gardens.

Organic fertilizers rarely contain the N-P-K ratios to match recommendation from a soil test report. However, you can use the steps below to figure out how much fertilizer you need, whether you use the values in Table 2 or those listed in the nutrient analysis of a purchased amendment.

A soil test report recommends 2-3 lb of N, 1-2 lb of P_2O_5 , and 3-5 lb of K_2O per 1,000 square feet of garden. To calculate the organic fertilizer required from several sources, complete the following steps:

1. Calculate the nitrogen (N) recommendation first.
2. Calculate the phosphorus (P_2O_5) recommendation next.
3. Calculate the potassium (K_2O) recommendation next.

An example of these calculations is provided in Figure 3.

It's fairly easy to use organic sources to meet your garden's fertility requirements, and organic fertilizers are increasingly accessible. However, it is important to understand that for nutrients to become available from most organic sources (other than minerals and rock powders), they must be decomposed by soil organisms. Thus, it is important to understand how temperature, moisture, and other environmental factors affect soil organisms and the decomposition process. The effects of pH and temperature are described briefly below. For additional information, Jeff Lowenfel's book, *Teaming with Microbes*, is an excellent gardener-friendly primer on soil ecology and the activity of soil microorganisms (see Additional Resources).

Table 2. Nutrient content and release rates of organic fertilizers.

Materials	N (%)	P_2O_5 (%)	K_2O (%)	Relative Availability
Alfalfa meal	3.0	1.0	2.0	Medium-Slow
Blood meal	12.0	1.5	0.6	Medium-Rapid
Bone meal	0.7-4.0	11.0-34.0	0.0	Slow-Medium
Feather meal	11.0-15.0	0.0	0.0	Slow
Fertrell "Super N"	4.0	2.0	4.0	Slow
Fish meal	10.0	4.0	0.0	Slow
Fish emulsion	5.0	1.0	2.0	Medium-Rapid
Greensand	0.0	1.0-2.0	5.0	Slow
Kelp ¹	0.9	0.5	1.0-4.0	Slow
Manure² (fresh)				
Cattle	0.25	0.15	0.25	Medium
Horse	0.3	0.15	0.5	Medium
Poultry (50% water)	2.0	2.0	1.0	Medium-Rapid
Poultry (15% water)	6.0	4.0	3.0	Medium-Rapid
Manure² (dry)				
Dairy	0.7	0.3	0.6	Medium
Steer	2.0	0.5	1.9	Medium
Horse	0.7	0.3	0.5	Medium
Marl	0.0	2.0	4.5	Very Slow
Mushroom compost	0.7	0.9	0.6	Medium
Sulfate of potash magnesia (K-Mag)	0.0	0.0	22.0	Rapid-Medium
Soybean meal	6.7	1.6	2.3	Slow
Wood ashes ³	0.0	1.0-2.0	3.0-7.0	Rapid

Source: Adapted from How to Convert an Inorganic Fertilizer Recommendation to an Organic One, University of Georgia Cooperative Extension. Adapted from Boyhan, 2009. See Additional Resources.

¹ Kelp also contains common salt, sodium carbonates, and sodium and potassium sulfates.

² Manure contents may vary with amount of straw/bedding included, feed quality, and method of storage. (See the health and safety questions in the Cooperative Extension Publication *Composting* (ID-192).

³ Potash content depends on the tree species burned. Wood ashes are alkaline and contain approximately 32% CaO.

Figure 3. Example calculation to determine organic fertilizer required to meet soil test report recommendations for 1,000 square feet of garden space.

1. Calculate the nitrogen (N) recommendation first. In this example, we will use blood meal for the nitrogen source (12-1.5-0.6, see Table 2). For the 3 lb of N recommended, the quantity of blood meal required to meet the nitrogen recommendation can be calculated as:

$$(3 \text{ lb N} \div 1000 \text{ ft}^2) \times (1 \text{ lb blood meal} \div 0.12 \text{ lb N}) = (25 \text{ lb blood meal} \div 1000 \text{ ft}^2)$$

2. Calculate the phosphorus (P₂O₅) recommendation next. Subtract the amount of P supplied by the N source (blood meal):

$$25 \text{ lb blood meal} \times (0.015 \text{ lb P}_2\text{O}_5 \div 1 \text{ lb blood meal}) = 0.375 \text{ lb P}_2\text{O}_5$$

Use bone meal (approx. 1-11-0) for the phosphorus source to fulfill the remaining P requirement.

$$1.5 \text{ lb P}_2\text{O}_5 - 0.375 \text{ lb P}_2\text{O}_5 \text{ from blood meal} = 1.125 \text{ lb P}_2\text{O}_5$$

$$(1.125 \text{ lb P}_2\text{O}_5 \div 1000 \text{ ft}^2) \times (1 \text{ lb bone meal} \div 0.11 \text{ lb P}_2\text{O}_5) = (10 \text{ lb bone meal} \div 1000 \text{ ft}^2)$$

3. Calculate the potassium (K₂O) recommendation next. The quantity of K supplied in the bone and blood meal is negligible, so the K recommendation can be calculated without subtracting the K present in the N and P sources. Using K-mag (sulfate of potash magnesia) to complete the fertility plan:

$$(4 \text{ lb K}_2\text{O} \div 1000 \text{ ft}^2) \times (1 \text{ lb K-Mag} \div 0.22 \text{ lb K}_2\text{O}) = (18 \text{ lb K-Mag} \div 1000 \text{ ft}^2)$$

Based on these calculations, meeting the soil test report fertilizer recommendations will require 25 lb blood meal, 10 lb bone meal, and 18 lb K-Mag for 1000 square feet of garden space.

pH and liming

Garden plants typically grow best in a pH from 6.0 to 6.5, and microbial activity is restricted when pH is less than 5.5. Soil testing and adjusting pH according to lime recommendations helps ensure that soil organisms are operating under optimal conditions. Calcium, the neutralizing agent in agricultural lime, will not spread quickly throughout the soil profile. For that reason, it must be thoroughly incorporated before planting—ideally two to three months before planting—throughout the rooting zone, at a depth of 6 to 8 inches. If you can't apply lime this early, it will still help if you can apply and incorporate it at least a month before seeding or transplanting.

Temperature

Cool temperatures in early spring also limit microbial activity. Soils must be warm enough to stimulate microbial activity in order to decompose organic fertilizers and make nutrients available to crop plants. Growth may be stunted early in the season if plants don't get enough nutrients or those nutrients are immobilized by decomposing microbes (also known as "N rob").

To avoid stunted growth, use a readily-available organic fertilizer such as fish emulsion or other liquid organic fertilizer when you transplant, and use it weekly for one to two weeks after transplant. Using healthy transplants with enough fertility in the transplant mix to carry some nutrient forward into the garden bed will also help make up for insufficient soil nutrients early in the season.

Organic Transplants and Seed Sources

Organic seedling mix can be expensive, and nutrient delivery tends to be less consistent than with conventional seedling mixes (though there are notable exceptions). Add fertilizer once the first set of true leaves appear. Typically, organic gardeners use a liquid, fish emulsion-based organic fertilizer. To avoid burning plants, follow dilution directions on the packaging.

The cost of organic seedling mixes increases rapidly with soil or compost-based mixes, so many organic gardeners and farmers make their seedling mix. Several common recipes used in organic seedling production are listed in Table 3. For additional information on organic seedling mix ingredients, nutrient release rates, and additional recipes, see the publication *Potting Mixes for Certified Organic Production* at <http://attra.ncat.org/attra-pub/potmix.html>. Note that one recipe is intended for use with “soil blockers,” which are hand tools designed to form free-standing blocks of potting soil that substitute for peat pots, seedling flats, etc. Soil blockers have been popular among small-scale producers, and are readily available through some garden suppliers specializing in organic production (see Additional Resources).

Pest Management: Weeds, Insects, Diseases

One of the main differences between organic gardening and conventional gardening is the use of pesticides. Organic gardeners choose not to use any synthetic chemicals to control weeds, insects, or diseases. Instead, they use a combination of cultural, physical, and biological controls. The philosophy behind organic pest control is that using “many little hammers” allow the organic gardener to beat back pests to a manageable threshold even though these techniques lack the chemical strength of many conventional garden inputs.

Cultural controls, used to prevent pests from ever becoming a threat, are the first line of defense in the garden. They include proper plant selection, fertility management, crop rotation, and physical exclusion. Physical or mechanical controls manually remove pests from the garden. Biological controls, which can be organic pesticides or beneficial organisms, are used to manage an existing insect or disease problem. It is a common misconception that organic gardening prohibits the use of pesticides in any form. A number of pesticides that are derived directly from biological or mineral sources are organically approved. They may be highly toxic, but they typically break down much more quickly in the

Table 3. Common recipes for organic potting and germination mixes.

Organic substitute for Cornell Mix	Classic soil-based mix ¹	Soil blocking mix	Organic potting mix	Vegetable transplant recipe
<ul style="list-style-type: none"> • ½ cu. yd sphagnum peat • ½ cu. yd vermiculite • 10 lb bone meal • 5 lb ground limestone • 5 lb blood meal 	<ul style="list-style-type: none"> • ½ mature compost or leaf mold, screened • ½ garden topsoil • ½ sharp sand 	<ul style="list-style-type: none"> • 3 buckets² • brown peat • ½ cup lime (mix well) • 2 buckets coarse sand or perlite • 3 cups base fertilizer (blood meal, colloidal phosphate, and green sand mixed together in equal parts) • 1 bucket soil • 2 buckets compost 	<ul style="list-style-type: none"> • 1 part sphagnum peat • 1 part peat humus (short fiber) • 1 part compost • 1 part sharp sand (builder’s) <p>To every 80 qt of this add:</p> <ul style="list-style-type: none"> • 1 cup greensand • 1 cup colloidal phosphate • 1½ to 2 cups crabmeal, or blood meal • ½ cup lime 	<p>Equal parts by volume of: compost, peat moss, and perlite or vermiculite</p>

Sources: For the blocking and organic potting mixes, Coleman’s *The New Organic Grower: A Master’s Manual of Tools and Techniques for the Home and Market Gardener*. For the vegetable transplant recipe, Rynk’s *On-Farm Composting Handbook*. (See Additional Resources.)

¹ This mix is heavier than modern peat mixes but still has good drainage. Compost promotes a healthy soil mix that can reduce root diseases. Vermiculite or perlite can be used instead of sand. Organic fertilizer may be added to this base.

² Standard 10-qt bucket.

environment than their synthetic counterparts. Organic management of weeds, insects, and diseases integrating cultural, physical/mechanical, and biological controls is discussed below.

Weeds

Cultural controls for preventing weeds include

- crop rotation and spacing
- physical barriers on the soil
- bringing into the garden only materials that you know to be free of weed seed
- not allowing existing weeds to go to seed

Crops and cover crops planted in tight succession compete with weeds for light, nutrients, and water. The more these resources are in use by crop plants, the less available they are for weeds.

In addition, planting vigorous transplants on relatively tight spacing closes the plant canopy rapidly, helping crop plants out-compete weeds for light, water, and available nutrients. Techniques such as French biointensive gardening (Jeavons, 2004) and square-foot gardening (Bartholomew, 2005) emphasize close plant spacing and arranging plants by vertical size to produce a dense canopy that maximizes crop production and minimizes weed pressure.

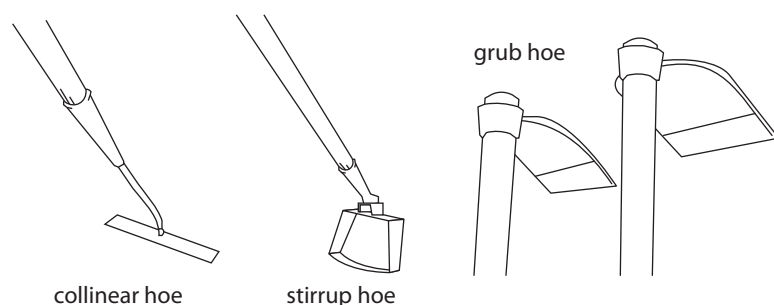
Mulches and Other Physical Barriers

Physical barriers such as mulches, plastic, landscape fabric, and even cardboard block light to germinating weeds. They greatly reduce weed emergence and also conserve water. When these barriers are plant-based, they add organic matter to the soil as well. Typically, a 1-to-2-inch layer of straw or hay mulch, with some additional hand weeding, will suppress weeds for much of the season. More mulch can lead to outbreaks of fungal and bacterial disease in warm, wet years. To minimize diseases, keep mulches off crop plant stems. Also, on long-season, disease-sensitive crops such as tomatoes and peppers, remove lower leaves touching

the mulch. Direct-seeded crops such as root vegetables and lettuces can be planted through a thin layer of mulch and still emerge. To promote crop emergence while minimizing weeds between the crop rows, you also can mulch with a thicker layer around the planting furrow and leave the furrow exposed.

Straw mulch is commonly used in home gardens, and it is effective in controlling weeds and conserving moisture. However, if it's not clean, straw may import weed seeds and create more weeds than it reduces. Mulches and hay and manures from animals eating them can contain herbicide residue, but most herbicides break down rapidly in the environment. However, picloram, clopyralid, and aminopyralid do not break down quickly, and, in concentrations as low as 1 ppb (parts per billion), they can be lethal to sensitive garden plants such as peas, beans, lettuce, spinach, tomatoes, and potatoes. These herbicides are used to control broadleaf, persistent weeds such as Canada thistle in pastures, under power transmission lines, and in hay and wheat crops. They are used because they are long-lived, effective, and low in toxicity to humans and other animals. They can, however, persist in the garden for several years. If you are buying hay or straw mulch from a local farm, you can avoid bringing in contaminated mulches by asking whether the field in which the crop was grown has been sprayed with picloram, clopyralid, or aminopyralid in the past two to three years. These herbicides are sold under the following trade names:

- **Picloram:** Tordon, Access, Surmount, Grazon, and Pathway
- **Clopyralid:** Curtail, Confront, Clopyr AG, Lontrel, Stinger, Millennium Ultra, Millennium Ultra Plus, Reclaim, Redeem, Transline
- **Aminopyralid:** Milestone, Forefront, Pharaoh, Banish.

Figure 4. Specialty garden hoes.

Weeding techniques

Once weed pressure begins to mount—and it generally does—physically removing weeds is the organic gardener’s only option. No consistently effective, approved organic herbicides are available at this time. The following methods are most commonly used.

Hand weeding—The oldest method of weed control is hand weeding, and it is still the most effective for commonly occurring weed species in Kentucky. Hand weeding is particularly effective for removing annual weeds with shallow root systems. With hand weeding, you can remove weeds growing in the row without harming growing crop plants. If you regularly hand-weed while performing other gardening tasks, you can do so rapidly and keep weed pressure low. Hand-weeding is also the easiest method to use when weeding in garden beds with mulches. However, if you’re weeding on a large scale or have high weed pressure, you may need to use tools.

Hoeing—Hoeing can be both efficient and effective for removing small weeds or chopping out larger ones. It is most effective for weeding between rows of crop plants that have a wide spacing between plants so the crop plants won’t be damaged. Hoe shallowly near plants so you do not damage their roots; hoe deeply when you need to unearth roots of persistent weeds such as curly dock, Johnson grass, nut sedges, etc. A sharp hoe makes hoeing much easier, as does having the right hoe for the job. For

light weeding in tight garden spaces or in fine seed beds, use a collinear hoe. It is a small, light tool that is dragged along the soil surface or slightly below it to kill weeds. For larger weeds or larger areas, a standard garden hoe is most commonly used. A stirrup hoe, or “hula hoe,” is an alternative to the garden hoe. It has a spring-steel blade that cuts in both directions for high efficiency. Unlike a fixed-blade garden hoe, the head of a stirrup hoe has a limited swivel joint at the top that allows the blade to remove weeds by pushing and pulling the hoe without having to lift the hoe. The ability to move the hoe back and forth without having to lift the hoe has also led to stirrup hoes also being called “scuffle hoes.” The stirrup hoe can work the soil deeper than a garden hoe in loose and light soils. To chop out larger or deeply-rooted weeds, a “chop” or “grub” hoe is an aggressive tool that quickly unearths weeds. Although grub hoes are effective, they can be heavy and physically demanding to operate.

Mechanical cultivation—Mechanical cultivation is generally used in large gardens that have wide spacing between rows. On a large scale, it can be much faster than hand weeding. Garden tillers are set at as shallow a depth as possible to so nearby crop plants won’t be damaged and soil disturbance at deeper depths will be minimized. Extensive, regular mechanical cultivation destroys soil structure and leads to increased breakdown of soil organic matter and organic amendments such as composts and manures. Mechanical cultivation should be conducted under proper soil moisture conditions to help minimize damage to soil structure. Soils that are too wet will stick to tillage implements and “smear” the soil and create compacted conditions when the soil dries. In general, soil moisture can be estimated by taking a handful of soil and forming a ball by gently squeezing it. If the ball readily holds its shape, it may be too wet to till. Soils that crumble gently but still have some tangible moisture are in better condition for tillage.

Insects

Insect control in the organic garden begins with growing healthy plants. Weak plants, which have nutrient deficiencies, tend to be the first to succumb to insect pressure. Nutrient excesses (particularly nitrogen) can lead to outbreaks of insects such as aphids. Soil testing and proper fertility management can help minimize both nutrient deficiencies and excesses.

Timing is also important. For pests that increase throughout the season, such as corn earworms, tobacco hornworms, cucumber beetles, etc., early plantings can minimize pest pressure. For pests such as flea beetles that subside with onset of summer heat, delaying plantings of eggplant and other summer crops that are sensitive to flea beetles can minimize their damage.

Row covers of lightweight fabric can be used as insect barriers to exclude insect pests from crop plants. When using row covers in the summer, the fabric should be of “insect-barrier” thickness so that temperatures under the fabric don’t get too hot and maximum light penetrates the fabric. The fabric can be removed after the threat of pest damage has passed. For crops that bear fruit, the insect barrier should be removed during flowering to allow for pollination. Row covers are particularly effective in preventing imported cabbageworms and cabbage looper moths from laying their eggs on Brassica crops. Use wire hoops, which are available commercially, or homemade PVC frames to support row covers during the summer. Both hoops and frames will allow air to circulate around the plants. These supports can also be used with thicker fabrics and/or plastic to extend the growing season into spring or fall. Avoid pinning plants to plastic mulches, where they can be damaged by excessive heat.

A wide variety of traps can be made or purchased. For example, slugs and snails can be attracted to a shallow container filled with beer and buried level with the soil. The slugs and snails drown in the beer. (The beer must be changed every several days, as the trap fills and/or becomes foul.) Prepared sticky traps are available in garden shops

for whiteflies and other insects but are best used for monitoring for insect pressure, not control. Japanese beetle traps, which rely on a synthetic lure or a sex pheromone to attract the beetles, are also available in garden shops. These traps are highly effective, even from long distances. However, beetles may linger and feed on crop plants, doing more damage than would have occurred without the traps. For that reason, these traps are not widely recommended. Instead, you might consider removing beetles and other insects by hand.

Trap crops are grown to lure pests away from more desirable crop plants. For example, flea beetles will feed on giant mustard over kales and other Brassica crops, and blue hubbard squashes are used as traps for cucumber beetles, which feed on a variety of cucurbit crops. Insect pests on the trap crop can either be left alone or destroyed by hand picking or with an organic insecticide. If you have to use pesticide to get rid of insect pests, trap cropping helps limit how much you have to spray in addition to protecting crop plants. For a summary of effective trap crop studies, see http://www.oisat.org/control_methods/cultural__practices/trap_cropping.html

Beneficial Insects

Beneficial insects, or “natural enemies,” are used in the organic garden to control pests biologically. A number of species of beetles, parasitic wasps, flies, and nematodes are predators or parasitoids of pest insects. (Parasitoids are organisms that lay their eggs or larvae in the body of a host [pest] organism. The immature parasitoid feeds on the body fluids and organs of the host and eventually emerges and kills the host.) A number of beneficial insects are available commercially. Sources can be found online and in the UK Cooperative Extension publication *Vendors of Beneficial Organisms in North America* (ENTFACT-125) at <http://www.ca.uky.edu/entomology/entfacts/ef125.asp>. Common, commercially available beneficial insects and the insect pests they control are listed in Table 4.

Table 4. Guide to insects as biocontrols.

Beneficial Insect	Pest Insect Controlled
Green lacewing (<i>Chrysoperla rufilabris</i>) ¹	Aphids, mealybugs, immature scales and whiteflies, thrips, spider mites
Lady beetle	Aphids, Colorado potato beetles (egg stage), and other insect pests
Beneficial nematodes (various species)	Root knot nematodes, flea larvae, grubs
Praying mantis (<i>Tenodera aridifolia sinensis</i>) ¹	Foliar feeding insects
Mealybug destroyer (<i>Cryptolaemus montrouzieri</i>)	Mealybug larvae
Trichogramma wasp	Over 200 species of moth eggs, including tomato hornworm, loopers, etc.
Spined soldier bug (<i>Podisus maculiventris</i>) ¹	Larvae of Mexican bean beetle, European corn borer, corn earworm, cabbage looper, cabbage-worm, Colorado potato beetle, and flea beetles.

¹ These beneficial insects are general predators, shown with the pest insects against which they are particularly effective.

In general, you can expect a delay between the time of beneficial insects' release and effective control of the pest. Effective control can be difficult if you release them after you notice a major pest outbreak, because a sufficient population has to build up to control the outbreak. You should release a large number of them at the first sight of the pests. Most importantly, you should create a habitat in which the beneficial insects can overwinter and persist in your garden or yard. Ideally, a year-round habitat for beneficial populations will limit outbreaks of pest insects. Typically, perennial vegetation, woody shrubs, crop residues, and even boards will provide overwintering habitat for beneficial insects and their offspring.

The most reliable way to control insect pests is to physically remove them from the plant by hand and drop them into a container of soapy water. Adding a squirt of dish soap to an empty quart jar then adding water creates a solution that effectively traps insects placed in the jar. The soap breaks the surface tension of the water, which prevents the insects from gaining traction and climbing out of the jar. This method works particularly well for beetles and caterpillars, which can generally be controlled at the garden scale by daily

scouting and removal while you take care of other garden tasks. Physical removal is less effective for small or fast-moving insects, which will likely require some of the other techniques explained above.

Although organic insecticides, which are derived from botanical or mineral sources, do not persist as long as their conventional counterparts, a number of them are used in organic gardening. In general, an organic insecticide requires that the pest insect ingest it directly or at least come in contact with it. For example, organic gardeners can use *Bacillus thuringiensis* (Bt) to control caterpillars. It should be applied as a spray or powder every three to five days as needed during periods of caterpillar pressure.

Several general insecticides, such as pyrethins, are approved for organic production. These insecticides should be sprayed just before sunset, when pest insects are active but pollinators are not, in order to prevent contact with bees and other pollinators. Examples of insecticides approved for organic production and the organisms they control are listed in Table 5. Organically-approved insecticides are available at some garden supply stores but are also available online in home garden quantities from commercial organic nursery and horticultural suppliers (see Additional Resources).

Table 5. Insecticides approved for use in organic production.

Active Ingredient	Origin of Active Ingredient	Pest Insects Controlled
<i>Bacillus thuringiensis</i> (Bt)	A toxin produced by the soil bacterium <i>Bacillus thuringiensis</i>	Caterpillars, such as cabbage looper, hornworm, imported cabbageworm, corn ear worm, etc.
Diatomaceous earth	Fossilized remains of diatoms, algae with a silica-based hard shell	Particularly effective on soft-bodied insects but also deters beetle, flea, and ant activity on plants
Insecticidal soaps	Salts of fatty acids derived from coconut and other oils	Soft-bodied insects such as aphids, thrips, whiteflies, etc.
Kaolin clay	A naturally occurring clay mineralogy ground into a fine powder	Numerous. Kaolin clay is sprayed on crop plants, deterring pests from landing, feeding, and depositing eggs.
Neem	The neem tree (<i>Azadirachta indica</i>), an evergreen native to the Indian subcontinent	Gypsy moths, leaf miners, whiteflies, thrips, loopers, caterpillars, and mealybugs (disrupts feeding and development)
Pyrethrins	Chrysanthemum (<i>Dendranthema grandiflora</i>) flowers	Numerous. Pyrethrins are general insecticides and affect beetles, caterpillars, and various sucking insects.
Sabadilla	Seeds of a tropical lily plant <i>Schoenocaulon officinale</i> , native to Central and South America	Sap-feeding insects, caterpillars, and thrips. ¹
Spinosads	Soil actinomycete, <i>Saccharopolyspora spinosa</i>	Numerous. Disrupts neurotransmitters and feeding patterns in moths, caterpillars, leaf miners, thrips, Colorado potato beetles, and fire ants
Sulfur	The mineral sulfur	Spider mites, psyllids, and thrips

¹ Highly toxic to honeybees, so application at sunset is recommended.

Diseases

Cultural controls are the best way to prevent disease in organic gardening, since few options exist for biological control of diseases. Gardeners can best control diseases from the outset through cultural practices that deter buildup of disease organisms. Crop rotation is especially important in controlling diseases of Solanaceous crops (tomato, pepper, potato, etc.) as bacterial and fungal diseases are particularly problematic when these crops are produced organically. It is also best to avoid composting residue of diseased plants of any Solanaceous crops so that disease organisms won't build up in the compost pile. Instead, dispose of residue of diseased plants or any Solanaceous crops in sealed garbage bags and burn it or throw it away with municipal garbage.

It's also important to select disease-resistant cultivars. There are a number of sources for high-quality, untreated and/or organic seed. Knowing disease issues that are problematic in your garden and in your

region are key to proper cultivar selection. It should be noted that treated and/or genetically modified seeds are prohibited in USDA-certified organic production.

Disease organisms are spread by moving infected materials from plant to plant. To help avoid such spread, remove diseased plants when leaves are dry and place them in sealed plastic bags. This practice will help prevent bacteria or fungal spores spreading to healthy plants. To minimize disease transfer between plants, avoid harvesting or pruning tomato plants while the leaves are wet. Use a bleach-treated cloth to wipe down pruners between working tomato or tree crops, which will also help minimize disease spread.

Many diseases spread by insect vectors—insects transporting disease from plant to plant as they feed. In Kentucky, bacterial wilt of cucurbits is a classic example of this method of disease spread. Spotted and striped cucumber beetles carry bacterial wilt of cucurbits between cucumbers and other cucurbit plants as they feed.

Therefore, this disease is controlled through the beetle vector, not the bacteria (*Erwinia tracheophila*) that causes the disease. This example highlights an important principle for the organic gardener: knowing the root cause of a disease or other problem in the garden requires understanding the entire garden as a *system*. One might view the disease as the problem because it may be the final fatal blow to the plant. However, if the root cause is insect or soil related, treating the disease is ineffective if the underlying condition or cause is not resolved.

Very few sprays are designed to control diseases organically. Copper-based products are considered synthetic but are allowed in USDA-certified organic production with certain restrictions. These products are restricted because they can accumulate in soil and create copper toxicity problems; are highly toxic to fish; and can also harm bees, beneficial soil bacteria and fungi, and earthworms. Copper-based products have been shown to be somewhat effective in controlling downy and powdery mildews, bean anthracnose, and tomato early blight. Bordeaux mix (a blend of copper sulfate mixed with hydrated lime) is considered a synthetic substance and is restricted in organic production due to its long residual activity and high toxicity to bees. Sulfur that is mined (elemental sulfur) rather than extracted through manufacturing/power generation can be used in certified organic production. In addition to serving as a trace mineral, sulfur has fungicidal effects.

Research and development of organically-approved disease controls is occurring rapidly. Up-to-date information and new products can be found eXtension's eOrganic website (http://www.extension.org/organic_production) as well as Caldwell's Resource Guide for Organic Insect and Disease Management listed below.

Additional Resources

- Bartholomew, Mel. 2005. *Square Foot Gardening: A New Way to Garden in Less Space with Less Work*. Rodale Press, Emmaus, PA. 352 pp.
- Boyhan, George. E. 2009. *Growing Vegetables Organically*. University of Georgia Cooperative Extension Bulletin 1011. Athens, GA. 10 pp. http://www.caes.uga.edu/applications/publications/files/pdf/B%201011_4.PDF
- Caldwell, Brian. 2005. *Resource Guide for Organic Insect and Disease Management*. New York State Agricultural Experiment Station, Geneva, NY. 169 pp. <http://www.nysaes.cornell.edu/pp/resourceguide/index.php>
- Coleman, Eliot. 1989. *The New Organic Grower: A Master's Manual of Tools and Techniques for the Home and Market Gardener*. Chelsea Green Publishing, White River Junction, VT. 340 pp.
- Gershuny, Grace, and Deborah L. Martin (eds). 1992 (Revised Edition). *The Rodale Book of Composting: Easy Methods for Every Gardener*. Rodale Press, Emmaus, PA. 278 pp.
- Jeavons, John. 2004 (Sixth Edition). *How to Grow More Vegetables (and Fruits, Nuts, Berries, Grains and Other Crops than You Ever Thought Possible on Less Land than You Can Imagine)*. Ten Speed Press, Berkeley, CA. 240 pp.
- Kuepper, George. *Potting Mixes for Certified Organic Production*. 2010 (reviewed edition). ATTRA Publication #IP112. National Sustainable Agriculture Information Service, Butte, MT. 20 pp. <http://attra.ncat.org/attra-pub/potmix.html>
- Lowenfels, Jeff, and Wayne Lewis. 2006. *Teaming with Microbes: A Gardener's Guide to the Soil Food Web*. Timber Press, Portland, OR. 196 pp.

- National Sustainable Agriculture Information Service (also known as ATTRA). An excellent source of information on all kinds of sustainable and organic agricultural practices, marketing, etc. www.attra.org.
- Online Information Service for Non-Chemical Pest Management in the Tropics. Trap Cropping. Hamburg, Germany. http://www.oisat.org/control_methods/cultural__practices/trap_cropping.html
- Oregon State University Extension Service. Organic Gardening Fundamentals. 10-Minute University Series. http://extension.oregonstate.edu/extension/mg/metro/sites/default/files/Organic_gardening.pdf
- Organic Gardening Magazine. Published by Rodale Press since the 1940s. Now available online at: www.organicgardening.com.
- Organic Materials Review Institute. www.omri.org.
- Riotte, Louise. 1998. *Carrots Love Tomatoes: Secrets of Companion Planting for Successful Gardening*. Storey Books, North Adams, MA. 224 pp.
- Rynk, Robert. 1992. *On-Farm Composting Handbook*. Natural Resource, Agriculture and Engineering Service.
- Stephens, James M. 2003. *Organic Vegetable Gardening*. Florida Cooperative Extension Service Circular 375. University of Florida, Gainesville, FL. 12 p. <http://edis.ifas.ufl.edu/pdffiles/VH/VH01900.pdf>
- United States Department of Agriculture Agricultural Marketing Service. The National Organic Program. <http://www.ams.usda.gov/AMSv1.0/nop>. Last modified: 11/09/2010.

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